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Measurement in Nursing and Health Research

Fourth Edition

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# Contents

*Contributors* vii  
*Preface* ix  
*Acknowledgment* xi  

## Part I  Basic Principles of Measurement

1. Introduction to Measurement 3  
2. Operationalizing Nursing Concepts 27  
3. Measurement Theories and Frameworks 49  

## Part II  Understanding Measurement Design

4. Strategies for Designing Measurement Tools and Procedures 91  
5. Measurement Reliability 145  
6. Validity of Measures 163  
   *With Karen L. Soeken*  
7. Standardized Approaches to Measurement 203  
8. Measurement Issues in Qualitative Research 225  
   *Judith E. Hupcey*  

## Part III  Measurement via the Digital World

9. Using Existing Administrative and National Databases 241  
   *Meg Johantgen*  
10. Computer-Based Testing 251  
   *Louise S. Jenkins*  
11. Internet Data Collection 259
Part IV Instrumentation and Data Collection Methods

12 Observational Methods 271
13 Content Analysis 279
14 Interviews 287
15 Questionnaires 301
16 The Delphi Technique 311
17 Visual Analog Scales 319
18 Magnitude Estimation Scaling 325
19 Guidelines for Writing Multiple-Choice Items 329
Karen L. Soeken
20 Measurement of Physiological Variables Using Biomedical Instrumentation 335
Kathleen S. Stone and Susan K. Frazier
21 Evaluation of Measurement Precision, Accuracy, and Error in Biophysical Data for Clinical Research and Practice 371
Nancy A. Ryan-Wenger
22 Collecting Sensitive Information 385
23 Selection and Use of Existing Instruments 393

Part V Measurement Issues

24 Ethical Issues 401
25 Issues in Measuring Quality Care 417
Karen Beckman Pace
26 Other Measurement Issues 433

Index 477
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The fourth edition of this text was written taking into account the needs and interests of nurses and our expanded audience of health researchers, the significant increase in interdisciplinary research collaboration, and growing emphasis on evidence-based practice as an important research outcome across all health disciplines. As in earlier editions, the intent, within the context of these trends, is to present a pragmatic account of the process involved in designing, testing, selecting and/or evaluating instruments, methods, and procedures for measuring variables in clinical, educational, and research settings.

We continue to strive to meet the needs of a large and diversified audience ranging from neophytes to those with more advanced knowledge and experience in measurement. Thus, we do not assume that most readers have an extensive background and experience in measurement or statistics. Rather, we begin our discussion of content assuming little background in these areas and subsequently develop, explain in detail, and illustrate by example the concepts and principles operationally important to the content presented. In this manner, it is possible for the less sophisticated reader to develop the level of knowledge necessary to understand the content that is included for the benefit of the more advanced reader. Thus, this book should serve as a valuable resource for readers who seek basic and advanced content to develop their skill in measurement.

This edition includes the best of the measurement content, strategies, and procedures presented in the previous editions. In addition, it provides the most up-to-date content, strategies, and procedures available with direct applicability for nurses and health researchers in a variety of roles including those of student, educator, clinician, researcher, administrator, and consultant. As in previous editions, the focus is on increasing the reader’s ability to employ measures that are operationalized within the context of theories and conceptual frameworks, derived from sound measurement principles and practices, and adequately tested for reliability and validity using appropriate methods and procedures. Throughout this edition, examples and studies conducted by nurses and health researchers in varied settings and/or in collaboration with others in their own and other disciplines are provided to illustrate important content and to reinforce the importance of using sound measurement principles and practices within the context of evidence-based practice. Attention is given to measurement issues resulting from changes in nursing and health research that have increased in number and complexity since the time of the last edition. Additional reference sources, readily available in libraries and/or online, are provided for readers who desire to further pursue the topics presented. Whenever possible, comprehensive summaries of literature in an area of interest are cited rather than a myriad of individual books and articles.

Some key features of this edition include:

• Chapter 6, “Validity of Measures,” provides an updated and expanded reconceptualization and definition of measurement validity, and includes new strategies for testing validity of measures.
• The content of Chapter 8, “Measurement Issues in Qualitative Research,” has been expanded to include additional content relevant to the use of a mixed methods approach to enhance measurement outcomes.
• A new section, “Part III: Measurement via the Digital World,” has been added.
and includes Chapter 9, “Using Existing Administrative and National Databases,” which provides examples of major databases and focuses on (1) using large data sets from national longitudinal research as sources for nursing and health research, and (2) employing large data sets from clinical information systems in hospital and multifacility health systems, especially in addressing quality and safety; Chapter 10, “Computer-Based Testing,” which focuses on the use of the Internet in the conduct of research and measurement efforts, including identifying issues and how to address them; and Chapter 11, “Internet Data Collection,” which contains expanded content on issues of data privacy and how to address them.

- Chapter 20, “Measurement of Physiological Variables Using Biomedical Instrumentation,” has been expanded and is focused on the methods for measuring physiological variables using biomedical instrumentation, including issues to be addressed and use in translational research.

- There is a new Chapter 21, “Evaluation of Measurement Precision, Accuracy, and Error in Biophysical Data for Clinical Research and Practice,” which presents content regarding the application of measurement principles and practices in clinical research and practice that focuses on clinical data collection methods, including (1) clinimetrics and the unique challenges of conducting research in clinical settings and situations where strict experimental control and standardization are not optimal and how to address them, (2) standards for evaluating precision and accuracy of clinical measures, and (3) issues to be addressed relative to use of outcomes as a basis for clinical practice.

- There is a new Chapter 25, “Issues in Measuring Quality Care,” which focuses on principles and practices in quality measurement, identifies issues in measuring quality of care, and explores challenges and how to address them.

We appreciate the positive feedback we have received from satisfied readers who have valued previous editions as a textbook for research and measurement courses, and from those conducting their own research and/or seeking to evaluate the quality of others’ research to decide whether to use their results as a basis for practice. Also, we thank the many readers who requested another edition and sincerely hope that you will find this fourth edition a significant resource.

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The authors sincerely appreciate the contributions of Sandra A. Murphy whose commitment, perseverance, organizational ability, and many talents were instrumental to us in preparing this manuscript. Sandy, we can’t thank you enough for so graciously contributing your time and effort to ensure the completion of this book. You are the best!
Part I

Basic Principles of Measurement
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Introduction to Measurement

The use of sound measurement principles and practices is an essential component of well-designed research studies and is of utmost importance when the goal is to employ research results as a basis for practice. In this chapter, we discuss terms and ideas essential to understanding the content of subsequent chapters, present an overview of the types of measures most often used, and introduce the two essential characteristics of any measuring tool or method, reliability and validity.

THEORY-BASED MEASURES

A theory is defined as “a set of interrelated constructs, definitions, and propositions that present a systematic view of phenomena by specifying relations among variables, with the purpose of explaining and predicting the phenomena” (Kerlinger, 1973, p. 9). Polit and Beck (2008) note that a theory “is a systematic, abstract explanation of some aspect of reality. In a theory, concepts are knitted together into a coherent system to describe or explain some aspect of the world” (p. 57). A theoretical rationale according to LoBiondo-Wood and Haber (1994) “provides a road map or context for examining problems, and developing and testing hypotheses. It gives meaning to the problem and study findings by summarizing existing knowledge in the field of inquiry and identifying linkages among concepts” (p. 157). Conceptual models, they note, provide a context for constructing theories that deal with phenomena of concern to a discipline and help define how it is different from other disciplines. Polit and Beck (2008) use the terms conceptual model and conceptual framework interchangeably. In their view a conceptual model includes “interrelated concepts or abstractions assembled together in a rational scheme by virtue of their relevance to a common theme” (p. 749).

For example, Arwood and Kaakinen (2009) designed a simulation model based on language and learning that was evolved from Arwood’s Neuro Sematic Language Learning Theory that provides a hierarchical framework for assessing and measuring conceptual learning outcomes. Evans and colleagues (2009) employed the Biopsychosocial Model to understand the health benefits of Yoga. They present a review and conceptual model of the potential biopsychosocial benefits of Yoga and empirical evidence that supports the involvement of physical, psychological, and spiritual domains as possible mechanisms of actions of Yoga upon well-being. Krogh and Naden (2008) report on a project undertaken by them using an information management system to develop a conceptual framework that would provide clinicians with an approach to documentation consistent with legal and organizational requirements and enable them to retain the ability to record all aspects of clinical nursing. The result was the Norwegian documentation KPO model that incorporates the Nursing Minimum Data Set and NANDA (Nursing Diagnosis, Nursing Intervention Classification, and Nursing Outcome Classification) and focuses on quality assurance, problem solving, and caring.

Various authors have defined and analyzed concepts in a number of ways (Allegood & Marriner-Tomey, 2002; George, 2002; Glaser & Strauss, 1967; Leonard & George, 1995; Meleis, 1999; Orem, 1995; Polit & Beck, 2008; Renpenning & Taylor, 2003). Simply defined, a concept is a thought, notion, or idea. It is an abstraction. For example, nursing concepts are thoughts, notions, or ideas about nursing or nursing practice. Thus, concepts define the content of interest in measuring phenomena. Phenomena
are observable facts or events. To render concepts measurable, it is necessary to translate them into phenomena. When one operationalizes a concept, one translates an abstract concept into concrete observable events or phenomena. For example, the concept of “attitude” is frequently operationalized as a tendency to respond in a consistent manner to a certain category of stimuli (Campbell, 1963). If the stimulus is a 17-item questionnaire regarding children’s concerns about health care, such as the Child Medical Fear Scale developed by Broome and Mobley (2003, pp. 196–206), in which the child indicates whether he or she was “not at all,” “a little,” or “a lot” afraid of selected experiences associated with health care described in the items, and the subject responds “a lot” to the majority of the 17 items, one would infer from the responses that the child’s attitude or fearfulness of the experiences associated with health care was high.

Variables are quantities that may assume different values; they are changeable. The process whereby one decides how to measure a variable is referred to as instrumentation, that is, the process of selecting or developing tools and methods appropriate for measuring an attribute or characteristic of interest. In the example above, the 17-item questionnaire was a form of instrumentation selected to measure attitudes of children toward the medical experience. Instrumentation is a component of the measurement process. Measurement is defined as the process of assigning numbers to objects to represent the kind and/or amount of attributes or characteristics possessed by those objects. This definition of measurement includes what has traditionally been referred to as qualitative measurement (i.e., assigning objects to categories that represent the kind of characteristic possessed and that are mutually exclusive and exhaustive) as well as quantitative measurement (i.e., assigning objects to categories that represent the amount of a characteristic possessed).

The utilization of a conceptual framework to systematically guide the measurement process increases the likelihood that concepts and variables universally salient to nursing and health care practice will be identified and explicated. That is, when measurement concerns emanate from an empirical rather than a conceptual point of view, there is higher probability of investigating and measuring these variables from an esoteric or limited perspective that overlooks important dimensions of the variables that should be measured. Concepts of interest to nurses and other health professionals are usually difficult to operationalize, that is, to render measurable. This is explained in part by the fact that nurses and other health professionals deal with a multiplicity of complex variables in diverse settings, employing a myriad of roles as they collaborate with a variety of others to attain their own and others’ goals. Hence, the dilemma that they are apt to encounter in measuring concepts is twofold: first, the significant variables to be measured must somehow be isolated; and second, very ambiguous and abstract notions must be reduced to a set of concrete behavioral indicators. What tools, therefore, are available to nurses and other health care professionals who must begin to grapple with this dilemma?

Because of the increased interest in evidence-based practice across health care disciplines and the challenge to provide services of broadening scope and diversity in order to keep pace with the rapidly changing and volatile health care scene coupled with severe shortages in nursing and other health care disciplines, a great deal of controversy and confusion has ensued regarding which functions should be included within the realm of each of the practice disciplines and which information should be shared. For nursing, this is evidenced by the proliferation of definitions and models for nursing practice evident in the literature. Although, for the most part, the definitions of nursing advanced in the literature remain ambiguous and global, in each view the major focus for nursing practice can be placed on a continuum ranging from direct to indirect involvement in patient care. Direct nursing practice involves the continuous, ongoing provision of direct services to patients and clients (e.g., the primary care nurse practitioner provides direct nursing services). Indirect nursing practice is usually characterized by activities on behalf of the patient, that is, working with or through others who are directly responsible for the provision of direct services to patients and clients. Nursing education, administration, and health policy activities exemplify indirect nursing practice.
This scheme for categorizing nursing practice has utility for the nurse who is attempting to operationalize nursing concepts.

More specifically, the first task is to identify a definition of nursing that is consistent with the nurses’ own views and beliefs about nursing practice. Similarly, although the extent to which available conceptual frameworks and models for nursing practice have been refined and tested varies, their very existence affords nurses a rich opportunity to select a conceptual framework to guide them in systematically identifying and further explicating concepts and variables germane to nursing and nursing practice concerns within their primary focus. The problems, settings, roles, and purposeful activities undertaken by nurses will differ, depending upon whether their primary focus is direct or indirect nursing practice. Furthermore, the goals for, and outcomes likely to result from, the application of direct and indirect nursing processes will vary. Although there will be differences among each of these categories of practice, there will also be commonalities in process and outcomes within each focus. Therefore, if nurses consider their measurement concerns within the context of their primary focus, delimit the processes and outcomes that characterize that practice, and then search for behavioral indicators within the primary focus that extend beyond their immediate setting (i.e., that are common across settings similar to their own), they are apt to reduce the abstract concepts emanating from their conceptual framework to behavioral indicators with more universal acceptance than those likely to result from a more esoteric approach. In this manner, nurses will ultimately make a contribution to the profession by accruing information to add to the body of knowledge about nursing, the specific definition and conceptual framework employed, and its utility as a guide for operationalizing nursing and nursing practice concerns. It should be noted that when nurses whose measurement concerns emanate from their ongoing practice fail to step back and rethink the problem from a conceptual point of view, they also have a high probability of investigating and measuring their variables from a limited perspective that overlooks important dimensions of the variables that should be measured.

For example, Stacey and colleagues (2009) report on their efforts to integrate a patient decision support theoretical framework and associated evidence-based resources throughout a baccalaureate nursing curriculum. Rew, Grady, Whittaker, and Bowman (2008) employed Social Cognitive Theory as a basis for their study to determine the effects of duration of homelessness and gender on personal and social resources, cognitive-perceptual factors, and sexual health behaviors among homeless use. The work of Ellenbecker, Porell, Samia, Byleckie, and Milburn (2008) exemplifies testing of a theoretical model of home health care nurse retention. The use of conceptual models as a basis for measurement is illustrated by the work of Landis, Parker, and Dunbar (2009) who employed a biobehavioral-ecological framework in their study of sleep, hunger, satiety, food cravings, and caloric intake in adolescents and Avci and Kurt (2008) who employed the Health Belief Model in their study of health beliefs and mammography rates of Turkish women living in rural areas. A conceptual approach within a qualitative phenomenological study was undertaken by Melby, Dodgson, and Tarrant (2008) who sought to describe the experiences of Western expatriate nursing educators teaching in East Asia. Additional examples of theories, conceptual frameworks, and theory-based measures can be found in Bramadat and Driedger (1993); Kempen, Miedema, Ormel, and Molenar (1996); Fry (2001); Armitage (2001); Weber, Kopelman, and Messick (2004); March and Olsen (2006); Kaji, Koenig, and Bey (2006); Olsen (2007).

In nursing and the health professions a salient concern is often with the measurement of process variables such as with developing and implementing process measures of quality, which are dynamic, as well as outcome variables, which are usually static, and in which results of the measurement are likely to be applied to the solution of significant problems across practice settings as in evidence-based practice (EBP). For example, Rubin, Pronovost, and Diette (2001) recognize the importance when developing process measures of rigorously developing quality indicators “that will provide insights into opportunities to improve quality of care” and identify the following steps to be
Part I Basic Principles of Measurement

to predict health-related quality of life three months after traumatic injury, employed multiple measurement methods including telephone interviews, clinical data, and questionnaires using rating scales.

Measurement reliability and validity is thus largely a function of a well-designed and well-executed measurement process. For this reason, the intent of this book is to provide the reader with a sound background in the theories, principles, and practices of measurement and instrumentation that are germane to the measurement of concepts in nursing and the health professions.

MEASUREMENT FRAMEWORKS

Just as it is important to identify and employ a conceptual framework for determining what is to be measured and delineating how it will be operationalized, it is equally important to identify and employ a measurement framework to guide the design and interpretation of the measurement per se. The two major frameworks for measurement are the norm-referenced and the criterion-referenced approaches.

A norm-referenced approach is employed when the interest is in evaluating the performance of a subject relative to the performance of other subjects in some well-defined comparison or norm group. The Stress of Discharge Assessment Tool (SDAT-2) developed by Toth (2003, pp. 99–109) is an example of a 60-item norm-referenced measure of the stress experienced by patients at hospital discharge and in the early recovery period at home following acute myocardial infarction. Scores on each item in the SDAT-2 range from 1 to 5 points, depending on the patient’s degree of agreement with the item. A high score indicates high stress for that item, and a low score indicates low stress. The total possible score ranges from 60 to 300 points, and its value for a given subject takes on meaning when it is considered in light of the scores obtained by other patients who responded to the same tool.

Similarly, the results of the application of physiologic measures such as blood pressure readings are often interpreted on the basis of
readings (usually ranges of values) considered normal for some well-defined comparison group (e.g., Black males over 40 years of age with no significant health problems). It should be noted that the terms “norm-referenced” and “standardized” are not synonymous. Standardized tests are one type of norm-referenced measure; there are other types as well. Unlike most other norm-referenced measures, a standardized measure is designed by experts for wide use and has prescribed content, well-defined procedures for administration and scoring, and established norms. The Graduate Record Examination (Stein & Green, 1970), the National League for Nursing Achievement Test Battery (Waltz, 1988), and nurse practitioner certification examinations such as the Neonatal Intensive Care Nursing Examination (Perez-Woods, Burns, & Chase, 1989) are examples of standardized measures.

A key feature of a norm-referenced measure is variance. The task when using a norm-referenced measure is to construct a tool or method that measures a specific characteristic in such a way that it maximally discriminates among subjects possessing differing amounts of that characteristic, that is, spreads people out along the possible ranges of scores. For example, if the characteristic to be measured is knowledge of human sexuality content, then test items are designed to differentiate between individuals with varying levels of knowledge of the content. The goal is to obtain scores in such a manner that the result is a few high scores, most scores in the middle range, and a few low scores. If this goal is achieved, the resulting distribution of scores on the measure should look much like a normal curve. Figure 1.1(a) illustrates the distribution of scores that one would expect to result from the employment of the hypothetical 5-item, norm-referenced measure of human sexuality content.

The sole purpose of a criterion-referenced measure is to determine whether a subject has acquired a predetermined set of target behaviors. The task in this case is to specify the important target behaviors precisely and to construct a test or measure that discriminates between those subjects who have and those who have not acquired the target behaviors. How well a subject’s performance compares with the performance of others is irrelevant when a criterion-referenced framework is employed. Criterion-referenced measures are particularly useful in the clinical area when the concern is with the measurement of process and outcome variables.

For example, a criterion-referenced measure of process would require that one identify standards for the patient care intervention and then compare subjects’ clinical performance with the standards for performance (i.e., predetermined target behaviors) rather than compare subjects’ performance with that of other subjects, all of whom may not meet the standards. Standards might be those resulting from international and/or national professional organizations such as Guidelines for the Management of Patients with Chronic Stable Angina published by the American College of Cardiology and the American Heart Association in 2007 or local site-specific standards such as those agreed upon by health care providers serving on the evidence-based practice committee in a local oncology outpatient setting regarding the management of chemotherapy-induced nausea and vomiting in their setting. Similarly, when a criterion-referenced measure is employed to measure patient outcomes, a given patient’s status is determined by comparing his or her performance with a set of predetermined criteria (e.g., EKG normal, diastolic pressure below 80, other vital signs stable for 4 hours post-op) or target behaviors (e.g., requests for pain medication have ceased by 2 days post-op, desire to return to normal activities is verbalized by 3rd day post-op) rather than by comparing his or her performance with that of other patients.

King’s (2003, pp. 3–20) Measure of Goal Attainment Tool is an example of a criterion-referenced measure of functional abilities and goal attainment behaviors. This tool was constructed to assess individuals’ physical abilities to perform activities of daily living and the behavioral response of individuals to the performance of these activities. Goal attainment was defined as mutual goal setting by nurse and patient, and assessment of goal attainment. Each of these areas comprises three components: (1) personal hygiene, (2) movement, and (3) human interaction. Essential tasks in performing actions related to each of these areas are reflected in items contained on the tool. Percentage scores are determined to evaluate the independence
or dependence of subjects related to the essential tasks. Thus, the individual’s performance, as reflected by the score, is interpreted on the basis of his or her ability to perform the essential tasks and is not related to the evaluation of the performance of others using the same tool.

One would expect the distribution of scores resulting from a 5-item, criterion-referenced measure to look like the one illustrated in Figure 1.1(b). It should be noted that not only does the distribution of scores resulting from a criterion referenced measure have less variance or spread than that resulting from a norm-referenced measure, but it also is skewed in shape. In a skewed distribution, scores tend to cluster at one end of the scale; in the example in Figure 1.1(b), the high end. A more detailed discussion of score spread (variance) and distribution shape (normal and skewed) is presented in Chapter 3.

Because the design, scoring, interpretation, reliability, and validity testing for norm-referenced and criterion-referenced measures differ, it is important to decide which of the two measurement frameworks will be employed prior to the conduct of any other steps in the measurement process.

**TYPES OF MEASURES**

Once the conceptual basis for the measure and the measurement framework has been determined, attention turns to the selection of the specific type of measure to be employed.

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**FIGURE 1.1** Distribution scores on (a) norm-referenced and (b) criterion-referenced measures.
Semantics is often a problem for newcomers to the field of measurement. Many different terms are employed to label like measures. For this reason, it is important to consider some of the classification schemes and terms that are used to label different types of measures. In addition to being categorized as either norm-referenced or criterion-referenced, approaches to measurement are also usually referred to as qualitative or quantitative in nature. Whether the approach is qualitative, quantitative, or mixed methods will largely be a function of the measurement problem, the conceptual basis guiding the determination of what is to be measured, and the nature of the variables to be measured.

When a qualitative approach to measurement is employed, objects are assigned to mutually exclusive and exhaustive categories that represent the kind of characteristic possessed by the object. Qualitative measurement methods are usually indicated when the theoretical orientation for the measurement derives from phenomenology, existentialism, symbolic interactionism, or ethnmethodology (Chenitz & Swanson, 1986, p. 3). Knafl (1989) suggests that within nursing, ethnography, phenomenology, and grounded theory appear to be the dominant approaches. The major goal of qualitative methods is to document and interpret as fully as possible the whole of what is being measured from the frame of reference of the subjects involved (Diekelmann, 1992; Duffy, 1987; Filstead, 1974; Girot, 1993). Hinds and Young (1987) note that qualitative methods usually attempt to describe processes and thus tend to be measures of dynamic and changing phenomena. For example, Turris (2009) employed a Grounded Theory approach in a study of women’s decisions to seek treatment for the symptoms of potential cardiac illness. Data for the study were obtained from in-depth interviews with women who went to one of two emergency departments within a specific time period for the treatment of symptoms indicating potential cardiac arrest. Hendrickson (2008) conducted a study to explore worries, safety behaviors, and perceived difficulties in keeping children safe at home in a sample of low-income predominately non-English-speaking mothers as a foundation for later nursing intervention. The study employed a qualitative descriptive design with content analysis of responses to three semi-structured interview questions (p. 137). A phenomenological approach was employed by Melby et al. (2008) to describe the lived experience of English-speaking Western nurse educators teaching in East Asian countries. Subjects were interviewed about their experiences and resulting narrative data were analyzed by each member of the research team “to identify themes and then through group discussions to reach consensus, develop clear understandings of language nuances and maintain the participant’s voices” (p. 176). Mbweza, Norr, and McElmurry (2008) used a Grounded Theory approach to examine “the decision-making processes of husband and wife dyads in matrilineal and patrilineal marriage traditions of Malawi in the areas of money, food, pregnancy, contraception and sexual relations” (p. 12).

While the measurement strategies and techniques employed across the qualitative theoretical perspectives may differ somewhat, the types of measures employed are often the same and are also employed when quantitative approaches are used. Qualitative measurement methodologies generally include content analysis of documents; reviews of the literature and of findings from studies to identify common themes; participant and nonparticipant observations; interviews or focus groups that may be structured or non-structured, but are usually open-ended; and open-ended questionnaires. Qualitative data collection and analysis procedures are discussed in Chapter 8.

Quantitative measurement assigns objects to categories that represent the amount of a characteristic possessed by the object. Quantitative methods emphasize the search for facts and causes of human behavior through objective, observable, and quantifiable data (Duffy, 1987). Hinds and Young (1987) suggest that quantitative approaches provide outcome data and information on the representativeness of the studied sample and thus tend to be measures of more stable phenomena. Specific types of methods employed with quantitative approaches include the variety of types of measures discussed in later sections of this chapter.

Single studies of a problem using qualitative or quantitative methods rarely involve full
exploration of the problem area (Bergstrom, 1989). When a mixed method approach, that is, when a combination of both qualitative and quantitative methods are employed together, the two approaches to measurement provide information regarding the internal and external validity of the studies or measurement processes (Campbell & Fiske, 1959; Vedich & Shapiro, 1955; Webb, Campbell, Schwartz, & Sechrest, 1966). For example, Escoffery, Glanz, Hall, and Elliott (2009) employed a multimethod process evaluation for a skin cancer prevention diffusion trial. Data collection methods in their study included surveys, database tracking, activity logs, process evaluation interviews, and site visits. Thus, to develop an adequate and useful repertoire of measurement principles and practices, one needs to understand when and how to use both qualitative and quantitative approaches to measurement, as well as how they can be combined as measurement methodologies.

Stainbeck and Stainbeck (1984) note that qualitative and quantitative approaches, because they derive from different perspectives, have several inherent differences that should be understood prior to considering how the two methods can complement each other in the measurement of nursing phenomena. Major differences noted by them include the following:

1. When quantitative approaches are employed, the goal is to arrive at an understanding of a phenomenon from the outsider’s perspective by maintaining a detached, objective view that hypothetically is unbiased. The perspective, on the other hand, when qualitative approaches are employed is that of an insider and the goal is to obtain information by talking to and/or observing subjects who have experienced firsthand the phenomena under scrutiny.

2. Quantitative methods focus on the accumulation of facts and causes of behavior assuming that facts gathered do not change, while qualitative methods are concerned with the changing, dynamic nature of reality.

3. When quantitative approaches are used, the situation is structured by identifying and isolating specific variables for measurement and by employing specific measurement tools and methods to collect information on these variables. In contrast, qualitative approaches attempt to gain a complete or holistic view of what is being measured by using a wide array of data including documents, records, photographs, observations, interviews, case histories, and even quantitative data.

4. Usually highly structured procedures, designed to verify or disprove predetermined hypotheses, are employed with quantitative approaches. Flexibility is kept to a minimum in an attempt to minimize bias. Procedures used with qualitative approaches, on the other hand, are usually flexible, exploratory, and discovery-oriented.

5. Quantitative approaches yield objective data that are typically expressed in numbers, while qualitative approaches focus on subjective data that are typically expressed or reported through language.

6. Quantitative data are usually collected under controlled conditions, while qualitative data are usually collected within the context of their natural occurrence.

7. In both approaches, reliability and validity are valued. In the quantitative approach, there is a heavy emphasis on reliability, that is, data that are consistent, stable, and replicable. Qualitative approaches, while recognizing that reliability is a necessary prerequisite for validity, tend to concentrate on validity, that is, data that are representative of a true and full picture of the phenomenon that is investigated (pp. 130–131).

Over time, more researchers have come to value using a mixed method approach and have begun to recognize the value of integrating qualitative and quantitative approaches within the context of a given study. It should be noted that the integration of qualitative and quantitative approaches is not simply mixing methods, but rather requires one to assume that the two approaches are complementary and that the primacy of the paradigmatic assumptions underlying one or the other approach can be eliminated as unproductive
(Haase & Myers, 1988). Triangulation, discussed in more detail in Chapter 25, is one methodological strategy for combining qualitative and quantitative approaches. In triangulation, multiple data sources, collection techniques, theories, and investigators are employed to assess the phenomenon of interest (Fielding & Fielding, 1986; Madey, 1982; Mitchell, 1986). Examples of the use of triangulation for combining qualitative and quantitative approaches can be found in Bretnauer, Ayres, and Knafl (1993), Floyd (1993), Corey (1993), Mason (1993), and Hendrickson (2008).

In addition to being categorized as norm-referenced or criterion-referenced, qualitative or quantitative, measuring tools and methods may be classified by (1) what they seek to measure, (2) the manner in which responses are obtained and scored, (3) the type of subject performance they seek to measure, or (4) who constructs them.

What Is Measured

In nursing and health care research, there is usually interest in measuring cognition, affect, and psychomotor skills and/or physical functioning. Cognitive measures assess the subject’s knowledge or achievement in a specific content area. Indicators of cognitive behavior usually are obtained as follows:

1. Achievement tests (objective and essay) that measure the extent to which cognitive objectives have been attained.
2. Self-evaluation measures designed to determine subjects’ perceptions of the extent to which cognitive objectives have been met.
3. Rating scales and checklists for judging the specific attributes of products produced in conjunction with or as a result of an experience.
4. Sentence-completion exercises designed to categorize the types of responses and enumerate their frequencies relative to specific criteria.
5. Interviews to determine the frequencies and levels of satisfactory responses to formal and informal questions raised in a face-to-face setting.
6. Peer utilization surveys to ascertain the frequency of selection or assignment to leadership or resource roles.
7. Questionnaires employed to determine the frequency of responses to items in an objective format or number of responses to categorized dimensions developed from the content analysis of answers to open-ended questions.
8. Anecdotal records and critical incidents to ascertain the frequency of behaviors judged to be highly desirable or undesirable.
9. Review of records, reports, and other written materials (e.g., articles, autobiographical data, awards, citations, honors) to determine the numbers and types of accomplishments of subjects.

The number of cognitive measures employed far exceed the number of other types of measures. Specifically, written multiple-choice tests are the most often used, perhaps because they are the most objective of the various cognitive measures and the most reliable, and because they have the greatest utility in measuring all types of knowledge. Multiple-choice tests are further discussed in Chapters 4 and 17. Examples of cognitive measures can be found in Smith (1991), Grant et al. (1999), Story (2001), Arnold (2001), Tiro, Meissner, Korbin, and Chollete (2007), Boom, Nelson, Laufman, Kohrt, and Kozinetz (2007), Rondahl (2009), and design of mail and Internet surveys are discussed in Dillman (2007). It should be noted that cognitive measures are not limited to paper and pencil tests and that a variety of other approaches exist including computer-based testing, simulations that are discussed in Chapter 10 and Internet data collection discussed in Chapter 11.

Affective measures seek to determine interests, values, and attitudes. Interests are conceptualized as preferences for particular activities. Examples of statements relating to interests are:

- I prefer community-based nursing practice to practice in the hospital setting.
- I like to work with student nurses as they give care to patients.
- I prefer teaching responsibilities to administrative responsibilities.
Part I Basic Principles of Measurement

- I would enjoy having one day a week to devote to giving direct care to patients in addition to my teaching responsibilities.

**Values** concern preferences for life goals and ways of life, in contrast to interests, which concern preferences for particular activities. Examples of statements relating to values are:

- I consider it important to have people respect nursing as a profession.
- A nurse’s duty to her patient comes before duty to the community.
- Service to others is more important to me than personal ambition.
- I would rather be a teacher than an administrator.

**Attitudes** concern feelings about particular social objects, that is, physical objects, types of people, particular persons, or social institutions. Examples of statements relating to attitudes are:

- Nursing as a profession is a constructive force in determining health policy today.
- Continuing education for nurses should be mandatory for relicensing.
- Humanistic care is a right of all patients.
- All nurses should be patient advocates.

The feature that distinguishes attitudes from interests and values is that attitudes always concern a particular target or object. In contrast, interests and values concern numerous activities: specific activities in measures of interest and very broad categories of activities in measures of value. It is extremely difficult to preserve the conceptual differences among interests, values, and attitudes when actually constructing measures of affect. Thus, for the purpose of rendering them measurable, they are all subsumed under the rubric of *acquired behavioral dispositions* (Campbell, 1963) and are defined as tendencies to respond in a consistent manner to a certain category of stimuli. For example, when patients are asked to respond to a questionnaire to indicate their satisfaction with the quality of care received, one is interested in measuring their tendency to consistently respond that they are satisfied or dissatisfied, given a set of questions that ask them about the care they received (the stimuli). Examples of the use of affective measures can be found in Grice, Picton, and Deakin (2003); Denny-Smith, Bairan, and Page (2005); Mackler, Wilkerson, and Cinti (2007); Gerend and Maglorie (2008).

**Self-report measures** are the most direct approach to the determination of affect. In this type of measure subjects are asked directly what their attitudes, interests, or values are. For example, subjects might be given a list of favorable and unfavorable statements regarding antagonistic patients and asked to agree or disagree with each. Such a self-report inventory is referred to as an attitude scale. Other indicators of affective behaviors include but are not limited to:

1. Sentence-completion exercises designed to obtain ratings of the psychological appropriateness of an individual’s responses relative to specific criteria.
2. Interviews.
3. Questionnaires.
5. Physiologic measures.
6. Projective techniques, for example, role playing or picture interpretation.
7. Observational techniques and behavioral tests, including measures of congruence between what is reported and how an individual actually behaves in a specific situation.
8. Anecdotal records and critical incidents.

Examples of self-report measures are included in Mackler et al. (2007) and Gerend and Maglorie (2008).

From the empirical evidence concerning the validity of different approaches, it appears that self-report offers the most valid approach currently available. For this reason, at present, most measures of affect are based on self-report and usually employ one of two types of scales: a summated rating scale or a semantic differential scale. A *scale* is a measuring tool or method composed of:

1. A stem, which is a statement relating to attitudes or an attitudinal object to be rated by the respondent.
Indicate your degree of agreement with the following statement:

**STEM:** Noncompliance on the part of the patient indicates a need for additional attention to be directed toward the quality of care received by the patient.

**SCALE STEPS:**

1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12.

**ANCHORS:**

Completely Disagree

Completely Agree

**FIGURE 1.2 The components of a scale.**

2. A series of scale steps.
3. Anchors that define the scale steps.

An example of a scale can be found in Chiravalle and McCaffrey (2005).

Figure 1.2 presents examples of the components of a scale.

There are different types of anchors that can be employed: numbers, percentages, degrees of agreement/disagreement, adjectives (e.g., worthless/valuable), actual behavior, and products (e.g., samples of nursing care plans to be rated 1 to 6). Usually numerical anchors are preferred for the following reasons: if the meaning of each step on the scale is specified at the beginning of the rating form, as is usually the case, numbers provide an effective means of coordinating those definitions with rating scales; numbers on scales constantly remind subjects of the meanings of scale steps; numbers facilitate the analysis of data, for example, inputting ratings for computer analysis (Nunnally, 1967; Nunnally & Bernstein, 1994).

**Summated Rating Scale**

A summated rating scale contains a set of scales, all of which are considered approximately equal in attitude or value loading. The subjects respond with varying degrees of intensity on a scale ranging between extremes such as agree/disagree, like/dislike, or accept/reject. The scores of all scales in the set are summed or summed and averaged to yield an individual’s attitude score. An example of a summated rating scale is given in Figure 1.3.

Summated rating scales are easy to construct, are usually reliable, and are flexible in that they may be adapted for the measurement of many different kinds of attitudes. Nunnally (1967) and Nunnally and Bernstein (1994) suggest that the reliability of summed scales is a direct function of the number of items. When there are a reasonable number of items (e.g., 20) on the scale, fewer scale steps for individual scales are required for a high degree of reliability. When there are fewer items, more scale steps for individual scales are required for reliability. In most cases, 10 to 15 items using 5 or 6 steps are sufficient. Individual scales on summed attitude scales tend to correlate substantially with each other, because it is fairly easy for the constructor to devise items that obviously relate to each other and for subjects to see the common core of meaning in the items. Additional information regarding summated attitude scales can be found in Edwards (1957), Shaw and Wright (1967), Nunnally (1967), or Nunnally and Bernstein (1994).

An example of a summated rating scale can be found in Lehoux and colleagues (2006).

**Semantic Differential Scales**

The semantic differential is a method for measuring the meaning of concepts that was developed by Osgood, Suci, and Tannenbaum (1957). The semantic differential has three components: (1) the
Indicate your degree of agreement with each of the following statements:

a. Antagonistic behavior on the part of the patient indicates a need for additional attention and time from the nurse.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely Disagree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Antagonistic patients receive more than their share of staff time and attention.

<table>
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<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely Disagree</td>
<td></td>
<td></td>
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</table>

FIGURE 1.3 Example of a summated rating scale.

c. If a noncomplying patient, said, “I dislike them very much,” this statement would represent a connotation or sentiment for that type of patient. The semantic differential is one of the most valid measures available for assessing the connotative aspects of meaning, particularly the evaluative connotations of objects. An example of a semantic differential scale can be found in Rempusheski and O’Hara (2005).

Factor analytic studies of semantic differential scales have suggested that there are three major factors of meaning assessed by such scales: (1) evaluation, (2) potency, and (3) activity. Table 1.1 presents the pairs of adjectives most frequently used to define each of these factors. Additional information regarding semantic differential scales can be found in the work of Cousins (1997), Czar and Engler (1997), Adam...
Rate the following concept in terms of how you feel about it at this point in time:

Noncomplying Patient

\[
\begin{array}{cccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 \\
\end{array}
\]

Ineffective

\[
\begin{array}{cccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 \\
\end{array}
\]

Weak

Strong

FIGURE 1.4 Example of a semantic differential scale.

TABLE 1.1 Frequently Employed Anchors for Semantic Differential Factors

<table>
<thead>
<tr>
<th>BIPOLAR ADJECTIVES</th>
<th>Evaluation</th>
<th>Potency</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>good .................. bad</td>
<td>strong ........... weak</td>
<td>active ........... passive</td>
<td></td>
</tr>
<tr>
<td>fair ................. unfair</td>
<td>large ............small</td>
<td>quick ........... slow</td>
<td></td>
</tr>
<tr>
<td>positive ............ negative</td>
<td>severe ............lenient</td>
<td>tense ........... relaxed</td>
<td></td>
</tr>
<tr>
<td>honest ............... dishonest</td>
<td>hard ............soft</td>
<td>sharp ........... dull</td>
<td></td>
</tr>
<tr>
<td>successful ........... unsuccessful</td>
<td>valuable ........... worthless</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The conceptual definition of the phenomenon to be measured forms the basis for how and where the observation should occur. Qualitative conceptual perspectives generally lead to free and unstructured observations in naturalistic settings, while quantitative conceptualizations more often lead to more structured observations using guidelines and trained observers. The work of Cohn, Matias, Tronick, Connell, and Lyons (1986) provides an example of a study combining both structured, standardized observation methods and naturalistic unstructured observations of depressed mothers and their infants. The reader will find an interesting comparison and contrast between the two approaches for collecting observational data.

Unstructured and semistructured observations involve the collection of descriptive information that is generally analyzed in a qualitative manner. When structured observation is employed, it is often necessary that the nurse prepare an observation guide to structure the observation and train the observer in its use. This guide increases the probability that the crucial behaviors of concern will be considered, which increases the reliability and validity of the method.

When possible, the guide should specify when an observation begins and ends as well as what behaviors are to be observed. Frequently, time is the vehicle for accomplishing this purpose. For example, it might be specified that observation of medical students' history taking begin when the student enters the room and continue for the first 5 minutes of the student-patient interaction. Using a more elaborate scheme, observations will begin when the student enters the room, and will continue for 2 minutes; then observers will rest for the next 2 minutes, rate for 2 minutes, rest for 2 minutes, and so forth, until the student leaves the room and the encounter ends. No matter how structured the observation or how well trained or competent the observer, observation techniques, in order to be sound, require more than one observer. This provides an estimate of the accuracy or reliability of the observations and provides a basis for determining the degree of confidence to be placed in the data.

Three factors must be considered in the discussion of observational techniques: (1) interaction between respondents and observers, (2) whether respondents know they are being observed, and (3) whether respondents know when they will be observed. Observation is difficult because watching a situation often changes it so that the observers are no longer certain of what they are observing. This implies that a basic criterion for evaluating studies in which observation is used is the extent to which the situation observed was natural. Observations of a subject's psychomotor skills should be accomplished with as little effect as possible on the natural situation in which the skills are normally performed. Webb et al. (1966) have published a useful book full of suggestions about how measures can be collected as unobtrusively as possible.

It is necessary to weigh the value of collecting observational data over time as opposed to collecting information at one isolated point in time. Observational data collected at one time are subject to more errors of measurement and, hence, lower reliability and validity than observational data collected at multiple times. When subjects' psychomotor performance is of interest, the concern is usually with how they perform most of the time, or typically; that is, patterns of performance or consistency in performance over time becomes important. When observational data are collected at one point in time, there is greater probability that the results of the measurement will reflect more of the conditions surrounding that isolated point in time than the true abilities of the subjects to perform the tasks or behaviors. Hence, whenever possible, measures of performance should occur at more than one point in time.

Observational techniques may be direct or indirect. In direct observation the observer evaluates psychomotor performance by simply watching the subject perform. A limitation of this approach stems from the fact that it is both time-consuming and expensive. It is, however, an excellent technique for the assessment of behavior in conjunction with clinical performance, especially when the concern is with dynamic or process variables. Similarly, a unique strength of the observation method results from the fact that if the observer wishes to learn how a subject functions under the pressure of supervision,
there is no substitute for direct observation that is known and scheduled.

Indirect observation methods include motion picture, television, videotaping, and other devices for recording subjects’ activities. The value of indirect techniques results from the opportunities they afford subjects to become involved in the evaluation of their performance as the recording is viewed jointly by the observer and respondents. Indirect observations are limited in that they are not sensitive to the tone, mood, or affect of the situation. Another limitation is that mechanical devices selectively record, depending on their placement, where they are aimed by the operator and, hence, the total situation may be missed. This limitation can be turned into an advantage, however, if multiple devices are used to record all that happens before them. Examples of psychomotor measures can be found in Bujak, McMillan, Dwyer, and Hazelton (1991); DeMattes, et al. (1993); Mason and Redeker (1993); Finke et al. (2001); Mims (2001); Kostopoulos (2001); Gilbert, Temby, and Rogers (2004); Philpin (2006); Williams (2006); and Cricco-Lizza (2006). Observational methods are discussed in more detail in Chapter 12.

Physiologic measures seek to quantify the level of functioning of living beings. Indicators of physiologic functioning include but are not limited to:

1. Blood pressure readings.
2. Temperature readings.
3. Respiratory measures.
4. Metabolic readings.
5. Diabetic and other screening devices.
6. Readings from cardiac and other monitoring instruments.
7. ECG and EEG readings.
8. Results of blood tests and analyses.

Physical functioning can often be measured by a scientific instrument, and the results of physiologic measures usually are expressed as a quantitative scale that can be graded into finely distinguished numerical values. For example, the variable diastolic blood pressure is measured using a scientific instrument referred to as a sphygmomanometer. Its scale is in a quantitative form ranging from 0 to 300, providing a total of 300 different continuous scale points or values to which a subject can be assigned and which differentiate among the various degrees of the variable possessed by the subjects measured. Thus, on the basis of blood pressure readings, one can state that a subject with a diastolic pressure of 100 is 20 points higher than one with a diastolic pressure of 80. This 20-point difference is significant in comparing the physical status of two patients.

Well-designed and implemented physiologic measures are among the most precise methods one can employ; they yield data measured at the interval or ratio level of measurement, allow a wide range of statistical procedures to be employed in their analysis, and tend to produce results that demonstrate a high degree of reliability and validity. Examples of physiologic measures can be found in Heidenreich and Giuffre (1990), Bridges and Woods (1993), Partridge and Hughes (2007). The physiologic approach to measurement is discussed in detail in Chapter 20.

How Responses Are Obtained and Scored

The distinction to be considered is whether a measure is objective or subjective. It should be noted that a given method or technique is generally viewed as more or less objective or subjective; that is, one may think in terms of a continuum anchored by the terms objective and subjective, and then place a given method on the continuum, depending on whether it possesses characteristics more like those of an objective or subjective measure.

Objective measures contain items that allow subjects little if any latitude in constructing their responses and spell out criteria for scoring so clearly that scores can be assigned either by individuals who know nothing of the content or by mechanical means. Multiple-choice questions and physiologic measures are examples of the most objective methods that can be employed.

Subjective measures allow respondents considerable latitude in constructing their responses. In addition, the probability that different scorers may apply different criteria is greater. Examples of subjective measures are the essay test,
Two general categories: (1) problems related to the difficulty in achieving consistency in scoring responses, and (2) problems associated with the sampling of content. Empirical evidence regarding the reliability of subjective measures suggests that different raters tend to assign different scores to the same response, a single rater tends to assign different scores to the same response on different occasions, and the differences tend to increase as the measure permits greater freedom of response (Finlayson, 1951; Hartog & Rhodes, 1936; Noyes, 1963; Pearson, 1955; Vernon & Millican, 1954). Different raters may differ as a result of a number of factors, including the severity of their standards, the extent to which they distribute scores throughout the score scale, and real differences in the criteria they are applying.

Basic to problems associated with the sampling of content is the notion that each sample unit should be independent and equally likely to be chosen in the sample. In general, the greater the number of different questions, the higher the reliability of the score. The compromise to be made, however, is between the desire to increase the adequacy of the sample of content by asking many different questions and the desire to ask questions that probe deeply the subjects’ understanding. Additional information regarding essay items is presented in Stalnaker (1951) and Coffman (1971). Examples of structured, unstructured, and semistructured interviews can be found in Irwin and Johnson (2005); Cricco-Lizza (2006); and Clarke, Booth, Velikova, and Hewison (2006), respectively. Other subjective measures are described in more detail in Part IV.

**Type of Performance Measured**

When performance is of interest, one may seek to measure typical performance or maximum performance. If the interest is in assessing subjects as they do their best (produce their highest quality work), then a maximum performance measure is appropriate. Such measures are indices of cognition that generally measure a set of skills a subject possesses but that differ among themselves in the specificity of their focus and the use to which scores are put. Maximum performance measures of particular interest include open-ended interview questions, case studies, and nursing care plans. The essay question is a method requiring a response constructed by the subject, usually in the form of one or more sentences. The nature of the response is such that (1) no single answer or pattern of answers can be listed as correct, and (2) the quality of the response can be judged only subjectively by one skilled or informed in the subject (Stalnaker, 1951). Thus, significant features of the essay method are (1) the freedom of response allowed the respondents, (2) the fact that no single answer can be identified as correct or complete, and (3) responses must be scored by experts who themselves usually cannot classify a response as categorically right or wrong. Essay questions may require subjects to express their own thoughts on an issue of interest to the profession, outline a research design for investigating a research question, derive a mathematical proof, or explain the nature of some nursing phenomenon. Items may require only a brief response or may demand an extensive exposition.

Advocates of the essay approach argue that an important characteristic of individuals is their ability to interact effectively with other individuals in the realm of ideas. The basic tool of interaction is language, and successful individuals are those who can react appropriately to questions or problems in their field as they encounter them. It is not enough, they contend, to be able to recognize a correct fact when it is presented or to discriminate among alternatives posed by others. Successful individuals are the masters of their collection of ideas and are able to cite evidence to support a position and contribute to the advancement of ideas and constructs within their field. The only way to assess the extent to which individuals have mastered a field is to present them with questions or problems in the field and assess how they perform. Hence, they argue, the essay format provides an avenue for assessing scholarly and/or professional performances better than other available methods (Coffman, 1971).

Even so, because of their subjective nature, essay questions have inherent limitations that must be recognized and minimized if sound measurement is to result from their use. The limitations of essays and other subjective measures fall into
aptitude measures, achievement measures, and diagnostic measures.

**Aptitude** tests are specific measures of capacity for success and tend to focus on various general aspects of human ability (e.g., mechanical aptitude, artistic aptitude). They are often used as predictors of performance in special fields.

**Achievement** measures are tests of particular skills and knowledge and are more specific than aptitude tests. They usually sample a wide range of skills and are constructed by nurses and other health professionals for their own use. Commercially produced achievement measures are also available in many different content areas. **Diagnostic** tests are even more specific in their focus than achievement measures, although this need not always be the case. They focus on specific skills and often employ multiple measures of particular skills. Their intent is to pinpoint specific weaknesses that might not be apparent otherwise. Once specific deficiencies are identified and remediation has taken place, one might predict that achievement, which is assumed to be dependent on these more specific skills, will improve.

If information about subjects’ typical behavior (i.e., what they usually do or would do) is of interest, it is appropriate to use a **typical performance** measure. These are measures of affective behavior and usually attempt to have respondents describe the way they typically perceive themselves or their behavior. Typical performance measures usually ask the subjects for scaled responses, forced-choice responses, or criterion-keyed responses. Exhibit 1.1 presents examples of each of these types of responses.

### Who Constructs Measures

**Standardized** measures are developed by specialists for wide use. Their content is set, the directions for administration (often including time limits) are clearly described, and the scoring procedure to be used is completely prescribed. Information on norms concerning scores is generally available. Examples of standardized measures employed to assess the outcomes of nursing education programs are presented in *Educational Outcomes: Assessment of Quality—A Prototype for Student Outcome Measurement in Nursing Programs* (Waltz, 1988). In Chapter 7, standardized approaches to measurement are discussed in detail.

**Informal tools and methods** are typically constructed by nurses and other health professionals for their own use. They are not content-constrained; that is, the user is free to define the content as well as administration procedures and scoring. Norms may be available for local groups but more often are not available for any group.

In summary, the measurement framework employed in a given situation will have important implications for instrument development and for what can be done with and on the basis of the resulting information. Thus, it is important to clarify at the outset the type of measurement that will yield data appropriate for the types of questions and/or hypotheses one seeks to answer. In Chapters 2 through 23, attention is focused on instrument development and testing in both the norm-referenced and criterion-referenced cases. In Chapters 24 through 26, measurement issues and important considerations to be made in using the types of measures presented in this section are addressed.

### RELIABILITY AND VALIDITY OF MEASURES

As indicated in the foregoing sections, reliability and validity are essential characteristics of any measuring tool or method. Factors that may affect the degree of consistency obtained for a given measure (reliability) are (1) the manner in which the measure is scored; (2) characteristics of the measure itself; (3) the physical and/or emotional state of the individual at measurement time; and (4) properties of the situation in which the measure is administered (e.g., the amount of noise, lighting conditions, temperature of the room).

Strictly speaking, one validates not the measurement tool or method but rather some use to which the measure is put. For example, an instrument designed to select participants who would benefit from a primary care fellowship experience must be valid for that purpose, but it would not necessarily be valid for other purposes such as measuring how well participants master
EXHIBIT 1.1 Sample Responses of Typical Performance Measures

Scaled response
When a scaled response is employed, the respondent indicates on a scale what his/her rating or answer is to a question posed. For example:

Do findings from this research study provide information that will be meaningful to you in your clinical practice? Please rate.
- not at all
- very little
- somewhat
- enough
- a lot

1 2 3 4 5

Forced-choice response
With a forced-choice response item, the respondent is asked to choose between 2 or more different alternatives, all of which may be appealing responses. The point is that one particular response is most appealing to the subject. For example:

A program of ongoing evaluation and implementation of research findings that may serve as a basis for practice does not exist in the agency with which you are affiliated. You are aware of the need to develop such a program. You would prefer to have this need met by:

1. Referring the task to someone else.
2. Supporting activities of the professional nursing organizations that are seeking to increase involvement in implementing evidence-based practice in all clinical settings.
3. Supporting a policy change in the agency responsible for care.
4. Serving as a resource person to staff by providing them with knowledge and materials to enable them to develop such a program.
5. Becoming a member of a committee of practitioners who are developing and testing a pilot program in conjunction with the patients for whom they deliver care.
6. Initiating the idea of such a program by implementing evidence-based practice for patients on your unit and sharing with staff the various approaches you employ in evaluating and implementing research findings in your practice.

Criterion-keyed response
Criterion-keyed responses depend on information previously obtained about how certain groups answered the items. If a subject’s score looks like those of members of a predefined group, he/she is classified as a member of that group. The assumption is that the criterion for membership in a specific group is having a set of responses on the measure that looks like those from the predefined group. For example, the Minnesota Multiphasic Personality Inventory (MMPI) was originally used with hospitalized psychiatric patients and normal (i.e., nonhospitalized subjects) to construct a criterion-keyed set of questions that had some value as predictors of mental stability, that is, if a specific item was responded to differently by the two groups, it was included on the measure.

objectives at the completion of the fellowship experience.

Both reliability and validity are matters of degree rather than all-or-none properties. Measures should be assessed each time they are used to see if they are behaving as planned. New evidence may suggest modifications in an existing measure or the development of a new and better approach to measuring the attribute in question. Reliability is a necessary prerequisite for validity; that is, if a measure does not assign scores consistently, it cannot be useful for the purpose for which it is intended. Reliability is not, however, a sufficient condition for validity; that is, because a measure consistently measures a phenomenon does not ensure that it measures the phenomenon of interest.

As stated earlier, the determination of the reliability and validity of a specific tool or method will differ depending on whether it is norm-referenced or criterion-referenced. Specific techniques for determining reliability and validity in each case are discussed in Chapters 5 and 6. In either case, the reliability and validity of the measurement process itself is increased when multiple measures of the same thing are employed; that is, more than one type of instrumentation is used to answer a given question. Similarly, reliability and validity increase when the answer to a given measurement concern is elicited by collecting data from a number of different sources using the same measurement tool or method.

Evidence for reliability and validity of a tool or method is accrued over time, so although
one cannot rely on “old” reliability and validity evidence, it is important to seek information regarding reliability and validity testing results in previous studies. Often difficulties are encountered in locating information regarding reliability and validity evidence for existing tools. An article by Strickland (2006) presents strategies for searching for evidence of reliability and validity for an existing instrument that may be useful in this regard.

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Rondahl, G. (2009). Students’ inadequate knowledge about lesbian, gay, bisexual and
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Concepts are the basic building blocks of nursing knowledge, thought, and communication. In recent years, many books and articles have described approaches that can be used to analyze and develop concepts, and have provided examples of concept analyses. These applications have called attention to the importance of a conceptual approach to measurement. Concepts that are commonly used in nursing research and practice differ considerably in their level of maturity or clarity. According to Morse, Hupcey, Mitcham, and Lenz (1996), a mature concept is clearly defined, and has distinct characteristics and defined boundaries, so it is ready to be operationalized. However, concepts that have multiple meanings, even within a discipline, or whose meanings and boundaries are vague or variable, need further development before they can be operationalized effectively for research purposes. For example, following an analysis of the concept of trust in discipline-specific literature, Hupcey, Penrod, Morse, and Mitcham (2001) determined that the concept was immature. They identified commonalities and structural features of trust as used in the literature of several disciplines, and also identified areas in which the meaning remains unclear and needs further research and refinement. In a classic review of measures of the concept of health in 17 nursing studies, Reynolds (1988) found that although health was believed to hold a central position of importance, there was little agreement on its meaning. Therefore, even a concept as prevalent, taken-for-granted, and central as health needs to continue to be evaluated and the links between accumulated knowledge and observation strengthened. The position of the authors of this book is that concepts provide the basis for measurement, and this chapter presents strategies for defining and operationalizing them.

**Terminology**

A concept is a word or term that symbolizes aspects of reality that can be thought about and communicated to others. It denotes a notion or idea by naming it. Often such notions are formed from particular observations or sensory experiences, but may be constructed on the basis of more abstract experiences, such as listening or reading. The concept name is used to denote phenomena (objects, attributes, characteristics, or events) that share a combination of similar properties or characteristics that set them apart from other phenomena that do not share the properties. The concept “ferret” denotes a class of animals that share certain characteristics which, when taken together, are different from those of other classes of animals. Because a concept is a symbol, it is an abstraction from observable reality, in essence, a shorthand device for labeling ideas. Concepts provide a language link between abstract thought and sensory experience.

It is often asserted that concepts are the basic elements, or building blocks, of scientific theories. **Theories** are interrelated sets of propositions or statements that provide the basis for describing, explaining, predicting, and/or controlling phenomena. **Propositions**, in turn, are statements that include and specify the relationship(s) between two or more concepts. A theory generally contains many concepts. A conceptual framework (or conceptual model) also contains a number of concepts. In a conceptual framework concepts are identified, defined, and
linked by broad generalizations. A conceptual framework provides an orienting scheme or worldview that helps focus thinking and may provide direction for the development of specific theories. In short, concepts provide the basis for building the complex statements and theories that form the subject matter for the discipline.

A distinction is generally made between concepts, which are abstract, and those attributes, properties, behaviors, or objects that are perceptually accessible, directly or indirectly, through the senses. The latter are often called “observables,” even though they may not be directly observed in the ordinary sense of the word. The color of a patient’s skin or the odor of discharge from a wound can be sensed directly. Such directly observable properties (e.g., color, odor) often are used to indicate more complex concepts, such as infection. Some properties of individuals require amplification or transformation devices to be made observable. For example, cardiac arrhythmias are observed indirectly through an electrocardiograph. Advances in the use of electronic data gathering devices that are easy to use in a variety of settings have increased their use in nursing research.

Observable attributes or characteristics associated with a given concept are often termed indicators of the concept, or its empirical referents. Redness, swelling, and a foul odor discharge are indicators of an infection. Other indicators would include pain/discomfort, increased temperature, and increased white cell count. A given observable may be an indicator for more than one concept. For example, shortness of breath could be an indicator of cardiac insufficiency, dyspnea, or anxiety. An infant’s cry can be an indicator of pain, hunger, or boredom.

Behavioral concepts tend to be relatively abstract; however, they can be indicated by behaviors that can be observed. For example, the behaviors that are displayed by mother and infant in front of an observer can be used to indicate concepts such as parenting skill, level of maternal-infant attachment, or a developmental disorder. Some behaviors and characteristics are observed indirectly through responses to questions. For example, a client can report the frequency with which he or she contacted a helpline (an indicator of help-seeking), or responses to questions can be used to indicate the client’s level of satisfaction with a health care provider, or the likelihood of engaging in a particular risky behavior (an indicator of risk-taking). Qualitative approaches, such as interviews, are also used to elicit from subjects the essential aspects of a complex, highly abstract concept that then guide the identification of indicators. For example, Lyneham, Parkinson, and Denholm (2008) interviewed emergency department nurses in a hermeneutic phenomenological study to explore intuition in relation to Benner’s concept of expert practice.

Operationalization is the process of delineating how a concept will be measured. It involves making a concept explicit in terms of the observable indicators associated with it and/or the operations that must be carried out in order to measure it. The process of operationalization involves a mode of thinking that proceeds from the abstract to the concrete. In a process that is decidedly not arbitrary, one moves from a relatively abstract idea (the concept) to identifying the dimensions of its meaning or its attributes, the concrete observables associated with those meaning dimensions or attributes, and the way in which those observables will be measured. The operational indicators for a given concept are specified based on theoretical and empirically observed regularities.

The term “operationalization” is most often used in conjunction with research. It is also an inherent part of nursing and health care practice, even though not commonly identified as such when it is being carried out. If a note in a patient’s record states that the patient seemed anxious about his upcoming surgery because he was restless, unable to sleep, and complained about diarrhea, the health care provider who wrote the note actually operationalized the concept of anxiety by suggesting several observable indicators of the condition.

Careful operationalization of concepts is an essential step in nursing research, particularly research using quantitative methods. Given a problem or question to be investigated or a theory to be tested, the researcher must identify the key ideas or concepts involved, and define and operationalize each of them before the study can be carried out. Other practice-based activities
require precise operationalization of concepts as well. For example, in order to develop a care plan the nurse or other care provider must decide what needs to be known about the patient and which observations must be made to yield the information. Specifying the observations that must be made in order to assess health-related quality of life in chronic illnesses, including those involved in assessing functional health of individuals with the chronic conditions of HIV/AIDS and rheumatoid arthritis, is an example of operationalizing that concept (Sousa, Kwok, Ryu, & Cook, 2008). Operationalization is not necessarily an easy undertaking. According to Penrod and Hupcey (2005), operationalization occurs at a high level of pragmatic development of a concept; therefore, it should be reserved for relatively mature concepts. Mature concepts are those that are well understood, in that they have clear definitions and are well differentiated from other concepts (see also Hupcey & Penrod, 2005).

In order to render patient assessment precise and ensure that other providers will base their judgments on the same kinds of observations, various checklists, protocols, or guidelines may be developed. All such devices incorporate the operationalization of concepts. Other examples of activities that require precise operationalization of relatively complex concepts include evaluating the quality of care, identifying patient outcomes to judge the effectiveness of a given intervention (e.g., Hammond, Bryan, & Hardy, 2008), or to assess performance in the clinical setting (e.g., Coleman et al., 2009; Pappas, 2008).

**NURSING CONCEPTS**

Nursing has key concepts that designate its essential subject matter. Some represent ideas that are vital to the thought and language of all nurses, regardless of the settings and specialties in which they practice. Although these concepts may be claimed by nurses as being core to their discipline and used frequently in nursing research and practice, the same terms may be important in other fields as well.

Among the concepts that are considered central to nursing and are important in all subspecialty areas are person, health, nursing, environment, care or caring, patient safety, interaction, and quality of care. Other concepts represent narrower domains of knowledge, because they are of concern primarily to specific subgroups within the profession. For example, the concept “mother-infant attachment” is of interest primarily to nurses working with infants and young families, and the concept “dyspnea” is of primary interest to nurses working with persons with cardiac or pulmonary symptoms or illnesses. There need not be agreement that a given concept is important to nursing knowledge; however, specific concepts that emerge as most important for building nursing knowledge will be the most likely to generate cumulative knowledge building by multiple researchers.

There is considerable variation among nursing concepts, since they represent a wide range of phenomena that are of interest to the profession. Some represent animate or inanimate objects (e.g., patient, crutch, needle, endorphins), whereas others represent attributes or characteristics of objects or persons (e.g., size, color, intelligence, attitudes). Some nursing concepts represent either relatively static characteristics (e.g., socioeconomic status) or those that may vary considerably over time (e.g., job satisfaction, hope) but can be measured by taking a “snapshot” at a given point in time. Others represent dynamic processes that, by definition, unfold over time (e.g., socialization, interaction) and are difficult to characterize using a snapshot approach. Some concepts can be viewed both as static and dynamic; social support, for example. It can be viewed either as a commodity that is given and received and can be described at a particular point in time, or it can be viewed as an ongoing process of social interaction. A formal distinction is made between relatively stable and more situationally variable manifestations of a concept, for example, trait anxiety and state anxiety. Whereas some concepts refer to individuals or their properties, others represent relations between and among individuals, (e.g., subordination, exchange) or properties of collective units such as families, groups, or communities (e.g., structure, pattern). Often, individual-level concepts such as health are applied to aggregates (e.g., families, organizations, or communities).
Such extension requires making some important conceptual decisions about the nature of both the property or entity and the aggregate to which it is being applied.

Table 2.1 contains examples of some concepts used in nursing research projects and specifies the ways in which each was operationalized. This table reveals that nursing concepts differ in several respects. First, they differ in their complexity; that is, the number of observable properties, characteristics, or behaviors designated by the concept name. Although the concept “perfusion” is relatively straightforward and is designated by one observable property (partial pressure of transcutaneous O\(_2\)), others such as mother-infant interaction quality are highly complex, in that they encompass a large number of characteristics (or behaviors) and their meanings have several dimensions.

In general, the more complex the concept, the more difficult it is to specify its meaning, the less likely it is to be defined identically by everyone using it, and the more complex its operationalization. The relatively complex concepts in

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### TABLE 2.1 Concepts and Indicators From Reports of Nursing Research

<table>
<thead>
<tr>
<th>Concept</th>
<th>Operational Indicator(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain (in pre- and nonverbal children)</td>
<td>Score on the University of Wisconsin Children’s Hospital pain scale (consisting of observed infant behaviors in 5 domains: crying, facial expression, behavioral response, body movement, and sleep) (Hatfield, 2008)</td>
</tr>
<tr>
<td>Abuse</td>
<td>Score on the Women Abuse Screening Tool (an 8-item self-report measure) and the investigator’s evaluation based on responses to the Evaluation Interview Frame for Nurses and Midwives (9 broad interview items) (Svavarsdottir &amp; Orlygsdottir, 2008)</td>
</tr>
<tr>
<td>Treatment seeking</td>
<td>Time in hours from onset of symptoms for the acute event to the time of admission to the emergency department (self-reported symptom onset time compared with ED admission time) (Zerwic, Ryan, deVon, &amp; Drell, 2003)</td>
</tr>
<tr>
<td>Infant health</td>
<td>Number and length of hospitalizations, number and diagnoses of illness episodes, and number of emergency room visits in the 24 months following birth (Koniak-Griffin et al., 2003)</td>
</tr>
<tr>
<td>Asthma medication adherence</td>
<td>Number of daily uses of medication canister as measured by electronic Doser CT (a device secured to top of the medication canister that records number of puffs taken each day of use; adjusted doser data were used to control for excess usage) (Bender et al., 2000)</td>
</tr>
<tr>
<td>Perfusion</td>
<td>Partial pressure of transcutaneous oxygen as measured with a Novametrix 840 Pr0(_2) monitor (Wipke-Tervis, Stotts, Williams, Froelicher, &amp; Hunt, 2001)</td>
</tr>
<tr>
<td>Mother-infant interaction quality</td>
<td>Scores on the Nursing Child Assessment Teaching Scale (NCAT) and Mother-Infant Communication Screening Scale (Byrne &amp; Keefe, 2003)</td>
</tr>
<tr>
<td>Nurse staffing</td>
<td>RN proportion or skill mix: #RN hours/#all hours, where RN hours is the number of productive hours worked by RNs per patient day and all hours is the total number of productive hours worked by all nursing personnel per patient day (Cho, Ketefian, Barkauskas, &amp; Smith, 2003); hospital score aggregated from nurse responses to questions about the “number of patients on the ward during the last shift worked and the total number of nurses covering those patients” (Rafferty et al., 2007)</td>
</tr>
<tr>
<td>Occupational burnout</td>
<td>Score on the Emotional Exhaustion subscale of the Maslach Burnout Inventory (self-report instrument, 9 items) (Flynn, Thomas-Hawkins, &amp; Clarke, 2009)</td>
</tr>
<tr>
<td>Pressure ulcer risk</td>
<td>Scores on the Norton scale, the Waterlow scale, and the Braden scale (Papanikolaou, Lyne, &amp; Anthony, 2007)</td>
</tr>
</tbody>
</table>
Table 2.1 are either operationalized with several discrete observables (e.g., infant health, nurse staffing) or by means of indices that combine several discrete observable indicators into one score (e.g., pressure ulcer risk; pain). In the studies cited in Table 2.1, a concept (treatment seeking) that represents a complex process was measured using a single indicator that addressed only one aspect of the concept (length of time between symptom onset and admission to the emergency department). As a result, the potential complexity of the concept meaning is not readily apparent to those who are not familiar with the literature. The concept “nurse staffing” was measured in two different ways in separate studies. In one case, objective data obtained from hospital databases was used, and in the other study, nurses were queried to obtain data. The former approach is more commonly used to measure this concept.

Nursing concepts also differ in their level of abstraction, that is, in the number of inferential steps needed to translate observation into meaning. The concept “syringe” is relatively concrete, in that most of its properties are directly observable. On the other hand, the concepts in Table 2.1 are more abstract, because they cannot be observed directly and their presence or occurrence must be inferred. Concepts such as asthma medication adherence and perfusion require the use of special devices or instruments. The concept mother-infant interaction quality is inferred through a combination of direct observation and the use of instruments.

Most nursing concepts are relatively abstract. As a result the multiple dimensions and characteristics included in their meaning must be specified carefully and with precision. Highly abstract concepts that are not directly observable are sometimes termed constructs because they are constructed of less abstract concepts that are observed directly or indirectly. Morse et al. (1996) refer to such abstract concepts as behavioral concepts, in order to differentiate them from more concrete physiological or disease-state terms. Examples of constructs or behavioral concepts include quality of life, stress, coping, moral development, self-concept, anxiety, job satisfaction, vulnerability, and resilience. In this chapter, the term “concept” is used inclusively and refers to ideas at all levels of abstraction.

Many of the concepts that appear in Table 2.1 that express important ideas in nursing are also used as basic elements of theory in other disciplines as well. Functional status, for example, is commonly used in several disciplines, including sociology, epidemiology, social work, physical therapy, and medicine. The term “borrowed concepts” has been used to describe concepts that have a rich tradition and plentiful literature in another field, but are being used in nursing research. In reality, knowledge is not owned by a given discipline, so to call such concepts “borrowed” is actually a misnomer. Because nursing incorporates and builds on the knowledge of related sciences and the humanities, its concepts are generally not unique; however, the perspective taken by nursing and the use to which its knowledge is put helps guide the selection of concepts from other disciplines and influences the ways in which they are defined, conceptualized, and operationalized, and the practice implications that can be drawn from studying and applying them (Gagnon & Holmes, 2008; Hupcey et al., 2001; Song & Lipman, 2008).

**THEORETICAL AND OPERATIONAL DEFINITIONS**

A theoretical definition provides meaning by defining a concept in terms of other concepts; it involves substituting one or more words for another. An operational definition provides meaning by defining a concept in terms of the observations and/or activities that measure it.

The theoretical definition of a concept generally consists of words, phrases, or sentences selected from among several alternative or possible meanings. Sometimes several meanings, each equally plausible, are included. Theoretical definitions vary considerably in complexity. In the scientific and practice literature they should be sufficiently complex to include the essential meaning of a concept as it is being used in that particular practice or research context, yet very precise and clear. The theoretical definition is the primary vehicle for communicating the meaning of a concept to the reader or listener.
Theoretical definitions may be derived from common usage, borrowed intact from a preexisting theory, or synthesized from literature and/or observation in the clinical or field setting. Ideally, the theoretical definition of a concept is consistent with its use within the discipline. In theoretical and empirical literature a theoretical definition based simply on common usage of the concept, or borrowed uncritically from another discipline, is generally inadequate because the meaning of many concepts is discipline- and context-specific. Within the context of a given theory, a concept may either be defined within the theory itself using the concepts of the theory to construct the definition, or may be introduced into the theory without a definition as long as it has an agreed-upon meaning (Meleis, 2006).

The operational definition is stated in terms of the way the concept is being measured. It includes the empirical indicators of the concept and any procedures (e.g., instruments, laboratory protocols, specific settings) that are being used to discern those indicators. It represents the outcome of the process of operationalization. For example, the concept functional health status was theoretically defined by DiMatteo and Tulman (2003) as “performance of activities associated with life roles” (p. 99). The operational definition of the concept was the patient’s scores on two instruments: the Inventory of Functional Status in the Elderly (Paier, 1994) and the Sickness Impact Profile (Dami-ano, 1996). Giuliano, Scott, Brown, and Olson (2003), in a study of the impact of bed position on cardiac output, defined the latter as “the amount of blood in liters ejected from the left ventricle per minute” (p. 242). The physiological device-assisted measures used were thermodilution and the continuous cardiac output method of measuring the transfer of heat. See Table 2.2 for these and other examples of theoretical and operational definitions.

The operational definition of a concept generally refers to the way in which the concept is measured within the context of a particular study or activity. It is frequently acknowledged that a given operationalization does not completely reflect the full richness of the theoretical meaning of the concept. The operational definition usually is more restrictive and situationally specific than the theoretical definition.

Both theoretical and operational definitions are important and useful for understanding and building nursing knowledge. To define nursing concepts either exclusively in terms of their observable indicators and operations or in terms of other concepts would inhibit essential links between theory and research. Theoretical and operational definitions play complementary roles. The presence of a carefully developed theoretical definition helps guide the selection of indicators and is the basis for determining whether a given set of indicators is relevant. Indicators lend focus and clarity to, and help demonstrate the utility and validity of, theoretical ideas. An operational definition helps focus the meaning of a theoretically defined construct within a particular context, and a theoretical definition can give greater breadth of meaning than highly specific indicators. Unfortunately, investigators studying relatively commonly encountered and seemingly straightforward concepts (e.g., pain, adverse events, nurse staffing, pressure ulcer risk) often do not provide theoretical definitions, even though they describe the chosen measures in detail.

Because it may be difficult to capture all of the rich meaning of a complex concept in operational indicators, it is important not to rush prematurely toward closure in operationalizing a concept before the theoretical work to elucidate its dimensions and nuances of meaning is well advanced. Hupcey et al. (2001) and Hupcey and Penrod (2003) noted that the nursing literature embodies many examples of uncritical use of the concept of “trust” without clear concept development. They provided an example of how techniques of concept analysis and concept development using data from the literature and sequential qualitative studies were used to advance the meaning of the concept, thereby paving the way for its use in research. The recent surge of interest in qualitative research in nursing and in concept analysis and development approaches that are grounded in both real-world observation and the literature (see Hupcey & Penrod, 2003; Sadler, 2000; Swartz-Barcott & Kim, 2000) has helped to reveal the potential richness of meaning of concepts in common use and has provided considerable insight that needs
### TABLE 2.2 Examples of Theoretical and Operational Definitions

<table>
<thead>
<tr>
<th>Concept</th>
<th>Theoretical Definition</th>
<th>Operational Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>“A subjective feeling of tiredness that is influenced by circadian rhythms and can vary in unpleasantness, duration, and intensity” (Piper, Lindsey, &amp; Dodd, 1987)</td>
<td>Total score on the 22-item Piper Fatigue Scale, which has 4 dimensions: behavioral, sensory, cognitive, and affective (Hamilton, Stewart, Crandell, &amp; Lynn, 2009)</td>
</tr>
<tr>
<td>Coping</td>
<td>Strategies identified by African American cancer survivors within four domains: help received (emotional, instrumental, and informational support from family and friends); help given to others (activities “that resulted in feelings of being connected to and valued” by others in their social network); help from God (“coping through a personal relationship with God”); and self-help strategies (Hamilton et al., 2009, p. 246)</td>
<td>Subscale scores from the Ways of Helping Questionnaire, a 62-item questionnaire (Hamilton et al., 2009)</td>
</tr>
<tr>
<td>Cardiac output</td>
<td>“The amount of blood in liters ejected from the left ventricle per minute”—the product of heart rate and stroke volume (Giuliano, Scott, Brown, &amp; Olson, 2003, p. 242)</td>
<td>(1) Thermodilution approach in which the difference between the temperature of solution injected into a pulmonary artery catheter and the blood in circulation in the heart is plotted on a time-temperature curve, and (2) the continuous cardiac output method, measuring the transfer of heat from a heated filament in the pulmonary artery catheter to the blood that flows by a thermistor near the tip of the catheter (Giuliano et al., 2003, p. 243)</td>
</tr>
<tr>
<td>Lymphedema symptom experience</td>
<td>The totality of symptoms perceived in conjunction with lymphedema, “an abnormal accumulation of lymph fluid in the interstitial spaces of the affected limb” (Fu, Axlerod, &amp; Haber, 2008, p. 341)</td>
<td>Total score on the Lymphedema and Breast Cancer Questionnaire (structured interview containing yes/no questions about a list of symptoms commonly associated with lymphedema) (Fu et al., 2008)</td>
</tr>
<tr>
<td>Sleep pattern disturbance</td>
<td>Deviations from normative sleep patterns and perceptions of poor sleep quality, i.e., objective and subjective patterns. Includes insomnia symptoms of trouble falling asleep or staying asleep or frequent awakening (Caldwell &amp; Redeker, 2009).</td>
<td>Objective measures collected by wrist actigraph, with scoring of “sleep efficiency, time in bed, total sleep time, awake time after sleep onset, and number of nocturnal awakenings.” Data from a sleep diary were used to interpret the actigraph data. The subjective measure was the Pittsburgh Sleep Quality Index (15 self-report items) (Caldwell &amp; Redeker, 2009, p. 180).</td>
</tr>
</tbody>
</table>

To be taken into account in developing operational definitions.

**OPERATIONALIZING NURSING CONCEPTS**

The process of operationalizing a concept is an ongoing and cumulative process that involves several interrelated steps: (1) developing the theoretical definition; (2) specifying variables derived from the theoretical definition; (3) identifying observable indicators; (4) developing means for measuring the indicators; and (5) evaluating the adequacy of the resulting operational definition. Each of the steps represents progression from the abstract to the concrete; however, there is actually considerable interplay between...
steps, and one is rarely completed before the next is begun. Although there is no specific way to go about operationalizing a concept, the following is a description of the approach that we have found to be useful. Each of the major steps is considered in detail with specific strategies included. For an excellent example of the application of this approach, refer to Beck and Gable’s (2001) description of the development and assessment of the Postpartum Depression Screening Scale.

**DEVELOPING THE THEORETICAL DEFINITION**

The purpose of defining a concept is to convey as clearly as possible the idea that is represented when a given term is used. Generally, when a concept is used in conversation or encountered in the literature, the user or reader has some idea, more or less precise, of the meaning assigned to the term. In order to formulate a theoretical definition for a concept that is to be used in theory, research, or practice it is necessary to translate one’s informal, personal working definition of the concept into a theoretical definition that is precise, understandable to others, and appropriate for the context in which the term will be used. The series of activities involved can be long and intense. The activities include (1) developing a preliminary definition, (2) reviewing literature, (3) developing or identifying exemplars, (4) mapping the concept’s meaning, and (5) stating the theoretical definition. The activities involved in developing a theoretical definition are similar to those involved in conceptualization, the act of arriving at abstract understanding of a phenomenon, but are often formalized, and culminate in a written product.

Although parallels can be drawn between conceptualization and the processes of concept analysis and development, as described in the theoretical and qualitative research literature of nursing and related disciplines (e.g., Hupcey, Morse, Lenz, & Tason, 1996; Rodgers & Knafl, 2000), some distinctions are necessary. Whereas conceptualization is an active, generational process of theoretical thinking, concept analysis is more reflexive, involving critical evaluation of conceptualization that has already occurred (Kim, 2000). It more closely resembles the inductive, integrative thinking involved in concept development. As will be shown below, the steps involved in formulating theoretical definitions generally entail both active conceptualization and analysis of preexisting conceptualizations. The recent literature that has focused on concept analysis, development, exploration, and advancement (e.g., Hupcey & Penrod, 2003; Rodgers & Knafl, 2000) has been oriented primarily toward theory-building rather than toward research applications. Therefore, the most advanced thinking about concepts and the most careful and elaborate conceptualization has often not been linked directly to operationalization. Conversely, many of the concepts that have been studied empirically have been operationalized without benefit of thoughtful conceptualization.

As a means of short-cutting the process of conceptualization, one may be tempted to turn to the dictionary or a frequently cited reference and simply borrow the definition. Such short-cuts are problematic. Dictionary definitions reflect the meanings of terms as they are used in everyday language. Common sense meanings may differ from, and are much less precise than, scientific meanings, which reflect the result of systematic study and have been consensually validated by the members of a scientific community. For example, disease-oriented definitions of health derived from the biomedical model are not consistent with the basic philosophical stance or human health response model reflected in contemporary nursing thought. Although a dictionary definition can often serve as a useful early step in developing a concept, it should not substitute for examining the scientific literature.

Use of a preexisting theoretical definition may sometimes be the most appropriate approach to defining a concept. For example, if one is testing a theory in which clear theoretical definitions have been stated, they should not be altered. Likewise if theoretical development is being done within the context of a well-established theory with accepted, clearly defined concepts, it is appropriate to use the definitions without modification, assuming they convey the essential meaning. Borrowing another’s theoretical definition also may be acceptable, even if the definition was
developed within a different context or discipline, provided it clearly represents the meaning to be conveyed. Usually, however, its appropriateness cannot be determined until a variety of possible definitions have been explored. The activities that are undertaken to develop a theoretical definition are described below.

The Preliminary Definition

It is often useful to begin development of a theoretical definition by writing one’s own definition of the concept, including key ideas and synonyms. The sources of this definition may include clinical observation and experience, or literature. Additionally, it is helpful to indicate the purpose for which the concept is being defined and operationalized. Possible purposes might include testing a particular theory, conducting research to describe a health-related phenomenon, developing and testing instruments for use in patient assessment, documenting the outcomes of nursing interventions, or identifying the defining characteristics of a new nursing diagnosis. The preliminary definition is only a starting point for conceptualization, so should never be viewed as an end in itself. For example, assume that the concept to be operationalized for research purposes is help-seeking. A preliminary definition might be stated as follows: help-seeking is the process of looking for assistance from others to solve a problem. This preliminary definition suggests that help-seeking involves a sequence of behaviors (a “process”) that are interpersonal (involve “others”) and are purposely undertaken by the searcher in order to achieve a goal (“solving a problem”).

These preliminary activities help to set the stage for concept definition in several ways. First, they force translation of an idea into words and call attention to aspects that may be important to include in a later, more precise formulation of the definition. Second, they help to place limits or boundaries around the concept and eliminate meanings that are irrelevant to the purpose at hand. Many concepts have a wide range of possible meanings depending on the context in which they are used. For example, the concept “reaction” conveys a different sense when used in the context of chemistry or pharmacology (e.g., chemical reaction, negative reaction to a drug) than when used in the context of human behavior (e.g., psychological reaction to a stimulus event). Third, the preliminary definition helps to identify the perspective or worldview that will be used and the assumptions that will be made in defining the concept. Each discipline has a somewhat unique worldview, but even within a discipline there can be many different perspectives that suggest very different definitions for a given concept. For example, within the field of sociology, some definitions of social support are based on theories of attachment and role, and others are based on exchange theories. Depending on the theoretical perspective, the respective definitions would be likely to emphasize either the need for human contact and types of support emanating from different role relationships, or the reciprocal nature of the support. One’s own orientation should be recognized and compared with others’ orientations in order to reveal biases or inconsistencies that should be rectified as the definition is refined.

Literature Review

Once the preliminary working definition has been written, the very essential next step is to examine the current knowledge about the concept by means of a review of relevant literature in nursing and related fields. Additionally, exemplars or cases that synthesize the meaning gleaned from the literature and exemplify the concept can serve to enhance refinement of the theoretical definition. The step of reviewing literature is consistently included in descriptions of concept analysis and development, and is a vital activity. Walker and Avant (2005) and Rodgers (2000) recommend an extensive literature review in order to generate and then validate the ultimate choice of the concept’s defining attributes. Morse (2000) and Morse et al. (1996) recommend conducting an exhaustive review of the literature about a concept to determine its level of maturity. “A mature concept, that is, one that can be readily adapted for research purposes, is well-defined, has distinct attributes or characteristics, delineated boundaries and well-described pre-conditions and outcomes” (Hupcey et al., 2001, p. 283).
The literature needs to be identified by searching bibliographic databases from a variety of disciplines, not just nursing. Frequently, literature in related disciplines is helpful in defining a concept, and sometimes the bodies of literature that can contribute to concept development and definition seem distant indeed. The information published in the literature of other disciplines should be interpreted with care, recognizing possible limitations in one's ability to understand what is written. Often it is helpful to seek input and validation of one's understanding from scholars in the parent discipline of the publication.

Choice of literature to review should be guided by the purpose for which the concept is being developed and measured, the unit(s) of analysis to which it applies (e.g., individual, group, family, community, society), and the conceptual or theoretical framework that is being used. While the review should not be overly limited in scope, choice of literature should be targeted to relevant materials. The review should include, but not be limited to, recent publications. Frequently tracing the historical evolution of a concept reveals important advances that have been made in reformulating it or adding new dimensions to its meaning (Broome, 2000; Rodgers, 2000).

A number of techniques that can be used to help construct theoretical definitions by integrating the results of information gleaned from the literature review and from case development are listed below. Usually a combination of techniques is required.

1. List all definitions of the concept (that is, the word label) from the literature that are potentially relevant. Include both explicit and implicit (suggested but not stated) definitions. Identify commonalities and differences. Elements common to the definitions of a concept are considered critical attributes. They are the elements that one would want to be sure to include in a meaningful theoretical definition, because they express the meaning of the concept and help differentiate it from others. For example, DeSantis (2008) examined the literature concerning the concepts of vulnerability and resilience in the context of HIV infection. He found that the concept of resilience had been described and defined quite consistently by a number of authors. All of the definitions included a core of components that would be considered critical to address in a theoretical and an operational definition of the concept: “an adverse event, a confrontation of this adverse event, and a gradual adaptation and integration of this event into the lives of the clients” (p. 282).

2. List synonyms and their definitions. This activity is useful in differentiating terms and identifying subtle differences in meaning.

3. List examples or instances of the concept recorded in the literature or recalled from clinical practice. Some authors recommend making up fictitious examples or cases that serve to clearly exemplify the concept (model case) or its opposite (contrary case), or a similar or related phenomenon (borderline case or related case, respectively). This strategy was suggested by Wilson (1963) and adapted by Walker and Avant (2005), Avant (2000), and Sadler (2000), and others. It is a mental exercise that can aid in clarifying the concept and its critical attributes, has been applied with varying degrees of success by many authors of articles communicating the results of concept analyses, and remains very popular (see Hupcey et al., 1996, for examples and a critique of these approaches). Used very selectively and thoughtfully, this strategy can add richness to one’s understanding of the concept itself and how it fits into a larger network of ideas; it may also help differentiate concepts that are similar, but not identical, in meaning. Made-up examples and cases are generally less useful than real-world examples taken from the empirical literature or from one’s own “meticulously collected observational or interview data” (Hupcey et al., 1996, p. 202). Unfortunately, many applications of the techniques have resulted in confusing analyses that add little to our understanding.

4. For complex concepts it may be desirable to identify multiple concepts that are similar
or related—or even opposites—and analyze them simultaneously. The simultaneous activity results in a richer analysis than single-concept analysis. This is a complicated undertaking on which several experts (termed a consensus group) may be involved. Haase, Leidy, Coward, Britt, and Penn (2000) describe the process used to analyze the concepts of spirituality, perspective, hope, acceptance, and self-transcendence. After each concept was analyzed individually, a validity matrix was constructed, and ultimately a process model developed. DeSantis (2008) analyzed simultaneously the literature about the related concepts of vulnerability and resilience in order to determine which of the concepts was more fully developed.

The literature review and the above techniques serve several useful purposes. They set limits and create boundaries around the meaning of a concept, help differentiate the concept from others related to it, and indicate the aspects or dimensions of meaning that should be included in the theoretical definition and ultimately in the identification of empirical indicators.

**Mapping the Meaning**

After having determined the critical attributes of a concept and the aspects of its meaning, it is helpful to develop a scheme for logically organizing the meaning of the concept, often termed its meaning space or content domain. Although the mapping process can be difficult, the purpose and context for use of the concept, the theoretical framework (orienting perspective), and the literature provide helpful direction. State-of-the-science reviews of the literature surrounding a given concept, and articles addressing theoretical and methodological issues, often provide guidance for concept mapping. Dijkers (1999), for example, provided a structure for the study of quality of life that included several domains (e.g., activities of daily living, symptoms, social functioning).

There are also some common distinctions that provide starting points and structures for mapping the meaning of concepts. For example, many concepts of interest to nursing—quality of life is a good example—including objective (perceivable by others) and subjective (perceivable only by the individual experiencing it) aspects (see Dijkers, 1999). Although both aspects might make up the meaning in the larger sense, one aspect might be eliminated as irrelevant for a given purpose. If the purpose of an inquiry were to determine whether an individual’s perception of his or her quality of life was related to mood, objective aspects of the meaning might be less important than subjective aspects. Other common distinctions within the meaning space of concepts include differentiating stable from transitory patterns (referred to as trait and state characteristics, respectively), and the inclusion of both structural and functional patterns.

Recent research and theoretical literature contain many examples of suggested ways to organize the meaning of important nursing concepts. For example, the Middle-Range Theory of Unpleasant Symptoms (Gift, 2009; Lenz & Pugh, 2008; Lenz, Pugh, Milligan, Gift, & Suppe, 1997; Lenz, Suppe, Gift, Pugh, & Milligan, 1995) defines symptoms as subjectively perceived (by definition) and suggests that all symptoms can be described using common dimensions, such as intensity or severity, timing (duration and frequency), associated distress, and impact on function. Guided by a worldview that incorporates the assumption that persons are biopsychosocial beings, Lenz and colleagues included physiological, psychological, and social/environmental aspects in mapping the meaning of and influences on the symptom experience. This assumption would result in a very different map than would a framework that addresses people as solely physiologic entities. In examining the ways in which a concept has been mapped in the literature, it is important to remember that the discipline of the author and the population and context for which the concept meaning is being mapped influence the dimensions and aspects that are highlighted. Sources of information for concept mapping include existing literature, personal observation and experience, and previous research. Qualitative and exploratory studies of the phenomenon can provide rich information to inform the conceptualization. For example, Beck and Gable (2001) drew on Beck’s multistudy program of research about
postpartum depression to specify the concept domain. Weigel (2008) conducted three studies to clarify laypersons’ concepts of the family in order to better inform the potential uses of the concept in the professional literature.

Strategies that may be helpful in mapping the meaning space of a concept include the following:

1. List major elements in each major organizing scheme and identify similarities and differences. Determine whether one set of organizing elements or categories can be subsumed under another. Eliminate schemes that do not apply to the purpose at hand.
2. Construct an outline or table with major headings representing key aspects of meaning. Include under each heading elements that are subsumed or summarized. Table 2.3 is an example of an outline depicting the process of help-seeking that was adapted from an analogous process, information-seeking. Analogous thinking can help map concept meaning (see Walker & Avant, 2005).

3. Pose questions about the concepts that derive from the theoretical framework, purpose, and/or literature reviewed. Regarding the help-seeking concept, possible questions might include: What is being sought, from whom is it being sought, how is it being sought and for what purpose, and to what extent is the purpose achieved?
4. Construct diagrams to represent the concept meaning. Venn diagrams that depict meanings in terms of discrete, overlapping,

### TABLE 2.3 Outline of Several Variable Dimensions of the Help-Seeking Process

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<table>
<thead>
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<tbody>
<tr>
<td><strong>I. Stimulus</strong></td>
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<tr>
<td>A. Type of problem</td>
<td></td>
<td></td>
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<tr>
<td>B. Specificity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Immediacy</td>
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<tr>
<td><strong>II. Preliminary Activities</strong></td>
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<td></td>
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<tr>
<td>A. Feasibility of goal</td>
<td></td>
<td></td>
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<tr>
<td>B. Specificity of goal</td>
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<td></td>
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<tr>
<td><strong>III. Decision to Seek Help</strong></td>
<td></td>
<td></td>
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<tr>
<td>A. Immediacy</td>
<td></td>
<td></td>
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<tr>
<td>B. Active vs. passive</td>
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<td></td>
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<tr>
<td><strong>IV. Information Search</strong></td>
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<tr>
<td>A. Extent</td>
<td></td>
<td></td>
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<tr>
<td>B. Duration</td>
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<tr>
<td>C. Type of method</td>
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<tr>
<td>D. Number of consultants</td>
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<tr>
<td>E. Expertise of consultants</td>
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<tr>
<td><strong>V. Information Acquisition</strong></td>
<td></td>
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<tr>
<td>A. Extent</td>
<td></td>
<td></td>
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<tr>
<td>B. Specificity</td>
<td></td>
<td></td>
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<tr>
<td>C. Degree of fit with goal</td>
<td></td>
<td></td>
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<tr>
<td><strong>VI. Resource Selection</strong></td>
<td></td>
<td></td>
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<tr>
<td>A. Relevance of criteria to goal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Specificity of criteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Number of options considered</td>
<td></td>
<td></td>
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<tr>
<td><strong>VII. Resource Contact</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Success</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Type of resource contacted</td>
<td></td>
<td></td>
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<tr>
<td><strong>VIII. Outcomes</strong></td>
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<td></td>
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<tr>
<td>A. Success (receipt of help)</td>
<td></td>
<td></td>
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<tr>
<td>B. Level of satisfaction with help received</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Continuation of search/termination of search</td>
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</table>
and/or inclusive sets are particularly useful (Thigpen & Drane, 1967). Flow diagrams are often used for mapping concepts that denote processes. Highly complex diagrams may be needed to depict the meaning of some concepts, such as trust (see Hupcey, 2002). It is important that any diagram's meaning be readily discernible and essentially self-evident. Therefore, a diagram should follow standard conventions (e.g., placement of elements to reflect time-ordering or causal linkages), and all of the diagram's elements (boxes, circles, arrows, and so forth) should be translatable into words.

5. Once the general structure of the meaning map is identified (major stages or subdomains), keep a list of the possible ways in which variation can occur within the categories of the structure based on literature or observation. These lists will be useful during the process of operationalization.

Depending on the nature of the concept, the mapping may be simple, consisting of one or two words that designate aspects of the meaning, or may be highly elaborate and complex. The map is essentially a tool that organizes the meaning of the concept into a usable framework and helps to assure that critical elements are identified, included in the theoretical framework, and ultimately taken into account in measurement. A preliminary map, which provides the basis for the theoretical definition, generally becomes more precise as the concept is operationalized. For a more detailed discussion of strategies that can be used for mapping the meaning of concepts, the reader is referred to Walker and Avant (2005) and Hupcey (2002).

**Stating the Theoretical Definition**

The preliminary procedures to identify and organize the essential elements and dimensions of meaning denoted by a concept pave the way for selecting or constructing the theoretical definition. Ideally, the theoretical definition includes critical attributes of the concept's meaning that differentiate it from other terms. It should orient the reader to the definer's frame of reference and help to assure that the concept will be interpreted similarly by all who read it. The process of constructing a theoretical definition from a conceptual mapping involves a process that is essentially the reverse of concept analysis. Whereas concept analysis involves breaking the concept into its component elements, the theoretical definition represents an integration and synthesis of those elements into a meaningful whole.

Although the theoretical definition is not long enough to capture the full richness of the meaning of the concept, it can communicate a great deal. For example, consider the following theoretical definition of fatigue by Piper, Lindsey, and Dodd (1987): "A subjective feeling of tiredness that is influenced by circadian rhythms and can vary in unpleasantness, duration and intensity" (p. 17). This definition tells the reader that fatigue is subjective, patterned, and varies along at least three dimensions.

Another definition to consider is the following: "Helpseeking is a multistage process that an individual undertakes for the purpose of securing needed assistance from another; it has cognitive and behavioral elements" (Lenz, 1991, p. 45). This definition denotes several essential aspects of the meaning intended by the definer: (1) help-seeking (the concept) involves both cognition and behavior carried out at the level of the individual; (2) it involves a sequence of several activities carried out over time (multistage process); (3) the sequence is carried out for a purpose; (4) it is carried out with a perceived need or goal (securing needed assistance) in mind; (5) the goal involves at least one other individual; and (6) the goal need not be achieved for the process to be carried out. This definition depicts the meaning of the concept as a sequence of cognitive and behavioral steps initiated by a mental process (perception of need for help). It also helps the reader to eliminate from consideration certain phenomena that do not meet the definitional criteria. For example, random behaviors are eliminated, because they are not purposeful or goal-directed. The definition would not necessarily eliminate looking for information from impersonal sources, such as books, provided the information was used...
PART I Basic Principles of Measurement

Concepts of interest to nurses tend to have multiple dimensions, each of which can vary. These multiple, variable dimensions are more important in practice and research than the definition of the concept per se. For example, nurses are less interested in whether a particular object can be classified as a needle than they are in its variable properties: its sharpness, length, diameter, curvature, and composition. This activity is closely related to the mapping procedure, but carries it a step further, in that essential parts of the meaning are expressed as characteristics that can assume different values.

A well-developed theoretical definition generally provides important clues to salient dimensions of the concept, as was illustrated in the above example of help-seeking. Dimensions of this concept can be identified from each of the key steps in the process. Possible variable dimensions would include: (1) the degree and immediacy with which assistance is required; (2) the nature of the information search carried out, including its extensiveness, duration, type of strategy(ies) used, and number of information sources consulted; (3) the extent and type of resource information obtained; (4) the type and nature of resource selected and factors taken into account in making the selection; and (5) the level of satisfaction with the assistance obtained.

Sometimes variable dimensions of a concept are not easily derived from the theoretical definition and require a return to the literature. Research reports suggest several generic variables that are applicable to many concepts. For example, most studies of expectations or beliefs reveal differences in the strength with which people hold the expectation or belief. Therefore, strength would represent a potentially salient variable for operationalizing such concepts. Studies of behavior often represent differences in the frequency with which the behavior is carried out, suggesting frequency to be a salient variable dimension in behavioral research. Examining examples of a given concept and determining ways in which these examples differ can also be a way to identify its variable dimensions. For example, asking oneself about ways in which patient education programs differ can reveal several variable dimensions such as length, comprehensiveness, difficulty level, complexity, content sequence, and types of information included.

Once possible variables are identified, the selection of those that ultimately will be included in the operationalization is determined by the purpose for which the concept is being developed and the context in which it will be used. The following are possible questions to ask when...
selecting variable aspects or dimensions for inclusion in an operationalization:

1. Which variables will provide the most useful information to nurses?
2. Which variables have others found to be most important in understanding the phenomenon?
3. Which variables have others found to be related to other concepts of interest or to help explain or predict occurrences of interest to nurses?
4. Which variables can be rendered observable and measurable, given our present state of knowledge and technology?

The selection of observable indicators of the concept is guided by the theoretical definition, the map of the concept's meaning, and the variable dimensions that have been identified. Three examples are provided below to demonstrate the way in which the selection of indicators flows directly from the previous steps.

**Example 1.** Continuing the example of help-seeking, specific indicators can be identified for each of the variable dimensions. Examples of possible indicators for the information search stages and outcomes are provided in Table 2.4.

### TABLE 2.4 Variables and Indicators for Selected Aspects of Help-Seeking

<table>
<thead>
<tr>
<th>Variable</th>
<th>Indicator</th>
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<tbody>
<tr>
<td>Extent of search</td>
<td>Number of search activities reported by the individual, calculated as the sum of separate activities undertaken by the individual for the purpose of acquiring information about potential sources of help.</td>
</tr>
<tr>
<td>Duration of search</td>
<td>Number of days during which the individual reportedly engaged in information-seeking activities, i.e., interval between deciding to seek help and contacting a potential source of help.</td>
</tr>
<tr>
<td>Method of search</td>
<td>Designation of reported search activities as personal or impersonal, with the categories defined as follows: personal method involves use of an individual known personally to the searcher as a source of information; impersonal method involves using a nonhuman source of information or an individual not known personally to the searcher.</td>
</tr>
<tr>
<td>Number of consultants</td>
<td>Number of persons whom the searcher reportedly contacted for information about sources of help, calculated as the sum of individuals from whom information was sought and/or received.</td>
</tr>
<tr>
<td>Expertise of consultants</td>
<td>Median level of expertise of persons consulted for information, with level of expertise being designated as lay, semiprofessional, or professional with respect to the health care system.</td>
</tr>
<tr>
<td>Receipt of help</td>
<td>Reported occurrence of receipt of assistance from a local resource contacted voluntarily for such help, defined as help received or help not received.</td>
</tr>
<tr>
<td>Level of satisfaction with help received</td>
<td>Expressed level of satisfaction with each resource from which help was received, as measured on a 5-point scale, ranging from very dissatisfied to very satisfied.</td>
</tr>
<tr>
<td>Continuation/termination of search</td>
<td>Reported occurrence (continuation) or nonoccurrence (termination) of any additional help-seeking activity carried out following receipt of service from a local resource.</td>
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</table>

Example 2. The concept “functional status” is defined as “a multidimensional concept characterizing one’s ability to provide for the necessities of life—those activities people do in the normal course of their lives to meet basic needs, fulfill usual roles, and maintain their health and well being” (Leidy, 1999, p. 20). Six dimensions of functional status were identified: body care, household maintenance, physical exercise, recreation, spiritual activities, and social activities. Each dimension can be represented by several behavioral indicators. For example, the body care dimension of functional health status could be indicated by the individual’s ability to bathe himself or herself or groom his or her hair (e.g., able without help, able with help, unable to perform). Recreation could be indicated by ability to go to entertainment venues such as movies, attend social events, or travel locally or to a remote location. A matrix could then be constructed to guide the selection of indicators. Ideally in operationalizing the concept for research purposes, several indicators would be identified for each dimension.

Example 3. The meaning of the concept “infant development” is frequently mapped as progressive change in several different aspects of functioning, such as gross motor ability, fine motor coordination, language ability, and social ability. Within these broad categories of functioning, specific behaviors have been found to emerge at different ages, and norms have been established. Indicators of infant development would therefore have to be age-specific and should represent each major category of functioning. For example, at 6 months of age the infant would be expected to display the following sample behaviors (one is given for each realm of development): (a) gross motor—plays with toes, (b) fine motor—holds cube in each hand, (c) language—babble, (d) social—holds arms up when about to be lifted.

When selecting indicators, it is important to determine whether the concept represents an either/or phenomenon (i.e., a state or object) or one that varies. One could define pain, for example, in terms of its presence or absence, or in terms of its variable degree of severity, location, and so forth. The indicators for the two different conceptualizations of pain would differ. If pain were defined as an either/or phenomenon, possible indicators might include a patient’s positive response to the question, “Are you experiencing any pain?” or whether the patient appears to be restricting movement because of discomfort. Defining pain as variable in severity would require indicators of degree, such as on a visual analog or numerical rating scale, or the frequency of requests for pain medication in a 24-hour period.

In Example 1, some dimensions of help-seeking were conceptualized as varying in number or degree (e.g., number of activities carried out, level of satisfaction) and others were conceptualized as either/or phenomena (e.g., receipt of help, continuation of search). In Example 2, functional status was conceptualized as a variable phenomenon throughout. In Example 3, infant development was conceptualized as variable; however, the indicators were stated as behaviors that the infant would or would not perform (either/or). In order to determine an infant’s level of development (varying), it would be necessary to sum the number of behaviors that the infant performed or compute a developmental quotient score on the basis of the performed behaviors.

The research and theoretical literature related to a concept is a rich source of possible indicators. A good strategy is to list indicators from the literature, then examine each to determine its degree of fit with the theoretical definition and purpose. For example, assume that one is to operationalize the concept hospital size for the purpose of studying nursing staff turnover. Various indicators that may be found in the literature include number of square feet, number of beds, number of departments or units, total number of employees, number of employees in the nursing department, number of patients served per year, number of bed days per year, and annual budget. Indicators such as number of beds and number of employees would be more relevant for most nursing purposes than those reflecting spatial aspects of hospital size. Because there are several ways in which the number of beds and employees may be counted, one would have to make additional decisions about how to operationalize the concept depending on the purpose of the investigation and the meaning to be conveyed.
The nursing literature often refers to instruments (e.g., questionnaires, checklists, attitude scales, or machines) that have been developed to measure a particular concept. It should not automatically be assumed that these tools will generate appropriate indicators. Considerations to be employed in selecting instruments are included in Chapters 11 and 12. These include, among others, congruence with the theoretical definition, the results of evaluations of the instruments or indicators, and, most important, empirical evidence that has accrued over time. In addition to the literature, other sources of potential indicators include one’s past experience and the experiences of others, particularly those who are in daily contact with the phenomena being conceptualized and operationalized. Nurses, patients, and family members can suggest indicators and can also help evaluate the relevance and potential observability of indicators derived from the literature in the light of pragmatic experience. It is vital that the selection of indicators not be isolated from reality and common sense.

**DEVELOPING APPROACHES TO MEASUREMENT**

The fourth step in the process of operationalization is to develop means by which the indicators can be observed and measured. This step constitutes the focus for the remainder of the book. At this point it is sufficient to say that the operations by which a particular indicator can be rendered observable and the rules by which numbers will be assigned to various states or degrees of the indicator must be specified. Having determined the way in which the concept is to be measured, it is possible to state the operational definition, which expresses the meaning of the concept in terms of the way it will be measured in a particular context.

**EVALUATING THEORETICAL AND OPERATIONAL DEFINITIONS**

The final step in the process of operationalization is to evaluate the adequacy of the products. Ultimately, judgment of the adequacy with which a concept has been defined and operationalized is made on the basis of accumulated evidence from empirical investigations. Fortunately, the nursing literature is beginning to reflect such cumulativity, and empirical assessments of nursing concepts are becoming more frequent.

Several criteria have been suggested as useful in evaluating the adequacy of an operationalization. They include the following:

1. **Clarity.** The definition, indicators, and operations for the concept are presented in a way that can be easily understood.
2. **Precision.** The observations and operations are explicit and specific. Mathematical formulas are examples of precise operationalizations of concepts, but are rarely used in nursing. Precision should be reflected in verbal operationalizations, such as instructions about how to make a particular observation or carry out an operation.
3. **Reliability.** Observation and operations are repeatable or reproducible.
4. **Consistency.** Terms are used in a consistent manner, and logical reasoning has been used to guide selection of indicators. Linkages among the aspects or dimensions of concept meaning, and between the language meaning of the concept and empirical reality, are logically consistent.
5. **Meaning Adequacy.** The meaning designated by a concept and the indicators selected to represent it are congruent, and indicators (as fully as possible) account for the various dimensions of meaning.
6. **Feasibility.** Indicators and operations are capable of being executed. This criterion presents a utilitarian view, which acknowledges the limits imposed by current technology. In determining the feasibility of measures, practical considerations, such as the age, language, culture, cognitive status, and stamina of subjects or patients, are important.
7. **Utility.** The operationalization is useful within the context of the specific investigation or other activity and, more generally, to the discipline of nursing. Concepts that are operationalized with variable indicators are
more useful both theoretically and practically than those operationalized in terms of nonvariable indicators.

8. **Validity.** The observations selected to represent or indicate a concept in fact do so. Assessment of the validity of an operationalization is an ongoing process that requires empirical investigation.

9. **Consensus.** The ultimate test of an operationalization is that it is accepted consensually by the scientific community because of clear and accrued empirical evidence.

**SUMMARY**

Concepts are abstract verbal symbols that help summarize and categorize ideas, thoughts, and observations. They are basic elements of the complex statements and theories that make up the language of any scientific discipline. They link thought and experience. Nursing concepts designate the subject matter of the discipline but are not necessarily unique to nursing. Because key nursing concepts tend to be complex and relatively abstract, they must be defined and operationalized carefully if they are to be useful in building and applying knowledge.

To operationalize a concept is to delineate what it means and how it will be measured. A multistep procedure is required. The first step is to formulate a theoretical definition that supplies meaning through the use of other concepts. The theoretical definition is developed following a review of the literature, analysis of previous conceptualizations, and identification of examples, which epitomize or are related to the concept. Through this process essential elements of the concept's meaning are delimited and logically organized. Subsequent steps are to specify variable dimensions of the concept's meaning, identify observable indicators, develop means to measure the indicators, and evaluate the adequacy of the operationalization. The steps are interrelated, in that each logically flows from and builds upon those that precede it. The products of the operationalization process are the theoretical and operational definitions. The latter provides meaning in terms of the observations or operations necessary to measure the concept. Operationalization, including its conceptualization phase, is an ongoing and cumulative process.

Nursing is reflecting increased sophistication in applying a conceptual approach to operationalizing its concepts. Particularly important is the growing body of literature reflecting both careful, theoretically based conceptualizations of key nursing concepts and empirical validation of the adequacy of those conceptualizations and operationalizations. The discipline is moving toward concepts that are defined and operationalized with clarity, precision, reliability, validity, feasibility, and utility.

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Measurement Theories and Frameworks

Health researchers employ a variety of different approaches and methods to study research problems, questions, and/or hypotheses that require the measurement of complex variables that are difficult to measure. The use of reliable and valid measures must be a salient concern in the conduct of all research studies. Thus, researchers and consumers, especially those evaluating research results for use as a basis for practice, need to be well informed regarding what constitutes sound measurement principles and practices that are likely to result in measures that demonstrate reliability and validity. In this chapter we present basic statistical principles and procedures required for understanding the measurement process and measurement theories and frameworks that define the various approaches to measurement.

Measurement problems may range from determining the best method for obtaining the accurate length, weight, and body temperature of a newborn infant, to trying to ascertain the quality of patient care provided on a clinical unit, the level of students’ performance in the clinical area, or determining public opinions and attitudes regarding national health policies. In some cases data collection methods that have been developed using sound measurement principles and practices and upon testing have demonstrated reliability and validity are available. For example, Hibino, Hitomi, Yasuhiro, and Hiroyuki (2009) used the shortened version of the Scale of Egalitarian Sex Role Attitudes (SES-RA-S) developed and tested by Suzuki in 1991 in a study exploring factors associated with the incidence of sexual harassment of hospital nurses by patients. When employed and tested within the context of their study for the assessment of nurse attitudes toward gender equality, they found that the resulting evidence for reliability and validity of the instrument compared favorably with that determined by Suzuki in his earlier work. Similarly, Bruyneel and colleagues (2009) conducted a study to determine evidence for predictive validity of the International Hospital Outcome Study Questionnaire, the instrument employed in the International Hospital Outcomes Study (IHOS), in preparation for its use in an upcoming European Union–funded project to investigate the effect of the nursing work environment and nursing staff deployment on nurse recruitment, retention, productivity, and on patient outcomes in 11 European countries. Their findings provided support for key factors previously identified in earlier international research. Additional examples can be found in the works of Ilhan, Durukan, Taner, Maral, and Bumin (2008) who employed the Maslach Burnout Inventory (1997) to determine the burnout level and its correlates among nursing staff; Grover et al. (2007) who used the validated Cardiovascular Life Expectancy Model and Framingham equations to determine the effectiveness of a coronary risk profile in treating dyslipidemia in a primary care setting; and O’Neill and O’Neill (2008) who employed existing data sources, including the Joint Canada/US Survey of Health, to compare health status, health care, and inequality between the Canadian and U.S. health care systems.

In the absence of existing measures, researchers have filled the gap by designing and testing their own measures. For example, Baldwin, Clark, Fulton, and Mayo (2009) developed and tested the reliability and validity of surveys for administration using paper and pencil and online formats to validate the 75 core National Association
attributes are often termed variables in scientific language. An attribute must be variable in order to be measured. Measurement provides for meaningful interpretation of the nature of an attribute possessed by an object or event.

The results of measurement are usually expressed in the form of numbers. In health research, there are many attributes of objects that are not easily measured. In such cases, the attribute of concern may be defined in a manner whereby it can be made measurable, that is, the attribute or concept is operationalized. Whenever an attempt is made to measure an attribute, it is necessary to define it in qualitative or quantitative terms. A unit of measurement for categorizing the kind and/or amount of the attribute must be established and a measurement rule or procedure must be derived that is congruous with the established unit of measurement. The unit may be a score, a centimeter, a milliliter, a second, a degree Centigrade, or any appropriate unit or category of measurement. The need for the establishment of a suitable unit of measurement, and for precision in measurement, has fostered the development and use of tools such as tests, thermometers, rulers, and balance scales. It is important to distinguish between the terms “unit of measurement” and “unit of analysis.”

The focus of measurement is to quantify a characteristic of an object. What is measured is not the object, but a characteristic or attribute of the object. In the published examples the attributes measured were how parents cope; patient satisfaction with the care provided; distress during painful medical procedures; and the diagnostic reasoning process. The attribute to be measured varies in kind and/or amount, and different objects may be assigned to different categories that represent the kind or amount of the attribute possessed. For example, various infants in a nursery have different weights. Similarly, different nursing students in a class will have different levels of ability. Therefore, attributes to be measured are variable and take on different values for different objects. Measurable attributes are often termed variables in scientific language. An attribute must be variable in order to be measured. Measurement provides for meaningful interpretation of the nature of an attribute possessed by an object or event.

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Measurement is the process of using a rule to assign numbers to objects or events that represent the kind and/or amount of a specified attribute possessed. The measurement rule is the precise procedure used to assign numbers to phenomena, for example, procedures for administering and scoring tests or using a balance scale to measure weight.

**SCALES OF MEASUREMENT**

Stevens (1946, 1951, 1958, 1960) classified the rules used for assigning numbers to objects to represent the kind and/or amount of a specified attribute possessed by them in a hierarchical manner. From lower to higher levels, the scales
of measurement are nominal, ordinal, interval, and ratio.

In **nominal-scale measurement** objects are placed into categories according to a defined property. Numbers assigned represent an object’s membership in one of a set of mutually exclusive, exhaustive, and unorderable categories. Numbers are used for labeling purposes only and have no quantitative significance. Categories used in nominal-level measurement differ in quality rather than quantity; hence, no statement can be made about the amount of the attribute possessed. All members of a category are regarded as similar or equal in some respect. For example, a group of registered nurses may be assigned to categories based on their sex, that is, 1 = male and 2 = female. The basis for classifying is a definition of the class. The basic distinguishing signs for determining inclusion within the class are specified by the definition. Regardless of the number of categories used, two essential conditions should be met. First, a set of categories should be **exhaustive**, that is, every object that is to be classified should belong to at least one category. Second, the designated categories should be **mutually exclusive**, that is, the definition of the categories should be such that no object could be placed in more than one category.

In **ordinal-scale measurement** numbers are assigned to objects according to rank order on a particular attribute. Numbers assigned represent an object’s membership in one of a set of mutually exclusive and exhaustive categories that can be ordered according to the amount of the attribute possessed. Ordinal-scale measurement may be regarded as the rank ordering of objects into quantitative categories according to relative amounts of the specified attribute. The rankings do not imply that the ranked categories are equally spaced on a scale, nor that the intervals between the scale categories are equal. Ordinal assignment of numbers merely means that the ranking of 1 (for first) has ranked higher than 2 (for second), and since 2 has a higher ranking than 3, then 1 also must rank higher than 3. If, for example, a group of clients are ranked according to their ability to undertake self-care, then a client ranked as 3 would possess less self-care ability than one ranked 2, but would have more ability for self-care than one ranked 4.

An **interval scale** is one for which equal numerical distances on the scale represent equal amounts with respect to the attribute or the object that is the focus of measurement. Numbers assigned in interval-scale measurement represent an object’s membership in one of a set of mutually exclusive, exhaustive categories that can be ordered and are equally spaced in terms of the magnitude of the attribute under consideration. However, the absolute amount of the attribute is not known for any particular object, because the zero point in an interval scale is placed in some arbitrary position. In addition to being able to categorize and rank objects, at the interval level one can also order objects according to the size of their numerals and the relative size of the differences between two objects. The Fahrenheit temperature scale is an example of a commonly used interval scale. One can say that two objects having temperatures of 90°F and 100°F are as far apart on the scale as two other objects with temperatures of 50°F and 60°F. One can also say, for example, that a patient’s temperature at 6 p.m. is 3 degrees higher than it was at noon, or that the drop in temperature after taking an aspirin was greater than after taking a sponge bath. One cannot say, however, that an object with a temperature of 0°F does not have a temperature at all.

**Ratio-level measures** give all information that is provided by interval-level measures, but in addition they have absolute zero points, where zero represents an absolute absence of the relevant attribute. The category and rank order of objects with respect to the attribute is known, the intervals on the scale are equal, and the distance or magnitude from the actual zero point is known. Volume, length, and weight are commonly measured by ratio scales and all can be assigned absolute zero values. With a ratio scale one can say that David is two times as heavy as Steven if David weighs 100 lb and Steven weighs 50 lb.

There is a great deal of controversy about the levels of measurement and the types of statistical operations that can be properly used with the resulting scores. Either the fundamentalist or pragmatist view of measurement rules may be taken. The **fundamentalist view** purports that all measures of attributes can be classified into one of the distinct levels of measurement, and that,
once classified, the level of measurement specifies the type of statistical operations that can be properly used. The hierarchical nature of the scales of measurement is considered when statistical operations are applied with scores derived at different levels of measurement. The higher the level of the scale, the broader the range of statistical operations that can be applied with the numbers obtained from measurement. Only nonparametric statistics are considered appropriate with lower level data, that is, nominal or ordinal data; but parametric statistics are permissible with higher level data, that is, interval and ratio data. Frequencies, percentages, and contingency-correlation coefficients are considered permissible at the nominal-scale level of measurement. Ordinal-scale data are believed to allow the same statistical operations permissible with nominal-scale data, but in addition, it is possible to use medians, centiles, and rank order coefficients of correlation. Practically all of the common statistical procedures are considered permissible with interval and ratio data.

The pragmatists point out that most measurement rules are not as clear-cut and easily classified as fundamentalists believe they are, and that it is not practical to waste effort in attempting to classify a variable into a level of measurement. For example, there is some controversy among measurement specialists as to whether scores from psychological tests represent ordinal- or interval-level measurement, because there is no assurance that equal differences between scores represent equal differences in the amount of the attribute of concern, particularly when Likert-type rating scales are used as a basis for scoring. Some contend that test scores simply order subjects according to the amount of the specified attribute possessed, while others purport that test scores represent the magnitude of the attribute possessed. Pragmatists minimize the emphasis on levels of measurement and suggest that the statistical techniques applied to any set of numbers should be determined by the nature of the research question addressed rather than by the level of measurement.

We believe that the statistical treatment of any data or set of numbers should be determined by the nature of the scientific inquiry, that is, the research question one is trying to answer, rather than the level of measurement alone. Readers interested in reading further regarding this debate are referred to Nunnally and Bernstein (1994, pp. 20–21).

**BASIC STATISTICAL PRINCIPLES AND PROCEDURES**

In most instances, measurement results in a number. This number represents the kind and/or amount of some attribute or characteristic of the object or event that is measured. The number that results from measurement may be referred to as either the observed score or the raw score. In many situations a group of objects is measured on the same attribute, which results in a series or group of observed scores. One might determine, for example, the lung capacity of a group of adult smokers, the arterial pressure of a group of cardiac patients, or the scores on a critical thinking test for a group of nursing students. Unfortunately, it is difficult to make much sense out of a group of numbers obtained from such situations when they are presented in raw score form. One usually would want to know what the highest and lowest scores are, if the scores are spread out or concentrated at some point along the distribution, and what score occurs most often. Statistical procedures enable one to better understand such groups of numbers and to answer these basic questions about the characteristics of the group of scores. This section presents some basic statistical principles and procedures that are important for understanding measurement and interpreting groups of scores.

**Distribution**

One step in obtaining information about any group of measures or scores is to arrange them in order from their highest to lowest value and to note how many times a particular score occurs, or whether it occurs at all. This will indicate the **distribution of scores**, which can be represented by a table or graph in which each score is paired with its frequency of occurrence. An illustration of a **frequency distribution** of the hematocrit levels for 50 female patients is shown in Table 3.1. The
first column includes scores, that is, the hematocrit values, which are ordered from the highest to the lowest. The second column contains the frequencies, that is, the number of patients with each hematocrit value, and clearly displays how many patients had each.

Frequency distributions also can be presented in the form of a histogram. A histogram is a bar graph representation of a frequency distribution and makes the shape of the distribution more obvious. Figure 3.1 presents a histogram for the data in Table 3.1. Further discussion of the ways to present frequency distributions is provided in Chapter 4.

Distribution Shape
Frequency distributions can occur in various shapes. Because the shape of a distribution provides important information, it is necessary for one to

<table>
<thead>
<tr>
<th>Hematocrit Value or Score</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>1</td>
</tr>
<tr>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>46</td>
<td>2</td>
</tr>
<tr>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>44</td>
<td>6</td>
</tr>
<tr>
<td>43</td>
<td>6</td>
</tr>
<tr>
<td>42</td>
<td>9</td>
</tr>
<tr>
<td>41</td>
<td>7</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
</tr>
<tr>
<td>39</td>
<td>3</td>
</tr>
<tr>
<td>38</td>
<td>2</td>
</tr>
<tr>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>2</td>
</tr>
</tbody>
</table>

\[ n = 50 \]

FIGURE 3.1 Histogram for data presented in Table 3.1.
know some of the descriptive terms used to indicate the various shapes. Several common distribution shapes are shown in Figure 3.2. The shape of a frequency distribution can be either symmetrical or asymmetrical. A *symmetrical distribution* is one in which both halves of the distribution are identical in shape. Normal and flat distributions are symmetrical in shape. *Skewed distributions*, that is, distributions in which scores trail off in one direction, are *asymmetrical*.

**FIGURE 3.2** Common distribution shapes.
A bimodal distribution may be symmetrical or asymmetrical. The extent to which a distribution departs from symmetry is referred to as its degree of skewness. The direction of skewness refers to the fact that in some asymmetrical distributions most scores pile up at one end of the scale as far as frequency of occurrence is concerned, while there are fewer scores at the other end. When the frequency of scores is low on the right side of the distribution, it is positively skewed. If the frequency of scores is low on the left side of the distribution, then it is negatively skewed. Difficult tests or situations in which scores are generally low in a group will result in distributions that are positively skewed. Easy tests or instances in which most scores tend to be high within a group will yield negatively skewed distributions. In instances in which scores occur in the middle range with few scores in the low and high levels, normal distributions will result. Bimodal distributions will often occur when two distinctly different populations are measured on a selected attribute. For example, if the hematocrit levels of a group of healthy males and females are determined, a bimodal distribution would be likely to result, because males normally have higher hematocrit levels than females. In this case, males and females are actually two different populations, because the variable of interest, that is, hematocrit, is influenced by sex. In the norm-referenced measurement situation, a normal distribution is desirable. A skewed distribution would be expected in a criterion-referenced measurement situation following a specific intervention or treatment. The theoretical basis for the occurrence of these distributions as indicated for each measurement framework is discussed in Chapter 4.

The shape of a distribution also may vary in regard to the peakedness of the curve of the distribution as shown in Figure 3.3. Kurtosis refers to the peakedness of a distribution’s curve. The curve of a normal distribution, as indicated by curve A in Figure 3.3, is referred to as mesokurtic and is used as the standard with which the curves of other distributions are compared to determine

![Figure 3.3 Types of kurtosis.](image-url)
their kurtosis. A very peaked slender curve is called *leptokurtic* and is illustrated by curve B. A *platykurtic* curve is flat or broad as shown by curve C. The scores in a leptokurtic curve are closer together, that is, have less variance, than in the normal curve. On the other hand, the scores in a platykurtic curve are more spread out, that is, have more variance, than in the normal curve. If a distribution is bimodal, the kurtosis of each curve is considered separately.

### Measures of Central Tendency

Rarely do all the individual members of a group or population have the same amount of some common attribute. Instead, different objects vary on the attribute of interest. In many instances, one might be interested in the averageness of some specific attribute. For example, one might want to know the average weight and length of a group of newborn infants or the average score on a depression scale for a group of psychiatric clients. The mode, median, and mean are three statistical indices of averageness or central tendency.

The *mode* is the score in a distribution that occurs most frequently. The mode of the scores in Table 3.1 is 42. The mode is determined by inspecting the data to ascertain which score occurs most often. It is the easiest measure of central tendency to calculate.

Occasionally a frequency distribution will have two or more modes rather than one. In some cases more than one score will have occurred at maximum frequency. A distribution in which two scores occur most often is called a bimodal distribution and is illustrated in Figure 3.2. If a distribution has three scores that occur most often, it is referred to as a trimodal distribution.

The *median* is the score value in a distribution above which 50 percent of the scores fall and below which 50 percent of the scores fall. The 50th percentile is another label for the median. When a distribution includes an unequal number of scores, the median is the middle score. For example, if a distribution included the scores 4, 6, 10, 11, 13, 15, and 16, the median would be 11. Because the median represents the middle score, it may be a value that is not included in the scores in the distribution. This may be the case when the distribution includes an even number of scores. Where there is an even number of scores, the median is calculated in the following manner.

1. The scores in the distribution are arranged from the lowest to the highest value.
2. If no score occurs more than once, the median is the midpoint between the two middle scores. For example, in the case in which the scores are 3, 5, 6, and 8, the median is the midpoint between 5 and 6. Thus:

   $$\text{Median} = \frac{5 + 6}{2} = 5.5$$

3. When tied scores occur, as in Table 3.2, a frequency tabulation is required.
   a. Determine placement of the median score. In this case the median score is $n/2$ or 40/2. Hence, the median score will be the 20th score from the bottom of the distribution.
   b. Find the score corresponding to the 20th score.

   (1) The 20th score is located between the score interval from 81 to 85.
   (2) A cumulative frequency of 18 is found in the lower limit of this interval: Thus, $20 - 18 = 2$ points above 18 is required for the 20th score.

### Table 3.2 Frequency Distribution Used for Demonstrating Computation of Median

<table>
<thead>
<tr>
<th>Score</th>
<th>Frequency</th>
<th>Cumulative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>95</td>
<td>3</td>
<td>38</td>
</tr>
<tr>
<td>93</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>88</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>85</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td>81</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>78</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>69</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>61</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>55</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

\[n = 40\]
(3) The number of frequencies in the interval containing the 20th score is equal to 26 – 18 = 8 frequencies. 
(4) Multiply 2/8 by the width of the interval containing the 20th score, that is, 85 – 81. Thus 2/8 × 4 = 1. 
(5) Hence, 81 + 1 = 82. This is the score equal to the median.

The median has the advantage that its value is not influenced by extreme scores. This makes it a useful measure of central tendency when small samples are used.

The mean is the sum of scores in a distribution divided by the number of scores entered into the computation of the sum.

Example: Calculation of mean

Given the following 5 raw scores: 2, 4, 8, 6, 10

Mean = 2 + 4 + 8 + 6 + 10/5
     = 30/5
     = 6

The mean is the balancing point of a distribution. It is the point value where a linear scale would balance as illustrated in Figure 3.4. The more equal the difference between the size of the scores around the mean, the more likely is the mean to be in the center of the scale. However, when extreme scores occur, the mean shifts toward the extreme score away from the middle score on the scale.

The location of the median and mean in a distribution is related to the shape of the distribution. Figure 3.5 illustrates the relationship between the measures of central tendency and the shape of a distribution of scores. The values of the mode, median, and mean are the same in a normal distribution (A). When a distribution is positively skewed (B), the mean is larger than the median and mode, and the mode is the smallest value. In a negatively skewed distribution (C), the opposite occurs; that is, the mean is the smallest value, the median is next, and the mode is the largest.

The mean is usually the preferred measure of central tendency, particularly when large samples are used or when the distribution of scores is nearly symmetrical. The mean also has the greatest stability and can be used for further statistical manipulations. The median is most appropriately used when the distribution shows marked skewness. The mode is best employed in situations in which a rough estimate of central tendency is required quickly or where the typical case is needed. Although these rules are generally appropriate, one should consider each set of data in terms of the specific situation or particular need to

![Figure 3.4](image-url)
determine which measure of central tendency is best to employ.

**Dispersion**

An important characteristic of any distribution of scores is the amount of spread or scatter among the scores, which is referred to as dispersion. To illustrate this concept further, assume that fasting blood sugar levels are taken over a 6-month period for two diabetic children. One child has diabetes that is easy to control, and the other has diabetes that is difficult to control. One might obtain distributions of blood glucose levels for the two children similar to the ones shown in Figure 3.6.

Note that the two distributions have means that are equal. However, the spread or dispersion of blood glucose levels for the two children is quite different; that is, the dispersion of the fasting blood glucose levels for the child with diabetes that is difficult to control is more spread out than that of the child with controlled diabetes. The fasting blood glucose levels for the child with easily controlled diabetes are rather consistent and more easily kept within the normal range with treatment, while the child with difficult-to-control diabetes has fasting blood glucose levels that are sometimes low, sometimes normal, and sometimes high. In other words, the variability of fasting blood glucose levels for the child with difficult-to-control diabetes is greater than those for the child with easily controlled diabetes.

The dispersion of a distribution of scores may be measured by three indices: (1) range, (2) variance, and (3) standard deviation.

The range is the distance from the lowest score in a distribution to the highest score. Hence, it is calculated by subtracting the lowest from the highest score. The range is the simplest of the three indices of dispersion and is
A. Distribution for child with diabetes that is easy to control

B. Distribution for child with diabetes that is difficult to control

FIGURE 3.6 Hypothetical distributions of fasting blood glucose levels for two children with diabetes.

The variance and standard deviation are based on the deviation of each score in a distribution from the arithmetic mean. A deviation score represents the distance between a subject’s raw score and the mean of the distribution. It is calculated by subtracting the mean from the raw score. In the example, infant A weighs 6 lb, infant B, 10 lb, infant C, 8 lb, and infant D, 4 lb, the mean of this distribution of weight is 7 lb. The deviation score, in terms of each infant’s weight, is 6 – 7 or –1 for infant A, 10 – 7 or +3 for infant B, 8 – 7 or +1 for infant C, and 4 – 7 or –3 for infant D. It should be noted that the sign of the deviation score indicates whether the raw score is above (+) or below (–) the mean. In addition, the sum of the deviation scores in a distribution should always equal zero.

The variance of the distribution of scores may be calculated by using the deviation scores as illustrated in the example that follows.

Example: Calculation of the variance of a distribution of scores using deviation scores

Given the infant weights of: 6, 10, 8, and 4, with a mean = 7 lb,
1. Determine the difference or deviation of each infant’s weight from the mean: 
(6 – 7 = –1), (10 – 7 = +3), (8 – 7 = +1), (4 – 7 = –3) 
2. Square the deviation from the mean for each infant: 
(–1 × –1 = +1), (+3 × +3 = 9), (+1 × +1 = +1), (–3 × –3 = +9) 
3. Determine the sum of the squared deviation scores: 1 + 9 + 1 + 9 = 20 
4. Determine the average of the squared deviation scores: 20/4 = 5 square units 

It can be seen from this computational method that the variance is the average of the sum of the squared deviation scores.

Raw scores also may be employed to calculate the variance as exemplified below.

Example: Calculation of the variance of a score distribution using raw scores 

Variance = sum of the squared raw scores – sum of the sum of raw scores/number scores/number of scores in the distribution 

Given the following raw scores: 6, 10, 8, 4

1. Sum the raw scores: 6 + 10 + 8 + 4 = 28 
2. Square the raw scores: 36, 100, 64, 16 
3. Sum the squared raw scores: 36 + 100 + 64 + 16 = 216 
4. Square the sum of the raw scores: 28 × 28 = 784 

Variance = 216 – (784/4)/4 = 216 – 196/4 = 20/4 = 5 square units 

It should be noted that the variance is a square measure rather than linear. To transform a square measure to linear it is necessary to calculate the positive square root. 

The standard deviation of a distribution of scores is the square root of the variance. Hence, the standard deviation is the linear counterpart of the variance. In the example, the standard deviation is the square root of 5 square units (the variance) or 2.24. 

The standard deviation is a useful statistic for comparing differences in variability among two or more distributions. For example, if distribution A has a standard deviation of 3, while distribution B has a standard deviation of 5, then one would know that the variability in distribution B is greater than that for A.

The standard deviation also may be thought of as a unit of measurement along the baseline of a frequency distribution. For example, in a normal distribution there are about three standard deviations above the mean and three below. Therefore, the range of the distribution is made up of approximately six standard deviations and all deviations above the mean are positive, and those below the mean are negative. If a distribution has a mean of 20 and a standard deviation of 5, one could divide the baseline into standard units. To do this one would start at the mean and add one standard deviation (5) to the value of the mean (20) to obtain +1 standard deviation, or 25. The raw score 25, then, is exactly one standard deviation above the mean. Likewise, scores that are two and three standard deviations above the mean are 30 and 35, respectively. To determine the value of –1 standard deviation one would subtract one standard deviation (5) from the mean (20) with a result of 15, which is one standard deviation below the mean. The score values for –2 and –3 standard deviations would be 10 and 5, respectively. This is illustrated in Figure 3.7.

The standard deviation is also useful because in normal distributions it is known what percentage of scores lie within specified standard deviations from the mean.

**Measures of Correlation**

A number of procedures have been developed for assessing the quality of norm-referenced tests and test items that involve the use of the Pearson product–moment correlation coefficient (r<sub>xy</sub>) or other measures of linear association. For this reason, Pearson product–moment correlation is discussed to present information necessary for understanding reliability and validity theory and the proper application and interpretation of correlation in measurement contexts.

The linear relationship of two sets of scores can be represented by a **scatterplot** or **scattergram**. Suppose two alternate forms of a 12-item professionalism scale were administered to a group of eight nurses and resulted in scores on the two forms as shown in Table 3.3.
quantitatively summarize scatterplot information is the Pearson product–moment correlation coefficient ($r_{xy}$). Hence, $r_{xy}$ is a quantitative measure of the linear relationship between two sets of scores. In other words, it measures the extent to which two sets of scores in two-dimensional space follow a straight line trend.

The value of the correlation coefficient lies between the interval –1.00 to +1.00. If a coefficient of 1.00 was obtained, it would represent a perfect positive relationship between the two sets of scores and is illustrated by a scatterplot with a line that slopes downward from right to left as shown by scatterplot A in Figure 3.9. If the line slopes downward from left to right, as in scatterplot B, a coefficient of –1.00 would result. This represents a perfect negative relationship between the two sets of scores.

If the scores obtained from the same group of subjects on a measure are not perfectly correlated with the scores obtained on a second measure, patterns similar to those shown in scatterplots C and D in Figure 3.9 may occur.
Scatterplot C implies that increases in the value of one score (Y) tend to be associated with increases in the value of the other score (X). In scatterplot D, increases in the value of one score (Y) tend to be associated with decreases in the value of the other score (X). In other words, a positive linear relationship indicates that a person who scores high on one measure or test is also likely to score high on the other, and that a person who scores low on one test is also likely to score low on the other. A negative relationship suggests that a person who scores high on one test is likely to score low on the other. When a perfect correlation does not exist, it results in a scattering of points away from the straight line that best summarizes the trend. In general, the more widely scattered the points, the closer the correlation coefficient is to zero.

Two types of scatterplot patterns will lead to a correlation of zero (or a value very close to zero): (1) when there is no recognizable pattern in the scatterplots, or (2) when the pattern of the scatterplot is curvilinear, that is, seems to follow a well-defined curve. An example of the former case is presented in Figure 3.10 in scatterplot A, and an example of the latter case is illustrated by scatterplot B.

When the configuration is an amorphous glob, as in scatterplot A, a correlation value of zero is accurately reflected because there is no useful relationship between the two sets of scores. However, where a curvilinear relationship exists, as illustrated in scatterplot B, a correlation value of zero is very misleading because a useful relationship exists. Statistical indices are available that are appropriate for measuring the degree of curvilinear association between sets of scores, for example, eta (Guilford, 1965).

At this point, attention is given to interpretation of the Pearson correlation coefficient. It is useful to convert the correlation coefficient to a percentage in order to provide further interpretation. This is done by squaring the coefficient value and by changing the result to a percentage. The value that results is the percentage of explained variance between two sets of scores. This means that scores obtained from one measure could be used to explain the variance in another measure and vice versa. For example, if the value of the correlation coefficient is +0.70, then the percentage of explained variance is determined by squaring the value of the correlation coefficient, that is: ($+0.70$) ($+0.70$) = 0.49, or 49%. This means that 49% of the variance in the scores from one measure or test would be explained on the basis of the scores from the other measure or test and vice versa.

Potential problems may influence the interpretation of the correlation coefficient. First, reducing the variability in the distribution of
either or both sets of scores (X and/or Y) tends to decrease the value of the correlation. This can occur when (1) there is loss of measurement information (e.g., when a nominal level measurement scale is employed rather than a higher level measurement scale), and (2) there is restriction of range in the data, that is, when a homogeneous subset of data points in the scatterplot is used to calculate the correlation (Martuza, 1977, p. 76).

The effects of restriction of range are illustrated by the scatterplot in Figure 3.11.

Suppose the true association between X and Y in a population was as illustrated in Figure 3.11, but the correlation was calculated using individuals with scores of 60 or higher on variable X. The standard deviation is also. The value of the coefficient would be close to zero and, therefore, would misrepresent the correlation. This would happen because data points in the included portion of the scatterplot do not exhibit a strong linear trend. In most instances restriction of range will decrease the value of the correlation; however, in some instances it may be increased.

The second problem that may be encountered in the interpretation of the correlation is that measurement error can affect the value of

![Figure 3.9](image-url)
the coefficient. Random errors of measurement, that is, factors that can inadvertently increase or decrease the score values obtained from measurement, will distort the value of the correlation. When either or both sets of scores have been influenced to a large degree by random error, the true nature of their relationship will be distorted, and so will the correlation. The value of the correlation may be increased or decreased by random error of measurement. In most cases, however, a decrease in the value of coefficient will result. Random error of measurement is discussed more fully in subsequent sections of this chapter.

Several variations of the Pearson correlation coefficient can be employed. These coefficients are summarized in Table 3.4. Waltz and Bausell (1981, p. 264) point out that some of the coefficients in Table 3.4, that is, phi, Spearman rho, and point biserial are equal to the Pearson correlation, that is, they are simply the product-moment correlation coefficient formula applied to nominal and ordinal data. The remaining coefficients, tetrachoric and biserial, are approximations of the product moment correlation coefficient.

Formulas employed for the calculation of correlation statistics are complex and difficult to determine without the use of computer programs for analysis. Readers interested in further information regarding correlation statistics and their formulas are referred to Kirk (1968), Glass and Stanley (1970), Nunnally (1978), Agresti and Agresti (1979), Nunnally...
TABLE 3.4 Coefficients for Use With Various Types of Data

<table>
<thead>
<tr>
<th>Variable X</th>
<th>Nominal</th>
<th>Ordinal</th>
<th>Interval or Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Y: Nominal</td>
<td>Phi</td>
<td>Cureton’s Rank</td>
<td>Biserial</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Contingency</td>
<td>Biserial</td>
<td>Point Biserial</td>
</tr>
<tr>
<td>Interval or Ratio</td>
<td>Cureton’s Rank</td>
<td>Spearman Rho</td>
<td>Tau</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Biserial</td>
<td>Kendall’s Tau</td>
<td></td>
</tr>
<tr>
<td>Interval or Ratio</td>
<td>Point Biserial</td>
<td>Tau</td>
<td>Pearson Product</td>
</tr>
<tr>
<td>Interval or Ratio</td>
<td></td>
<td></td>
<td>Moment</td>
</tr>
</tbody>
</table>


Now that an introduction to measurement and the basic statistical principles and procedures that undergird measurement has been provided, attention will be given to measurement theory.

MEASUREMENT ERROR AND RELIABILITY AND VALIDITY OF MEASURES

The goal of all measurement is to achieve accurate results. However, this is not completely possible
because measurement error, to some extent, is introduced into all measurement procedures. There are two basic types of error that affect the precision of empirical indicators: random error and systematic error.

Random error, also termed variable or chance error, is caused by chance factors that confound the measurement of any phenomenon. An important characteristic of random error is that it occurs in an unsystematic manner in all measurement. A measurement tool or method affected by random error will yield empirical indicators that will sometimes be higher and sometimes lower than the actual magnitude of the attribute measured. Assume that a nurse takes a patient’s oral temperature six times during the course of a day. Also assume that on two measurement occasions the temperature is taken with the patient breathing through the mouth and on another measurement occasion the temperature is taken immediately after the patient has taken several sips of hot coffee. This is an example of random error because the temperature readings would sometimes be lower and sometimes higher than the patient’s actual body temperature as a result of the introduction of various factors into the measurement procedure. Even if there were no fluctuations in the patient’s true body temperature, the temperature readings obtained from measurement to measurement would not be consistent. Therefore, random error primarily affects the reliability, that is, the consistency or stability of empirical indicators from measurement to measurement, and consequently validity as well, because reliability is a necessary prerequisite for validity. However, one should recognize that this does not mean that the validity of measures is not affected at all by random error. The introduction of error always affects the validity of specific measures to some degree.

Systematic error, the second type of error that affects empirical measurements, has a systematic biasing influence on measurement procedures. Suppose a patient’s thermometer always registers 0.4°F higher than the actual temperature. This is an example of systematic error because repeated temperature readings taken with this thermometer would always be 0.4°F higher than it really should be. A systematic increase of 0.4°F would always be introduced into the results. Hence, the extent to which the thermometer measures what it purports to measure, that is, temperature, is compromised.

Given the above information about the occurrence of random and systematic error, a central question arises about how one can determine the extent to which a given tool or method measures the concept under consideration. Stated in different terms, how well do the results of a measuring procedure represent a given concept? For instance, how can one evaluate the extent to which an instrument designed to measure nursing professionalism accurately represents that concept? Reliability and validity of empirical measurements are two basic aspects of measurement that can be used to examine these questions. The occurrence of random error in measurement procedures is the central threat to the reliability of the measurement. In a similar manner, the validity of a measurement is more threatened by the occurrence of systematic error.

**Reliability and Random Error**

The reliability of a measurement method is directly influenced by random error. There is an inverse relationship between the amount of random error introduced into measurement and the reliability of the measurement. The higher the reliability of the measurement, the less random error is introduced into the measurement procedure. A large amount of random error decreases the reliability of the measurement.

A measurement tool is reliable for a particular subject population to the extent to which it yields consistent results on repeated measurements of the same attribute. Because reliability refers to the consistency or stability of empirical indicators from measurement to measurement, it naturally follows that empirical indicators obtained from any measurement procedure are reliable to the extent that they are free of random errors. Because sets of measurements of the same attributes for the same objects or events will never exactly duplicate each other, unreliability in measurement is always present to some extent. Thus, the reliability of a measure is a matter of degree. While the amount of random error may be large or small, it is always present.
If the random error is large, then the consistency of empirical indicators that result from repeated measurements will be poor and reliability will be compromised. If, however, there is only a small amount of random error, the stability of empirical indicators on repeated measurements will be high and reliability will be high. Stated in different terms, the more consistent and stable the results obtained from repeated measurements, the higher the reliability of the measurement procedure, but the less consistent and more variable the results, the lower the reliability.

The occurrence of random error is a common problem that affects the reliability of any measurement procedure. The following illustrations should clarify how random error is introduced into measurement procedures. First, suppose three nurses are given the task of independently measuring the height of two adult patients to the nearest 1/8 in on the same day using the same method. It is probable that there will be noticeably different measurements of height obtained by these nurses as long as they are unaware of each other’s results. Since height is not likely to change in the same day, obviously discrepancies between findings must be due to measurement errors. You can probably think of a number of chance factors that could influence the results, for example: (1) factors resulting from individual differences in patients, such as height of hair, (2) factors resulting from differences in the nurses’ instructions to patients during the procedure, such as instructing patients to stand tall without slumping the back, or (3) differences in the nurses’ procedure such as location or placement of the measuring tape on the patients’ heads.

Similarly, suppose a nurse takes the same patient’s blood pressure twice with the patient lying in a recumbent position in a relaxed manner at a 1-min interval. It is likely that the two blood pressure readings will vary somewhat without any actual change in the patient’s blood pressure. Differences in noise level in the room could affect auditory acuity during the repeated readings. Other factors that could affect the final results are variations in the nurse’s eye level in relation to the column of mercury in the sphygmomanometer during readings and differences in the speed at which the blood pressure cuff is deflated on successive measurements.

In both of these examples, certain factors influenced the measurement procedure, which affected the results obtained. In each illustration, if random error had not occurred, one could expect error-free results and results would have been the same across measurements. This is not the case in reality. A very important point should be made. Fluctuations in measurement results that occur due to random error do cancel each other out if many independent measurements are made. "They do not directly influence the meaning of the measurement but do directly affect the precision with which the characteristic of interest is being measured" (Martuza, 1977, p. 9). For example, if the heights of 20 adults were measured repeatedly for 3 days in succession, one would not expect each person’s height to be precisely duplicated on repeated measurements. However, one would expect that the person who was the tallest on the first day would be among those measured the tallest on the second and third days. Although each person’s height would not be exactly the same from measurement to measurement, it would tend to be consistent in relation to the heights of others in the group.

There are numerous sources of random error. Some examples are (1) the manner in which a measure is scored or coded, (2) characteristics or state of the subject or respondent (such as attention span, anxiety, or illness), (3) chance factors affecting the administration or appraisal of measurements obtained (such as fatigue of observers, different emphasis placed on different words by an interviewer, the amount of heat or lighting in the room, or luck in the selection of answers by guessing), and (4) characteristics of the measurement tool or method such as type of items employed in constructing a test or the parameters of a mechanical instrument.

Validity and Systematic Error

In addition to being reliable, it is desirable for a measurement procedure to be valid. Any measurement tool or method is valid to the degree that it measures what it purports to measure. Hence, an empirical indicator of a particular nursing concept is valid to the extent that
it successfully measures the intended concept. For example, a rating scale designed to measure maternal behavior would be valid to the extent that it actually measures maternal behavior rather than reflects some other phenomenon.

As noted above, the validity of a specific measurement tool or method is influenced by the degree to which systematic error is introduced into the measurement procedure. There is an inverse relationship between the degree to which systematic error is present during a measurement procedure and the extent to which the empirical indicator is valid. The more systematic error is included in the measure, the less valid the measure will be, and vice versa. Therefore, validity is a matter of degree just as reliability is a matter of degree. The goal of obtaining a perfectly valid empirical indicator that represents only the intended concept is not completely achievable. As previously noted, systematic error causes independent measurements obtained by the same tool or method to be either consistently higher or lower than they ought to be. This clearly presents a problem with validity because there is a common systematic bias in all results obtained by the tool or method, which influences the extent to which the attribute of interest is actually measured.

To illustrate the impact of systematic error on the validity of a measurement, suppose that an oxygen analyzer has an error in calibration so that it consistently registers the percentage of oxygen two points below the actual percentage of oxygen. Even though variations in the concentration of oxygen in a premature infant's isolette would be reflected in repeated measurements, each measurement would be 2 percentage points below the actual level due to systematic error in the measuring device, the oxygen analyzer. The effect is that a constant—2 percentage points—would be subtracted from the value that would be obtained if the oxygen analyzer were properly calibrated. An inference about the absolute concentration of oxygen in the isolette would be invalid.

Similarly, if a measurement procedure that was designed to measure only nausea also measures anxiety, then this would present a problem of validity. The measurement procedure would not be a totally valid measure of nausea because it simultaneously measures anxiety. Thus, systematic bias has been introduced into the results, which do not accurately measure the concept of interest. However, this bias would be included in all measurements obtained with the tool.

There are a number of biasing factors that can contribute to systematic error in measurement. Usually the sources of systematic error are associated with lasting characteristics of the respondent or subject, the measurement tool or method, and/or the measuring process. The sources of systematic error do not fluctuate from one measurement situation to the next as is the case with random error. Examples of systematic sources of error associated with the respondent or subject are chronic illness, test-taking skills, a negative attitude toward completing questionnaires or taking tests, and a poor comprehension of language used in the questionnaire or test items. Characteristics of measurement tools that may systematically bias measurements are the inclusion of items that measure knowledge, skills, or abilities that are irrelevant to the concept being measured, and poor calibration of a measuring device. Another source of systematic error may be the measurement process itself; for example, observer or scorer bias (such as an observer's tendency to rate slim individuals higher than heavy individuals on items related to physical activity).

A significant threat to validity is the use of proxy response, that is, systematic error that may result when a subject is unable to respond to a measure, such as in the case when there is memory loss, dementia, or when a subject is too young to comprehend and/or respond and a proxy (e.g., caregiver or family member) responds on that person's behalf. For example, Magaziner and colleagues (1996) conducted a study of the use of proxies to measure health and functional status in epidemiologic studies of community-dwelling women aged 65 years and older comparing proxy and subject responses to survey questions about chronic conditions, health symptoms, and physical and instrumental functioning to determine extent of disagreement, direction of nonrandom discrepancies (i.e., bias), and how disagreement and bias vary by proxy and subject characteristics. They found that, with few exceptions, proxies were more likely than subjects to report the presence of a condition, symptom,
or functional problem. Variations in agreement and bias were noted by subject and proxy characteristics with different patterns observed for different measurement areas, and thus, they concluded that when using proxy reports in place of self-reports, it is important to evaluate the impact that using proxies has on study results. Similarly, Dassel and Schmitt (2008) studied caregiver reports of Alzheimer’s patients’ performance of activities of daily living (ADL) and found that proxy reports may not be reliable and that caregiver educational level and cognitive functioning were significant predictors of discrepancies between caregiver ADL reports and direct observation of patient performance of ADL. They concluded that researchers must be aware of potential biases when employing proxies in evaluating patients with memory disorders and that objective measures should be employed instead in assessing functional impairment. Further, they suggested that additional studies should be conducted to investigate whether cognitive training and education programs for caregivers will increase accuracy of ADL reports.

Theunissen and colleagues (1998) investigated proxy responses comparing child report versus parent report in health-related quality of life research. They found that, on the average, children reported a significantly lower health-related quality of life than their parent on physical complaints, motor function, autonomy, cognitive functioning, and positive emotions. In addition, they found that background variables related to agreement were gender, age, temporary illness, and visiting a physician. Similarly, Eiser and Morse (2001) conducted a systematic review of studies of parents’ ratings of their children’s health-related quality of life and found that: (1) agreement between parent and child is greater for physical domains when observation measures are employed and less for nonobservable measures, for example, social and emotional; (2) no clear conclusions could be made regarding the impact of illness assessed by parent and child; (3) agreement was better between parent and chronically ill children compared with parents of healthy children; (4) no effects were found for age or gender. Their review provided evidence for the importance of obtaining information from both parents and children whenever possible and that all results may be dependent on specific measures of health-related quality of life employed.

By now it should be clear that measurement error is central to questions related to reliability and validity. Any tool or method is relatively reliable if it is affected to a minimal extent by random measurement error. Even though high reliability of a measuring instrument is a laudable goal, measures that are reliable are only a portion of the answer to measurement concerns. It is also important that a tool or method be valid for the purposes for which it is used. Systematic error biases the degree to which an indicator measures what it is supposed to measure by reflecting some other phenomenon. Hence, validity is enhanced by the degree to which systematic error is kept to a minimum. While reliability focuses on the consistency of performance of the measure, validity is more of a theoretically oriented issue because it focuses on the crucial relationship between the concept and its empirical indicator (Carmines & Zellar, 1979).

Two important points should be made about the relationship of reliability and validity. First, a measurement procedure can be highly reliable but have low validity. Consistency of results does not necessarily mean that a tool effectively measures the concept that it is used to measure. Second, a measurement procedure that has low reliability when the measurement situation remains constant cannot have an acceptable degree of validity. As noted by Jennings and Rogers (1989), if a study uses an unreliable outcome measure, the results are not meaningful because it is not possible to know what the independent variables are predicting. The presence of large random error compromises the extent to which an empirical indicator represents the concept it is supposed to measure. Therefore, reliability is a necessary but not sufficient condition for validity.

**CLASSICAL MEASUREMENT THEORY**

The preceding section examined measurement error and related it to the concepts of reliability and validity. This section presents a discussion
of classical measurement theory, which is a model for assessing random measurement error. As noted previously, random error is present in the measurement of any phenomenon. The basic tenet of classical measurement theory evolved from the assumption that random error is an element that must be considered in all measurement. The underlying principle of this theory is that every observed score is composed of a true score and an error score. The true score is the true or precise amount of the attribute possessed by the object or event being measured. The error score reflects the influence that random error has on the observed score. The basic formulation of classical measurement theory is as follows:

**Formula 3.1:** Classical measurement theory

\[ O = T + E \]

where  
- \( O \) = observed score  
- \( T \) = true score  
- \( E \) = error score

This equation simply indicates that every observed score that results from any measurement procedure is composed of two independent quantities: a true score, which represents the precise score that would be obtained if there were no random errors of measurement; and an error score, which represents the contribution of random measurement error that happens to be present at the time the measurement is taken.

Consider the following examples as illustrations of true and error score components of the observed score. Suppose a student attempts to take the pulse of a patient for 1 min and misreads the second hand on her watch. She counts the patient’s pulse rate for 64 sec rather than the intended 60 sec, thereby increasing the patient’s actual pulse rate of 82 (the true score) to 88 (the observed score). According to Formula 3.1, the error score in this instance is +6 beats, since this is the discrepancy between the patient’s true pulse and observed pulse.

\[ O = T + E \]
\[ 88 = 82 + (+6) \]

Suppose that the random error had been in the other direction and the student counted the patient’s pulse rate for only 58 sec rather than the intended 60 sec. Although the patient’s actual pulse rate was 82 (the true score), the observed pulse rate was 78 (the observed score). Therefore, the error score in this case is –4.

\[ O = T + E \]
\[ 78 = 82 + (-4) \]

It should be noted that in reality one does not know the true score and the error score values. Only the observed score is known. The above examples are for the purpose of illustration only. Formula 3.1 assumes that the object or event being measured possesses a specific amount of the attribute of interest when the measurement is taken. The precise amount of the attribute is obscured because of the random error, which either increases or decreases the results. The influence of the random error on the observed measurement is called the error of measurement. Classical measurement theory assumes that the observed score that is obtained when a measurement is taken is a combination of the true score and the error of measurement. The implication of this assumption is that systematic errors become part of the true score and affect validity but not reliability.

True scores are conceived to be unobservable quantities that cannot be directly measured. When an attribute is measured, the true score is assumed to be fixed. If it were possible for the true score to remain constant while the attribute of interest was measured an infinite number of times, variability in observed scores would result from the impact of random error of measurement that would occur by chance when each measurement was taken. Random disturbances in the observed score due to random error means that some observed scores would be higher than the true score, while other observed scores would be lower than the true score. Classical measurement theory assumes that the mean of error scores is zero and that the correlation between the true score and error score is zero. Therefore, distributions of random error can be expected to be normally distributed; hence, the distribution of observed scores would be normally distributed. The effects of random error can be expected to cancel each other out if many
deviation of error scores is termed the standard error of measurement.

If it were possible to have a measurement procedure that was perfectly reliable, the observed score and the true score would be the same. There would be no error of measurement and, therefore, no error score. In such a case the standard error of measurement would equal zero. The more reliable a measurement procedure is the smaller will be the standard error of measurement. The less reliable the measurement procedure, the larger the standard error of measurement. The size of the standard error of measurement is an indicator of the amount of error involved in using a particular measurement procedure.

**Observed Score Variance**

If a large number of persons were measured with respect to some attribute, the observed scores

![Distribution of observed scores](image1)

**FIGURE 3.12** The true score and hypothetical distribution of observed scores for a person at a specific point in time.

![Distribution of error scores](image2)

**FIGURE 3.13** Hypothetical distribution of errors of measurement.
would not be the same. This is true because there would be real differences in the amount of the attribute possessed by different individuals, and because there would be differences in the effects of random error on each observed score. Since each person’s observed score is composed of true score and error score components, three different score distributions would result: (1) a distribution of the observed scores, (2) a distribution of true scores, and (3) a distribution of error scores. Figure 3.14 illustrates these distributions of scores. Each person’s observed, true, and error scores (e.g., for individuals J and L) are represented in each of the three distributions.

Remember that true scores and error scores are not observable. Only the values of the observed scores are known. Classical measurement theory assumes that the correlation between the true
score and error score is zero. If this is the case, the following formula holds.

**Formula 3.2:** Basic variance formula

\[
\text{Var (O)} = \text{Var (T)} + \text{Var (E)}
\]

where \( \text{Var (O)} \) = variance of the observed-score distribution,
\( \text{Var (T)} \) = variance of the true-score distribution,
\( \text{Var (E)} \) = variance of the error-score distribution

This basic variance formula holds only when true scores and error scores are not correlated; that is, when the true score cannot be used to predict the error score and vice versa.

### The Statistical Definition of Reliability

Formula 3.2 can be converted to illustrate the statistical definition of reliability. In order to do this, each term in Formula 3.2 is divided by \( \text{Var (O)} \). The result is as follows:

\[
\text{Var (O)} / \text{Var (O)} = \text{Var (T)}/\text{Var (O)} + \text{Var (E)}/\text{Var (O)}
\]

**Formula 3.3:** Statistical definition of reliability and unreliability

\[1.00 = \frac{\text{Var (T)}}{\text{Var (O)}} + \frac{\text{Var (E)}}{\text{Var (O)}}\]

Note that \( \text{Var (O)}/\text{Var (O)} \) is equal to one. The expression \( \text{Var (T)}/\text{Var (O)} \) is the statistical definition of reliability. It is representative of the proportion of variation in the observed score distribution that results because of true-score differences among respondents or subjects. The second ratio in Formula 3.3, \( \text{Var (E)}/\text{Var (O)} \), is the statistical definition of unreliability. It is a representation of the proportion of variation in the observed-score distribution that is due to random errors of measurement. A variance ratio is equivalent to a squared Pearson \( r \) (coefficient of correlation). Therefore, \( \text{Var (T)}/\text{Var (O)} \) is the squared correlation of true scores with observed scores. The second ratio, \( \text{Var (E)}/\text{Var (O)} \), is the squared correlation of error scores with observed scores. Thus, the squared correlation of true scores with observed scores is also a statistical representation of reliability and is termed the reliability coefficient. Similarly, the squared correlation of error scores with observed scores is a statistical representation of unreliability.

The square root of the reliability coefficient is the correlation between observed scores and true scores for a test or measure. This is usually called the test’s reliability index. Since a reliability coefficient is conceptually a squared value, the statistic used to estimate it empirically is never squared in practice. Reliability also can be expressed in terms of error variance. Referring to Formula 3.3:

\[1.00 = \frac{\text{Var (T)}}{\text{Var (O)}} + \frac{\text{Var (E)}}{\text{Var (O)}}\]

If \( \text{Var (T)}/\text{Var (O)} \) were transposed to the left side of the equation and 1.00 to the right side, it can be seen that:

**Formula 3.4:** Reliability of observed score as a measure of score

\[
\frac{\text{Var (T)}}{\text{Var (O)}} = 1.00 - \frac{\text{Var (E)}}{\text{Var (O)}}
\]

Hence, the reliability of the observed score (0) as a measure of the true score (T) is equal to 1.00 minus the error variance. It is obvious then that the reliability of a measure varies between 0 and 1. If the observed score is highly contaminated with random error, then the reliability is decreased and becomes closer to zero. Conversely, if only a small amount of random error occurs in the measurement of a phenomenon, the reliability increases and is closer to 1.00. Reliability coefficients provide an indication of the significance of interindividual differentiation in observed scores. If a reliability coefficient is high, then more credence can be given to interindividual differences in observed scores. A low reliability coefficient reduces the credibility. The variance of error of measurement indicates intraindividual variability in the person’s observed score due to the introduction of random error when the measurement was taken (Stanley, 1971, p. 373). When the variance of
error of measurement is large, this means that a large amount of random error was introduced into individual scores.

If a professor used an achievement test with an estimated reliability of 0.85 to test students’ knowledge of factors contributing to medication errors, this would indicate two things. First, 85% of the variance in the distribution of observed scores is due to actual differences in knowledge among the students tested. Second, the remaining 15% of variance in the observed score distribution resulted from random errors of measurement, for example, misinterpretation of items or guessing.

The derivation of the statistical definition of reliability for a distribution has been shown. However, it is optimal to compute the reliability coefficient directly with at least two observed scores per subject. When the observed score is a composite of more than one part of a measure, then the consistency among several parts can be examined and a reliability estimate obtained. For example, if a test contained two or more items, one could study how scores on items of the test co-vary with each other and determine the consistency of the test.

Two conceptual models that have evolved from classical measurement theory are commonly used for the discussion of measurement error: (1) the model of parallel measures, and (2) the domain-sampling model. Both are basic models for the computation of reliability coefficients.

The Model of Parallel Measures

This model purports to determine a measure’s reliability by correlating parallel measurements. It is assumed that two measures of the same thing are parallel if (1) they have the same correlation with a set of true scores; (2) variance in each measure that is not due to true scores is strictly the result of random error of measurement; and (3) they have the same standard deviation. For example, if two tools designed to measure depression are parallel, they would yield the same true scores when used in the same measurement situation. The differences in the observed scores on the measures would be due only to random error. Since random errors tend to cancel each other out, the standard deviations reflect true score variance. The model of parallel tests assumes that the correlation between any two tests of a domain is a complete and precise determination of the reliability coefficient rather than only an estimate. A major limitation of this model is that it disregards the fact that reliability cannot be precisely determined by sampling of items in a content domain.

Nunnally (1978, p. 203) points out that the model has limitations because it offers a conceptual dead end for the development of theories of measurement error since true scores are defined by only two tests. He contends that if there are three supposedly parallel tests rather than two, and the three correlations among them are different, what then is the reliability? Since the model explicitly assumes that all parallel tests have the same reliability, one is faced with a dilemma. However, this is not a problem for the domain-sampling model with which this possibility is admitted, and an estimate of the reliability of any one measure is the average of its correlations with other measures.

The Domain-Sampling Model

The domain-sampling model considers any measure to be composed of a random sample of items from a hypothetical content domain that it purports to measure. According to this model, if a 50-item test was designed to measure knowledge of pulmonary physiology, it could be considered to consist of a random sample of 50 items from a domain of all possible items that could test knowledge in this content area. A number of other tests could also be devised by randomly sampling the same domain. Each of the tests that would result from sampling the same domain would have somewhat different means, standard deviations, and correlations because of random error in the sampling of items. Tests or measures composed of items randomly taken from the same content domain are considered randomly parallel tests.

The domain-sampling model indicates that the goal of any measure is to estimate the score a person would obtain if examined on all possible items within the content domain. The score that an individual would obtain if it were possible to be measured with a test composed of all possible items from a domain would be the true score.
This is sometimes referred to as the domain score. In reality, it is not possible to obtain a domain score. In most instances, there are an infinite number of items in a content domain. It also is difficult to randomly sample a domain. Most test items are constructed for each specific measure. However, actual applications of the domain-sampling model do result in accurate predictions.

According to the domain-sampling model, the extent to which any sample of items from the domain is correlated with the true score is an indication of its reliability. If a sample of items has a low correlation with the true score or domain score, then the reliability also would be low. Conversely, a high correlation between a sample of items from the domain and the true score means that the reliability of the sample is high. The domain-sampling model is applicable regardless of the number of items in the sample. Reliability estimates can be obtained if there is only one item in the item sample, or if there are many items.

The only assumption of this model is that the average correlation of each item with all the others in the domain is the same for all items. The degree to which items in the domain measure the same attribute would be indicated by the average correlation of items in the domain. The wider the dispersion of correlations of items about this average, the less likely that the items in the domain measure a common attribute. When the average correlation of items in the domain is zero or close to zero, the items do not have a common element and do not measure one attribute. It is, therefore, desirable for item correlations in the domain to be relatively homogeneous, positive, and greater than zero. When item correlations in the domain are more homogeneous, reliability estimates are more precise. The degree of variance in the correlations among items in the domain is a reflection of random error connected with the average correlation for a particular sampling of items. Errors that would cause variation from item to item, such as guessing, would reduce item correlations and thereby reduce reliability.

Thus far, the discussion of the domain-sampling model has primarily focused on the correlations of single items in the domain. However, these concepts can be extended to whole tests as well. It was noted earlier that this model views tests as consisting of a random sample of items from a content domain. A number of tests generated from the same domain using random selection of items would be considered randomly parallel tests. Each would have means, standard deviations, and correlations with true scores that would differ by chance only. If it were possible to randomly select test items from the domain, the average correlation of a single test with a number of other randomly parallel tests would be an estimate of the average correlation of the test with all other tests in the domain. Conceptually, this would result in the reliability for the tests.

Since the whole test is a summation of its items, the average correlation among whole tests will be larger than the average correlation among items. This will result in higher correlations with true scores for the whole test. The domain-sampling model assumes that the reliability of scores obtained on a sample of items from the domain increases as the number of items sampled from the domain increases (Nunnally & Bernstein, 1994, pp. 230–233). Therefore, longer tests have higher reliability coefficients than shorter tests. However, Nunnally (1978, p. 208) noted that tests with as few as 10 items may have rather precise reliability.

On initial examination the model of parallel measures and the domain-sampling model appear quite different. However, Nunnally (1978) notes that the model of parallel measures is a special case of the domain-sampling model. Whereas the basic assumptions of the parallel measures model result in a specification of a characteristic of measurement error, the domain-sampling model estimates the same characteristic. Any formula obtained from the parallel measures model can be matched by a formula from the domain-sampling model, which is based on estimation. However, the reverse does not hold. There are many principles and formulas emanating from the domain-sampling model that cannot be provided for by the model of parallel tests.

The model of parallel measures and the domain-sampling model are the best-known conceptual approaches to measurement. Both have evolved from classical measurement theory.
and have proved to be useful and understandable approaches to the discussion of measurement error. Generalizability theory is another model that deals more fully with the various sources of measurement error and further extends classical measurement theory. The following section presents the central concepts of generalizability theory.

AN INTRODUCTION TO GENERALIZABILITY THEORY

Generalizability theory is an extension of classical measurement theory that is usually employed to analyze the effects of different measurement conditions on the psychometric properties of an instrument or measurement method (Embritson & Hershberger, 1999, p. 3). Generalizability theory (Cronbach, Glesser, Nanda, & Rajaratnam, 1972; Nunnally & Bernstein, 1994), or G theory as it is sometimes called, provides a framework for examining the dependability of behavioral measurements (Shavelson, Webb, & Rowley, 1989). Whereas classical measurement theory partitions score variance into two components (that is, true-score variance and error variance), generalizability theory acknowledges the multiple sources of measurement error by deriving estimates of each source separately. This approach provides a mechanism for optimizing estimates of reliability. The reliability coefficient that is derived is called a “generalizability coefficient.”

A fundamental notion of generalizability theory is that a score’s usefulness depends on the degree to which it allows one to generalize accurately to some wider set of situations, the universe of generalization. One’s universe score would be the person’s mean score over all acceptable observations and would be the best information on which to base decisions about the person’s behavior. Instead of focusing on how accurately observed scores reflect their corresponding true scores, generalizability theory is concerned with how well-observed scores permit us to accurately generalize about an individual’s behavior in a defined universe of situations (Shavelson et al., 1989). “The question of ‘reliability’ thus resolves into a question of accuracy of generalization, or generalizability” (Cronbach et al., 1972, p. 15).

Generalizability theory allows error components in a measurement to be identified and their magnitude estimated. The researcher who is concerned about the quality of measurement can systematically manipulate certain facets of error, control others, and ignore still others. In a manner similar to the ANOVA (analysis of variance) design, the researcher can isolate sources of error, called “facets,” and the levels of the facets, called “conditions.” The sources of error depend on the measurement design and procedure. Examples of sources could be raters, forms, items, occasions, and their interactions. Decomposition of an observed score in generalizability theory for a design in which raters and items are sources of error (according to Shavelson et al., 1989) would focus on the grand mean (persons, raters, and items) plus the person effect, rater effect, item effect, person by rater effect, person by item effect, rater by item effect, and residual (person by raters, by item error).

Analysis of variance procedures can be used to estimate variance components within the design. Only a single source of error, that is, raters or items, can be calculated at a time. However, variance components are calculated for each source of error. For example, if raters are considered the source of error, the score for each person by each rater would be summed over items. Mean squares are provided by the ANOVA for persons and the residual (person x rater interaction confounded with random error). Variance components can be estimated from the mean squares. The degree to which each facet contributes to measurement error is indicated by the magnitude of the variance components. From these estimated variance components, specific formulas can be used to calculate a generalizability coefficient that is analogous to a reliability coefficient (Nunnally & Bernstein, 1994; Shavelson et al., 1989).

The nature of the decisions to be made with the data is also considered in generalizability theory. A distinction is made between relative decisions and absolute decisions. In relative decisions the focus is on the dependability of the differences among individuals or the relative standing of individuals that result from the measurement procedure. Error components in relative decisions are due to variance associated with the rank ordering of individuals other
than the component that is the focus of measurement. *Absolute decisions* are based on the observed score, which reflects the performance of the individual without regard to the performance of others. In this case, error is defined as all variance components associated with a score, except for the component for the object that is the focus of measurement.

In generalizability theory two types of studies are done related to the assessment of measurement error: generalizability studies (G) and decision (D) studies. A *G study* is primarily concerned with estimating the magnitude of as many potential sources of measurement error as possible and is concerned with the extent to which a sample of measurements generalizes to a universe of measurements. The universe of a G study is usually defined in terms of a set of measurement conditions based on a set of sample measurements obtained. Often this universe is more extensive than the conditions under which the sample was obtained. In G studies all facets that are likely to enter into the generalizations of a diverse group of users are systematically studied. Examples of G studies include studies concerned with the stability of scores over time, the internal consistency or interrelationship of items on a scale or subscales on a scale, and the equivalence of two alternative forms of a measure or tool. Often, the purpose of a G study is to help plan a D study that will have appropriate generalizability (Crocker & Algina, 1986; Nunnally & Bernstein, 1994).

A *D study* is designed and conducted for the specific purpose of making a decision, such as describing examinees for placement or selection, comparing groups of subjects in an experiment, or investigating the relationship between two or more variables (Crocker & Algina, 1986). “D studies use information from a G study to design a measurement that minimizes error for a particular purpose” (Shavelson et al., 1989, p. 923). D studies may have facets that are either fixed or random. If facets are fixed, then the investigator should generalize the results only to those fixed conditions included in the D study. However, when random facets are selected to be included in the study, the investigator can reasonably assume that the conditions in the D study are a sample from a larger number of conditions, and can generalize to all of these latter conditions.

In general, a G study is conducted when a measurement procedure is being developed, while a D study employs the measurement procedure for a specific purpose. Therefore, G studies should be as fully crossed as possible and incorporate all possible facets and variance components. The results from a well-developed and well-designed G study can provide information upon which the generalizability for a wide variety of nested D study designs can be estimated (Shavelson et al., 1989). For a full discussion of the specific approaches to the development and implementation of G studies and D studies, see Crocker and Algina (1986), Fyans (1983), and Nunnally and Bernstein (1994).

# AN INTRODUCTION TO ITEM RESPONSE THEORY

Item response theory (IRT) is an approach to constructing cognitive and psychological measures that usually serves as the basis for computer-adapted testing. In classical measurement theory an attribute is assessed on the basis of responses of a sample of subjects or examinees to the set of items on a measure. Hence, it focuses on test performance. IRT, on the other hand, focuses on item performance and the examinee’s ability, that is, predicting how well an examinee or group of examinees might perform when presented with a given item. IRT differs from classical measurement theory with regard to how items are selected for inclusion in a measure and in how scores are interpreted.

IRT is based on two basic premises: (1) an examinee’s test performance can be predicted or explained by a set of factors referred to as traits, latent traits, abilities, or proficiencies; and (2) the relationship between an examinee’s item performance and the set of abilities underlying item performance can be described by a monotonically increasing function called an item characteristic function or *item characteristic curve* (ICC). This curve graphically illustrates that as the level of the ability increases, so does the probability of a correct response to an item (DeVellis, 2003; Embretson & Reise, 2001; Hambleton, Swaminathan, & Rogers,
attribute items like the ones on the test, and (2) the person to correctly answer a certain number of questions. It is the amount of the trait possessed by the person (examinee). The most popular unidimensional IRT models are the one-, two-, and three-parameter models. These models are appropriate for dichotomous item and response data. The Rasch (1960) one-parameter logistic model is the most frequently employed. In this model, items differ only in their difficulty. It is assumed that the only item characteristic that influences examinee performance is item difficulty. Person ability and item difficulty are measured on the same scale, therefore, items and persons can be directly related. The ICCs in this case differ only by their location on the ability scale. It is assumed that examinees of very low ability have zero probability of correctly answering the item and no allowance is made for guessing. Figure 3.15 presents a simplified example of an ICC for three items for the one-parameter model. The ICC for the three items in Figure 3.15 indicates that item 1 requires a higher level of ability to answer correctly with probability 0.50 than items 2 and 3.

In the two-parameter logistic model developed by Lord (1952) and modified by Birnbaum (1968, 1969), items differ in their difficulty and discrimination. Item discrimination is defined by the slope of the ICC. Items with steeper slopes are more useful for separating examinees into different ability levels than are items with less steep slopes. The two-parameter model, like the Rasch model, makes no provision for guessing. Figure 3.16 presents a simplified example of a two-parameter model. In Figure 3.16 the slopes for items 1 and 3 indicate they are better able to discriminate among examinees than is item 2. In terms of difficulty, item 2 tends to be the more difficult item (i.e., to answer with probability of 0.70 requires a higher level of ability as compared with items 1 and 3).

In the three-parameter logistic model, items differ in their difficulty, discrimination, and proneness to being answered correctly due to guessing. An ICC, in this case, graphically represents the probability of an examinee getting an item correct as a function of ability.

Many possible item response models exist that vary in the mathematical form of the item attribute function and/or the number of parameters specified in the model. All IRT models contain one or more parameters describing the item and one or more parameters describing the person (examinee). The most popular unidimensional IRT models are the one-, two-, and three-parameter models. These models are appropriate for dichotomous item and response data. In the analysis and selection, and a measurement scale for reporting scores.

Isaac and Michael (1995) note that the probability of a person correctly answering a test item is a function of two attributes: (1) the person attribute that can be any trait of interest but usually refers to “ability,” “achievement,” and “aptitude.” It is the amount of the trait possessed by the person to correctly answer a certain number of items like the ones on the test, and (2) the item attribute that refers to the difficulty level, defined as the point on the ability scale where the person has a 50% chance of answering the item correctly. The estimate of these two attributes, person ability and item difficulty, is referred to as calibration (pp. 119–120). Assumptions underlying IRT include unidimensionality, item independence, equal item discrimination, and no guessing.

Unidimensionality implies that one dominant ability influences test performance or, equivalently, that only one ability is measured by the items that make up the test. It is assumed that items can be arranged in order of difficulty along a single continuum such that the examinee’s performance on these items can be represented by a single score that is on the same continuum as the items. Thus, different items should be answered correctly by examinees with high ability more often than examinees with low ability.

Item independence, also referred to as local independence, means that when ability influencing test performance is held constant, examinees’ responses to any pair of items are statistically independent. For an examinee of given ability, a response to one item is independent of a response to any other item. Thus, a correct response to one item cannot depend on a correct response to any other item.

Equal item discrimination assumes that items represent equal units when summed to yield a total score.

No guessing assumes that no one correctly guesses an answer. When low ability examinees guess correctly on difficult items, the unidimensionality assumption is not tenable (Hambleton et al., 1991; Isaac & Michael, 1995; Wright & Shaw, 1979).
FIGURE 3.15 One-parameter ICC for three items.

FIGURE 3.16 Two-parameter ICC for three items.
It reflects the difficulty, discrimination, and proneness to guessing of the item. Figure 3.17 presents a simplified example of an ICC for the three-parameter model. In Figure 3.17, the third parameter, proneness to guessing, is illustrated by item 3, where the probability of respondents with low ability answering the item correctly is 0.25 as compared with items 1 and 2, where the probability is 0. The three-parameter logistic model also is exemplified in the work of Lord (1968), who performed an analysis of the verbal scholastic aptitude test using Birnbaum’s three-parameter logistic model.

The first step in any IRT application is to estimate these parameters. Item calibration involves the evaluation of the fit of the item difficulty parameter. Test calibration involves the evaluation of the fit of the person abilities to the model and the estimation of the ability parameter corresponding to each test score.

When IRT is employed, the traditional concept of reliability is replaced by the concept of information. Examinee interactions with items yield information about their ability. More information means more precise estimates. Information increases as item difficulty approaches examinee ability. For the one- and two-parameter logistic models, maximum information is obtained when item difficulty equals examinee ability. Item information also increases as item discrimination increases. Information increases as the guessing parameter decreases. Item information is additive. Item information functions may be added together to obtain a test information function or an item pool information function.

An IRT model is usually chosen in one of two ways: (1) by choosing the model with the fewer item parameters that fits the test data adequately, or (2) by choosing the model and then selecting the test items to fit the chosen model. Checking model data fit usually involves evaluating the assumptions of IRT, unidimensionality, equal discrimination (Rasch model), and minimal guessing (Rasch and two-parameter models). For example, using data from two samples of examinees, an ICC graph can be constructed.

FIGURE 3.17  Three-parameter ICC for three items.
to compare item difficulty based on Sample 1, with item difficulty based on Sample 2. Expected model features can also be evaluated by comparing invariance of examinee ability parameter estimates and invariance of item parameter estimates. The relative fit of different models can be compared to determine if one model fits significantly better than another model and/or if model predictions of actual data and simulated test results can be compared. Isaac and Michael (1995) noted that while the IRT model continues to gain in use, the two greatest challenges for users are its complex mathematical foundation that makes it extremely difficult to understand and/or explain to nontechnical audiences and emerging problems regarding the underlying assumptions and their empirical validation (p. 121). Readers interested in a more advanced discussion of IRT are referred to Crocker and Algina (1986), Hambleton et al. (1991), Embertson and Hershberger (1999), Embertson and Reise (2000). Item response theory is discussed in Chapter 10 as it is applied to computer-based testing. An example of an IRT scale can be found in Doorenbos, Verbitsky, Given, & Given (2005). Examples of the use of IRT can be found in Entink, Kuhn, Hornke, & Fox (2009) who evaluated cognitive theory using a joint modeling approach applied within the context of educational assessment using a large-scale investigation of figural reasoning ability and Bauer and Hussong (2009) who employed IRT when conducting an integrative analysis of data obtained from multiple independent studies in an attempt to establish commensurate measures for the constructs of interest.

**Score Variance**

For the most part, variance within a set of scores for a group of individuals occurs because different persons manifest different amounts of the attribute of interest. It should be kept in mind that the importance of the reliability coefficient for a measure is that it reflects the proportion of the variance in scores due to true differences within the particular population of individuals on the variable being evaluated. Therefore, it is desirable that measures be constructed and used so that they will be sensitive to real variations in true scores of individuals. The size of variation in true scores between persons is primarily determined by two factors: (1) the frequency of correct or appropriate responses to items, and (2) the correlations between the individual items. A measure will be most sensitive to real differences between persons when variance of the individual items is greatest—that is, when the probability of a correct response is 0.50 for any item chosen at random from the domain. When test items are either too easy or very difficult, score variance between individuals will be small, because such items do not adequately distinguish variations in the attribute of interest. This also is true for measures such as opinion questionnaires and attitude scales that have no correct answers. Each individual can be perceived as having a set probability of either agreeing or disagreeing with each statement. If statements are constructed in such a manner that true differences in opinions or attitudes are not elicited, then variations in scores will be small. True score variance also will be increased when the correlations between items in the domain are large and when the number of items in a measure is large.

It is desirable for measurements to have true score variance, particularly in the norm-referenced case. The magnitude of reliability coefficients depends upon the dispersion of true scores between individuals. Restriction of the range of variability is likely to lower the reliability of a measure in the manner noted earlier in the discussion of measures of correlation.
Error Variance Within a Set of Scores

Error variance within a set of scores obtained on a specific occasion occurs for many reasons. For any measure, error variance due to such factors as general ability to comprehend instructions, test-taking skills, and shrewdness in guessing is likely to affect scores. This type of systematic error results from lasting characteristics of each individual and results in stable individual differences in scores. Other such sources of systematic error include familiarity of the subject with test format, the nature of items, and level of comprehension of words, formulas, and generalizations that must be applied to correctly respond to certain items. Temporary characteristics of the individual can result in random error. Fatigue, emotional strain, and condition of the testing environment could result in an inability to concentrate, inadvertent skipping of items, misreading of items, and fluctuations in memory. Differences in standards and approaches to scoring would reduce correlations among items and thereby reduce reliability estimates. Errors in scoring could be assessed within a test if scoring errors tended to reduce correlations among items.

Variations in Scores Between Measurements

In some instances two randomly parallel tests are administered either simultaneously (during one testing period) or at short (e.g., 2-week) intervals. If the attribute of interest is such that there should not be noticeable variations for individuals tested, then the correlation between the two sets of scores should be nearly perfect. This may not be the case, however. Sets of scores on randomly parallel tests, also termed alternative forms, may not be highly correlated for three major reasons.

First, randomly parallel tests may not be truly parallel. There may be actual differences in the content of the two tests. The domain-sampling model envisions that randomly parallel tests are composed of items randomly selected from the same content domain. Since this is not possible in reality, some tests that are developed as parallel measures of an attribute may not be really parallel. Some aspects of the content domain may receive more emphasis in one test than the other, or one test may be constructed in such a manner that the use of certain words or terminology is emphasized more than in the other measure. The correlation between scores on the two tests might be lower because of these differences.

A second reason that variation may occur between measurements is because the conditions under which the tests were administered are markedly different and thereby influence the scores. Different environmental conditions such as a very hot room or noisy distractions may be present at one testing situation and not at the other. Temporary factors that can affect performance have already been discussed. If an entire group of people were tested together on both occasions under markedly different conditions, then the effect could be that a number of people in the group would have quite different observed scores on the two testing occasions. This would decrease the correlation between scores.

A third factor that might lessen correlations of scores between measurements is differences in scoring from one occasion to another. The use of different criteria for scoring either by the same scorer or two or more different scorers might result in somewhat different scores for the same person. This is particularly likely to happen when one scorer or rater is used on one occasion and a different scorer or rater is used on a subsequent occasion. However, even when a single scorer is used, rater drift can occur over time and the scorer can use different rating criteria without realizing that this is the case. For this reason, when raters are used in research studies, it is advisable to periodically assess intrarater and/or interrater reliability and retrain raters if indicated.

The Reliability of Change Scores

In some cases, it is desirable to determine the reliability of change scores, such as when one is considering a pretest and a posttest to determine whether there has been a change in the amount of a specific attribute of interest. In such an instance, the change score would be the posttest score of a subject minus the pretest score. To illustrate,
suppose a researcher wants to determine if the level of preoperative patient anxiety for a group of patients will decrease after a planned patient-teaching program is given. A state anxiety measure is used to measure patient anxiety prior to the teaching program, and patient anxiety after the patient teaching program is completed. The raw change score of each patient would be the difference between posttest and pretest scores. How will the researcher know if any changes that are exhibited are reliable?

One should keep in mind that errors of measurement previously discussed that could increase or decrease both sets of observed scores may have a significant impact on change scores, resulting in an interpretative problem. The obtained difference score equals true-score difference plus error-of-measurement difference. Although the posttest score minus pretest score seems to be the best way to measure change, it is not the best estimator of true change. Errors of measurement that are present in the pretest and posttest measurement procedures can seriously affect the difference score. Two commonly discussed problems associated with the measurement of change are the reliability of the difference score and the systematic relationship between measures of change and initial status.

The reliability of difference scores depends upon the variance and reliability of the pretest, corresponding values for the posttest, and the correlation between the pretest and the posttest scores. When the correlation between the pretest and posttest is high, the difference-score reliability tends to be low. For example, for a pretest and posttest with a common variance and a common reliability of 0.80, the reliability of the difference scores would be 0.60, 0.50, 0.33, and 0.00 when the pretest-posttest correlations were 0.50, 0.60, 0.70, and 0.80, respectively (Linn, 1979, p. 4). Hence, for the measurement of change, the lower the correlation between pretest and posttest scores, the higher the reliability of the measure of change. However, this fact creates a dilemma because the low correlation reduces confidence that one is measuring the same thing on each occasion.

The second problem frequently encountered with difference scores is that they generally are correlated with pretest scores. This is a disadvantage because a goal in the use of difference scores often is to compare the gains of individuals or groups that started with unequal pretest scores by removing initial differences. The problem arises from the fact that the sign of the correlation between the difference and pretest scores depends upon the variances of the pretest and posttest scores; where the variances for the pretest and posttest are equal, a negative correlation is to be expected. In this case, persons or groups with low pretest scores will tend to have higher gains than those with high pretest scores, and the initially lower-scoring group has a built-in advantage. On the other hand, if the posttest variance is substantially larger than the variance for the pretest, the correlation between the difference score and the pretest will be positive rather than negative. Where the correlation is positive, there is a built-in advantage to the group scoring higher on the pretest when comparisons are made in terms of simple difference scores (Linn, 1979, p. 5). Given the problems associated with using difference scores for the measurement of change, several alternatives have been offered: (1) residualized change scores, (2) estimated true-change scores, and (3) standardized change scores.

Residualized change scores are used because of the desire to obtain gain scores that are uncorrelated with initial status or pretest scores. However, they are not true measures of change (Cronbach & Furby, 1970). They are measures of whether a person’s posttest score is larger or smaller than the predicted value for that person. Residualized change scores are based on the assumptions of classical test theory regarding true-score and error-score components of observed scores and involve using the linear regression of the posttest on the pretest in order to determine predicted values (Nunnally & Bernstein, 1994). Major limitations to using residualized change scores are that they can be used only with measures taken at two points in time, and they are not really growth measures or change scores.

Estimated true-change scores are corrected measures of change. Cronbach and Furby (1970), as well as several other authors, have described procedures for estimating true change. They require estimates of reliability for the pretest and posttest for the sample involved. This is viewed as a major drawback of this approach, because
good reliability estimates for the sample often are not available (Linn, 1979).

The use of standardized change scores has been suggested as an alternative to raw difference scores by Kenny (1975). Standardized change scores simply are difference scores that have been standardized. This means that difference scores have been converted so that score distributions have means of zero and unit variances. Hence, standardized change scores will have a negative correlation with initial status or pretest scores, because they are based on pretest and posttest scores with variances that have been set equal.

Further information regarding the alternatives to using raw change scores can be found in Burckhardt, Goodwin, and Prescott (1982), Cronbach and Furby (1970), Kenny (1975), and Nunnally and Bernstein (1994). Specific alternatives to the measurement of change have advantages and disadvantages. Selection of an alternative approach should depend upon the nature of the study and the purposes for which change is to be measured. Since change scores are fraught with problems, we discourage their use and encourage the selection of alternative approaches to measurement whenever possible.

**SUMMARY**

This chapter presented the basic principles of statistics and measurement theory. Measurement is a process that employs rules to assign numbers to phenomena. The rules for assigning numbers to phenomena have been categorized hierarchically as either nominal, ordinal, interval, or ratio. The numbers that result from measurement are referred to as scores. The use of statistical procedures facilitates a better understanding of groups of numbers by providing numerical summaries of scores or data.

A distribution of scores may be described by its shape, measures of central tendency, and dispersion. A distribution’s shape may be symmetrical or asymmetrical. The extent to which a distribution departs from symmetry is referred to as its degree of skewness. The peakedness of a distribution is referred to as kurtosis. The mode, median, and mean are three statistical indices of the central tendency of a distribution of scores. The dispersion or amount of spread of a distribution is indicated by its range, variance, and standard deviation. The range is the distance from the lowest to the highest score in a distribution. The variance and standard deviation represent the amount of scatter among the scores within a distribution. The Pearson product–moment correlation coefficient \( r_{xy} \) is a statistic often used to summarize the relationship between scores within two separate distributions.

Whenever a measurement is obtained, error is introduced into the results to some degree. The two types of error of measurement are random error and systematic error. Random error results from chance factors that affect measurements, and systematic error arises from factors within the measuring tool, measurement process, or subject. Random error primarily influences the reliability of measurements, while systematic error primarily influences the validity of measurements.

Classical measurement theory is a model for assessing random measurement error. It purports that every observed score consists of a true score, which is the precise amount of an attribute possessed by an object, and an error score, which reflects the influence of random error. The model of parallel measures and the domain-sampling model are two approaches to reliability based on classical measurement theory. The model of parallel measures purports to determine reliability by correlating parallel measurements. The domain-sampling model provides for an estimate of reliability by an average of item correlations within the measure. Generalizability theory is an extension of classical measurement theory that takes into account the multiple sources of measurement error. It provides for the derivation of a generalizability coefficient, which indicates how accurately one can generalize the results of measurement to a specified universe. Item response theory is an approach to constructing cognitive and psychological measures that usually serves as the basis for computer-adapted testing. Item response theory focuses on item performance and the examinees’ ability, unlike classical measurement theory that focuses on test performance.

Variation in scores between measurements is due to actual changes in the true score, or to
variation in the amount of error introduced into measurements. It is problematic to use posttest minus pretest difference scores to assess change in true scores, because there is a systematic relationship between measures of change and the initial status or pretest, and the reliability of difference scores may be compromised by psychometric properties of the pretest and posttest. Alternative approaches to the measurement of change include residualized change scores, estimated true-change scores, and standardized change scores.

REFERENCES


Chapter 3 Measurement Theories and Frameworks


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Part II

Understanding Measurement Design
Strategies for Designing Measurement Tools and Procedures

As noted in Chapter 1, the two major frameworks for measurement are the norm-referenced and criterion-referenced approaches. This chapter focuses on the design and interpretation of each of these types of measures. Norm-referenced measures are employed when the interest is in evaluating a subject’s performance relative to the performance of other subjects in some well-defined comparison group. For example, Benkert and colleagues (2009) employed norm-referenced measures in their study of trust, mistrust, racial identity, and patient satisfaction in urban African American primary care patients of nurse practitioners and Rew, Grady, Whittaker, and Bowman (2008) employed a norm-referenced measure to study the effects of duration of homelessness and gender on personal and social resources, cognitive-perceptual factors, and sexual health behaviors among homeless youths. How well a subject’s performance compares with the performance of other subjects is irrelevant when a criterion-referenced approach is used. Criterion-referenced measures are employed when the interest is in determining a subject’s performance relative to a predetermined set of target behaviors. For example, Aiken and Poghosyan (2009) employed a criterion measure in their study to determine the extent to which direct care professional nurses working in inpatient units in four hospitals in Russia and Armenia agreed that certain characteristics that typify Magnet hospitals were present in their work setting, and Valentine and Cooper (2008) developed an instrument, the Study Design and Implementation Assessment Device (DIAD), to assess the quality of intervention effectiveness research study designs and implementation on multiple dimensions that results in a study quality profile. For this reason, different strategies are used when designing norm-referenced and criterion-referenced measures.

DESIGNING NORM-REFERENCED MEASURES

Essential steps in the design of a norm-referenced measure are (1) selection of a conceptual model for delineating the nursing or health care aspects of the measurement process; (2) explication of objectives for the measure; (3) development of a blueprint; and (4) construction of the measure, including administration procedures, an item set, and scoring rules and procedures. Since selection of a conceptual model is addressed in Chapters 1 and 2, the focus here will be on steps 2 through 4.

Explicating Objectives

The first step in the design of any measure is to clarify the purposes for the measurement. When a conceptual model serves as a basis for the tool’s development, this step is more easily undertaken than when it does not. For example, suppose an investigator is interested in assessing a geriatric patient’s ability to perform activities of daily living (ADL) upon admission
to an assisted living facility. Using self-care theory, activities of daily living are conceptually defined as the patient’s capacity to perform various physical (body care) tasks that permit the individual to provide self-care on a daily basis. Further, it is assumed that (1) body care tasks essential in everyday life are related to eating, dressing, bathing, toileting, transfer, walking, and communication; (2) the concept of self-care is not an absolute state but a continuum of ability levels that vary in the frequency with which the help of others is needed; and (3) the geriatric patient’s level of ability in performing certain activities of daily living may differ from the same individual’s level of ability in performing other activities.

On the basis of this conceptual definition of ADL self-care, the investigator is directed to operationalize ADL self-care in the following manner: (1) use a performance-objective type of measure, most appropriately, observation; (2) include in the measure multiple items reflecting salient characteristics or conditions related to each of the identified body care activities essential in everyday life; and (3) provide a way for respondents to demonstrate various levels of ability to provide self-care with and without the help of others.

Hence, the objective for the measure is this: Given a series of ADL tasks, the geriatric patient newly admitted to an assisted living facility will demonstrate the frequency with which he or she can perform the following tasks: eating, dressing, bathing, toileting, transfer, walking, and communicating, alone or with the help of others. It should be apparent that this objective derives from, and is consistent with, the conceptual definition of ADL self-care; it defines the relevant domain of content to be assessed by the measure as the geriatric patients’ performance of specific and varied ADL activities; and it specifies the type of behavior the subject will exhibit to demonstrate that the purpose of the measure has been met, that is, the frequency with which he or she is able to perform the behavior with and without the help of others.

To meet this objective, the investigator looks to the conceptual framework as well as empirical findings from studies defining ADL self-care in a similar manner to identify and list a number of behaviors salient to the measurement of the geriatric patients’ ability to eat, dress, bathe, toilet, transfer, walk, and communicate. This preliminary list is then subjected to scrutiny by experts in ADL for geriatric patients living in assisted living facilities who may add and/or delete behaviors. Each of these behaviors then becomes an item on the measure. Hence, each item included in the measure should be linked to the conceptual definition; that is, items that do not relate directly to the objective for the measure are superfluous and, if included, will tend to introduce error and thus, decrease validity.

To assess the level of ADL self-care, the investigator employs a five-point rating scale of the frequency with which the geriatric patient requires help from others ranging from never (0) to always (4). A portion of the resulting measure of ADL self-care is illustrated in Figure 4.1. It should be apparent from this hypothetical example that objectives provide the link between theories and concepts and their measurement. Additional examples of this linkage can be found in Waltz and Jenkins (2001) and Strickland and Dilorio (2003a, 2003b). Not only is it important to explicate objectives, but it is also paramount that they be stated correctly. A poorly stated objective can be more troublesome than no stated objective. For this reason, attention now turns to approaches for writing objectives that have gained favor with use.

Behavioral objectives are usually stated by using one of two approaches. The first approach is best characterized by the work of Mager (1962). In this view an objective has essentially four components: (1) a description of the respondent; (2) a description of the behavior the respondent will exhibit to demonstrate the accomplishment of the objective; (3) a description of the conditions under which the respondent will demonstrate accomplishment; and (4) a statement of the standard of performance expected to indicate accomplishment. This format for writing objectives is particularly useful when constructing measures of cognition, especially in a criterion-referenced framework, because it forces one to explicate clearly the
standard of performance expected prior to the construction of items. It should be noted, however, that its use is not limited to cognitive, criterion-referenced measures and that it has utility as well when constructing measures of affect and performance in a norm-referenced framework. Figure 4.2 illustrates Mager’s approach to the formulation of an objective for measuring the performance of a pediatric nurse practitioner student in a pediatric ambulatory care center.

The second approach reflects the views of scholars like Tyler (1950) and Kibler, Barker, and Miles (1970). Although similar to Mager’s approach, a behavioral objective in this case is composed of only three components: (1) a description of the respondent; (2) delineation of the kind of behavior the respondent will exhibit to demonstrate accomplishment of the objective; and (3) a statement of the kind of content to which behavior relates. This approach to objective explication is quite useful within a norm-referenced measurement context because it results in an outline of content and a list of behaviors that can then be readily used in blueprinting. Blueprinting is discussed in the next section of this chapter. Figure 4.3 illustrates the same objective written according to the Tyler-Kibler scheme. An example of use of Tyler’s (1950) approach to behavioral objectives can be found in Howard (2001).

A taxonomy is a useful mechanism for defining the critical behavior to be assessed by an objective in such a manner that all who use the same taxonomy or classifying scheme will assess the same behavior in the same way, thus increasing the reliability and validity of measurement. Numerous taxonomies have been proposed for the cognitive, affective, and psychomotor domains. Attention here will focus briefly on those that have gained favor through empirical use: (1) Bloom’s (1956) taxonomy of the cognitive domain; (2) Krathwohl, Bloom, and Masia’s (1964) taxonomy for the affective domain; and (3) Fitts’s (1962, 1964) scheme for the psychomotor domain.

Table 4.1 presents a simplified version of the taxonomy of the cognitive domain. In Bloom’s

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**FIGURE 4.1** A hypothetical sample measure of geriatric patients’ performance of ADL in an assisted living facility.
framework, the mental operations are grouped into a small number of simple-to-complex, hierarchically ordered categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. Hence, each subsequent level of mental activity involves the mental operations required at the preceding levels. For example, to be able to analyze, the respondent must first be able to know, comprehend, and apply.

A simplified version of the taxonomy for the affective domain appears in Table 4.2. As with the cognitive taxonomy, levels are hierarchical in nature, and performance at higher levels allows one to assume that the respondent can perform at lower levels as well.

Taxonomies for assessing the psychomotor domain are far less developed than for the other two; however, the approach by Fitts, which is summarized in Table 4.3, shows some promise in this area and is included for this reason. Fitts (1962, 1964) identifies three phases of skill development: cognitive, fixation, and autonomous. Phases overlap to some extent; that is, they are not distinct units and movement from one phase to another is a continuous process.

Objective: Given a well child newly admitted to the pediatric ambulatory care center, the PNP student will perform a comprehensive physical assessment as outlined in the center’s standards-of-care procedure manual.

<table>
<thead>
<tr>
<th>Component</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Description of respondent</td>
<td>PNP student</td>
</tr>
<tr>
<td>2. Description of behavior to be exhibited if objective is accomplished</td>
<td>Perform a comprehensive physical assessment</td>
</tr>
<tr>
<td>3. Description of conditions under which respondent will demonstrate accomplishment</td>
<td>A newly admitted well child</td>
</tr>
<tr>
<td>4. Statement of standard of performance</td>
<td>Perform assessment according to pediatric ambulatory care center standards of care outlined in the procedure manual</td>
</tr>
</tbody>
</table>

FIGURE 4.2 Formulation of an objective to measure performance of a pediatric nurse practitioner (PNP) student using Mager’s approach.

Objective: The PNP student performs a comprehensive physical assessment on a newly admitted well child.

<table>
<thead>
<tr>
<th>Component</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Description of respondent</td>
<td>PNP student practicing in a pediatric ambulatory care center</td>
</tr>
<tr>
<td>2. Description of behavior to be exhibited if objective is accomplished</td>
<td>Perform a comprehensive physical assessment</td>
</tr>
<tr>
<td>3. Statement of the kind of content to which behavior relates</td>
<td>An outline of standards of care contained in the center procedure manual was presented to the student in class prior to the PNP’s clinical rotation</td>
</tr>
</tbody>
</table>

FIGURE 4.3 Formulation of an objective to measure PNP student performance using the Tyler-Kibler scheme.
<table>
<thead>
<tr>
<th>Mental Operation Level</th>
<th>Action Verbs</th>
<th>Objective</th>
<th>Measurement</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge: measures subjects’ ability to recall or recognize information in essentially the same form as it was presented. The essential learner behavior is remembering.</td>
<td>Action verbs usually include: Cite, Classify, Complete, Correct, Identify, Label, List, Mark, Name, Read, Recall, Recite, Recognize, Show, State, Tell, Write</td>
<td>The newly employed acute care nurse will cite hospital standards for performing a physical assessment on a newly admitted critically ill adult patient.</td>
<td>PLC: Hospital standards for performing a physical assessment are outlined in the procedure manual given at orientation. Question: Cite hospital standards for performing a physical assessment on a newly admitted critically ill adult patient.</td>
<td>This is the lowest level of mental activity. The PLC reflects the information to be acquired by the subjects that is part of the objective stated during the program’s development.</td>
</tr>
<tr>
<td>Comprehension: measures understanding at the most rudimentary level, i.e., the subject’s ability to use previously acquired information to solve a problem. 1. Translation: ability to paraphrase, present in a different language, or recognize paraphrases symbolic changes.</td>
<td>Action verbs usually include: Conclude, Convey meaning of, Decode, Describe in own words, Explain, Extrapolate, Give reasons, Illustrate, Interpret, Reformulate, Restate, Rewrite, Summarize, Tell why, Translate</td>
<td>The newly employed acute care nurse will explain in his/her own words how to perform a physical assessment on a newly admitted critically ill adult patient.</td>
<td>PLC: During orientation the instructor explained how a physical assessment is performed on a newly admitted critically ill adult patient. Question: The orientation instructor assigns subjects to play roles of acute care nurse and instructor in a sociodrama and they are to act out these roles as explained to them by the instructor.</td>
<td>At this level, the subject must remember the information and use it to solve a novel problem. A key feature is that the item or the context in which it is asked is structured in such a way that subjects are made aware of information required to solve the problem. Items are designed to determine if the learner can solve a novel problem when information to be used is specified.</td>
</tr>
<tr>
<td>Mental Operation Level</td>
<td>Action Verbs</td>
<td>Objective</td>
<td>Measurement</td>
<td>Comments</td>
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<td>------------------------</td>
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<tr>
<td><strong>2. Interpretation:</strong> measures the subjects’ ability to make an inference based on the information in a communication, to explain what is meant by the communication, or to summarize the information in the communication.</td>
<td><strong>Examples</strong></td>
<td><strong>Given a case history of a newly admitted critically ill adult patient and a description of the comprehensive physical assessment performed on that patient, the newly employed acute care nurse will make conclusions about the patient’s status on the basis of the data.</strong></td>
<td><strong>PLC:</strong> The newly employed acute care nurse has been taught at orientation to perform a physical assessment on a newly admitted critically ill adult patient. The instructor then presents the learner with a case history and description of the physical assessment performed on the patient. <strong>Question:</strong> (True or False) On the basis of the results of the physical assessment, it is evident that the patient has altered mobility. <strong>Note:</strong> If this question were testing comprehension, the nurse would be told to use procedures outlined in the standards. <strong>Application:</strong> requires subjects to use previously acquired information in solving a novel problem. Neither the question nor the context in which it is asked helps respondents decide what previously acquired information must be used to solve the problem. Questions are aimed at determining if subjects are able to select and correctly employ appropriate knowledge in solving a new problem.</td>
<td>In Bloom’s taxonomy there is a third type of comprehension, extrapolation, that is not included here since it is so similar to comprehension and interpretation.</td>
</tr>
</tbody>
</table>
Analysis: may require subjects to (1) identify a logical error in a communication (e.g., a contradiction, error in deduction, erroneous causal inference) or (2) identify, classify, and/or recognize relationships among the elements (i.e., facts, assumptions, hypotheses, conclusions, ideas, etc.) in a communication. Items at this level usually assume specific training in a logical process to be used.

Synthesis: requires the respondent to produce or create: (1) a unique verbal or written communication, or (2) a plan or procedure for accomplishing a particular task.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze</td>
<td>Compose</td>
</tr>
<tr>
<td>Arrange in order</td>
<td>Construct</td>
</tr>
<tr>
<td>Combine</td>
<td>Design</td>
</tr>
<tr>
<td>Compare</td>
<td>Develop</td>
</tr>
<tr>
<td>Contrast</td>
<td>Devise</td>
</tr>
<tr>
<td>Criticize</td>
<td>Fabricate</td>
</tr>
<tr>
<td>Deduce</td>
<td>Form</td>
</tr>
<tr>
<td>Designate</td>
<td>Formulate</td>
</tr>
<tr>
<td>Detect</td>
<td>hypotheses</td>
</tr>
<tr>
<td>Determine</td>
<td>Integrate</td>
</tr>
<tr>
<td>Distinguish</td>
<td>Propose</td>
</tr>
<tr>
<td>Formulate</td>
<td>Reorganize</td>
</tr>
<tr>
<td>Formulate</td>
<td>Restructure</td>
</tr>
</tbody>
</table>

After watching a video of an experienced acute care nurse performing a physical assessment on a critically ill adult patient, the newly employed acute care nurse will list at least 5 behaviors of the nurse that may introduce error into the findings and at least 5 behaviors likely to result in valid conclusions regarding the patient’s status.

The newly employed acute care nurse will design a procedure for the unit to reduce the kind and amount of errors resulting from the nurse’s poor performance in conducting physical assessments.

PLC: The newly employed acute care nurse watches a video on strategies and techniques for minimizing errors and maximizing validity of findings of a physical assessment on a critically ill adult patient.

Question: List all of the actions taken by the acute care nurse performing the assessment that are likely to minimize errors and those likely to maximize validity.

PLC: The newly employed acute care nurse has read extensively regarding the strategies and techniques for maximizing validity of physical assessments and participated in staff development programs regarding strategies and techniques for minimizing errors in this regard.

Question: How can we reduce the effect of errors in procedure on the validity of the outcomes of physical assessments performed on this particular critical care unit?
## TABLE 4.1 A Simplified Version of the Taxonomy of the Cognitive Domain (Continued)

<table>
<thead>
<tr>
<th>Mental Operation Level</th>
<th>Action Verbs</th>
<th>Objective</th>
<th>Measurement</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation: requires the subjects to judge the value of ideas, people, products, methods, etc., for a specific purpose and state valid reasons for their judgment (i.e., the learners must state the criteria upon which the judgment is based).</td>
<td>Appraise, Ascertain value, Assay, Assess, Diagnose, Evaluate, Fix value of Judge, List in order of importance, Rank in order of importance</td>
<td>After observing an experienced acute care nurse perform a physical assessment on a newly admitted critically ill adult patient, the newly employed acute care nurse will judge the comprehensiveness and accuracy of the results and state the reasons for the judgment.</td>
<td>PLC: The staff development instructor demonstrates two contrasting approaches to performing a physical assessment. Question: Which do you think is likely to result in the most valid data regarding patient status? State your reasons for choosing the approach you did.</td>
<td></td>
</tr>
</tbody>
</table>


*PLC refers to the prior learning condition.*
<table>
<thead>
<tr>
<th>Affective Levels</th>
<th>Action Verbs</th>
<th>Objective</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiving (Attending): measures subject’s</td>
<td>Accept</td>
<td>The nurse will listen carefully and</td>
<td>Over time the nurse consistently</td>
</tr>
<tr>
<td>awareness and/or willingness to receive</td>
<td>Attempt</td>
<td>respectfully to all opinions rendered by the family of a frail elderly</td>
<td>demonstrates behavior that indicates s/he is listening respectfully</td>
</tr>
<tr>
<td>specified stimuli. Indicates the subject is</td>
<td>Comply</td>
<td>patient with dementia.</td>
<td>(eye contact, nondirective responses) to opinions expressed by the family.</td>
</tr>
<tr>
<td>capable of directing attention toward</td>
<td>Define</td>
<td></td>
<td></td>
</tr>
<tr>
<td>specified materials or behavior.</td>
<td>Identify</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Limit</td>
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<td></td>
<td>List</td>
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<tr>
<td></td>
<td>Listen</td>
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<td></td>
<td>Observe</td>
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<tr>
<td></td>
<td>Recognize</td>
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<td></td>
<td>Refrain</td>
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<tr>
<td></td>
<td>Reject</td>
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<td></td>
<td>Ask</td>
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<tr>
<td></td>
<td>Challenge</td>
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<tr>
<td></td>
<td>Choose</td>
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<tr>
<td></td>
<td>Cite</td>
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<tr>
<td></td>
<td>Consult</td>
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<tr>
<td></td>
<td>Delay</td>
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</tr>
<tr>
<td></td>
<td>Doubt</td>
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<tr>
<td></td>
<td>Hesitate</td>
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<tr>
<td></td>
<td>Inquire</td>
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<tr>
<td></td>
<td>Offer</td>
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<tr>
<td></td>
<td>Query</td>
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</tr>
<tr>
<td></td>
<td>Question</td>
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</tr>
<tr>
<td></td>
<td>Read</td>
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</tr>
<tr>
<td></td>
<td>Repeat</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Select</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Try</td>
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<td></td>
</tr>
<tr>
<td>Responding: measures the subject’s</td>
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<tr>
<td>tendency to respond in a favorable manner to</td>
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<td></td>
<td></td>
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<tr>
<td>specified stimuli. Response behavior</td>
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<tr>
<td>indicates that the subject has become</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adequately involved or committed to a</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>specified stimulus. If the subject consents,</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>seeks, and/or enjoys working with a</td>
<td></td>
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<tr>
<td>specified activity, s/he is responding</td>
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<td></td>
</tr>
<tr>
<td>favorably.</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

(Continued)
### TABLE 4.2  Simplified Version of the Taxonomy of the Affective Domain (Continued)

<table>
<thead>
<tr>
<th>Affective Levels</th>
<th>Action Verbs</th>
<th>Objective</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valuing: measures reflect that the subject displays behaviors with acceptable consistency under appropriate circumstances to indicate adoption of a certain value or ideal. In demonstrating the value behavior, the subject can select from among differing values on specified topics and may demonstrate a high degree of commitment, conviction, or loyalty to the accepted value.</td>
<td>Consider Display Examine Express Insist Join Participate Persist Practice Pursue Qualify Seek Specify Support Test Undertake Volunteer Weigh Adapt Analyze Compare Contrast Criticize Deduce Demonstrate Designate Design Determine Diagnose</td>
<td>The nurse will voluntarily participate in a hospital-sponsored benefit to raise funds for researching dementia in frail elderly.</td>
<td>The nurse volunteers to participate in the benefit and supports the work s/he chooses to undertake.</td>
</tr>
<tr>
<td>Organization: measures reflect that the subject is able to classify a value concept by (1) determining, analyzing, comparing its characteristics, and (2) placing all previously classified values into a harmonious and orderly relationship, thus building a personal value system.</td>
<td></td>
<td>The nurse will organize a community-based support group for families of frail elderly with dementia and schedule time weekly to participate in its implementation.</td>
<td>The nurse organizes the group and schedules time each week to be involved.</td>
</tr>
<tr>
<td>Characterization by a Value or Value Complex: measures indicate the subject is able to respond to the complex world and environment about him/her in a consistent, predictable, and comprehensible manner.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gather Identify Investigate Order Organize Propose Construct Design Develop Evaluate Formulate Plan Revise Synthesize</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nurse will solve problems regarding staff fear or unwillingness to care for the patient with dementia regarding patient consequences rather than rigid principles or emotions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The nurse is consistent in solving problems in terms of desired outcomes rather than rigid principles or emotions.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As a subject proceeds from early to late phases, the performance of the skill becomes progressively more automatic and more accurate, and demands less concerted effort on the part of the subject, allowing attention to be given to other activities concurrently.

From the tables it should be apparent that the use of taxonomies in explicating and measuring objectives provides several advantages. A critical aspect of any behavioral objective is the word selected to indicate expected behavior. A behavioral term by definition is one that is observable and measurable (i.e., behavior refers to any action on the part of an individual that can be seen, felt, or heard by another person). Cognitive and affective objectives, although they are concerned with thinking and feeling, which are not directly observable, are inferred from psychomotor or behavioral acts. In reality, the same behavioral term can be seen, felt, or heard differently by different people. Similarly, since it is impossible to measure every action inherent in a given behavior, different people frequently define the critical behavior to be observed, using a given objective, quite differently. When taxonomies are employed, action

### TABLE 4.3  Fitts’s Phases of Complex Skill Development

**Objective**: The newly employed acute care nurse performs a physical assessment of a newly admitted critically ill adult patient.

<table>
<thead>
<tr>
<th>Phase of Development</th>
<th>Measurement</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cognitive: measures indicate that the subject tends to intellectualize the skill and makes frequent errors in performing it.</td>
<td>Observation of nurse’s performance reflects preoccupation with the exam and attention to proceeding to the outline in the procedure manual even when deviation in the sequence of events appears appropriate. Interpersonal interaction with the patient is limited and the nurse makes frequent eye contact with the observer each time an action is taken.</td>
<td>Phase 1 subjects dwell on the procedure and plans that guide the execution of the skill.</td>
</tr>
<tr>
<td>2. Fixation: measures indicate a tendency to practice correct behavior patterns; errors are fewer than in phase 1 and decrease with practice.</td>
<td>Observation of the nurse’s performance reflects less preoccupation with skills and the observer, fewer errors are noted, and a pattern for proceeding with the assessment has emerged.</td>
<td>Phase 2 practice of the skill is important and errors decrease with practice.</td>
</tr>
<tr>
<td>3. Autonomous: measures indicate increasing speed of performance, errors occur infrequently, subject resists stress and interference from outside activities, and is able to perform other activities concurrently.</td>
<td>Observation of the nurse’s performance reflects few errors, a pattern of performance that is less rigid than during stages 1 and 2, interpersonal communication between patient and provider is high, and elements of the health history are considered and elicited in conjunction with the physical assessment.</td>
<td>Phase 3 skill becomes automatic and attention focuses on other aspects of the patient.</td>
</tr>
</tbody>
</table>
verbs and critical behaviors to be observed are specified, hence decreasing the possibility that the behaviors will be interpreted differently and increasing the probability that the resulting measure will be reliable and valid.

A measurement must match the level of respondent performance stated in the behavioral objective; that is, a performance verb at the application level of the cognitive taxonomy must be assessed by a cognitive item requiring the same level of performance. Any discrepancy between the stated objective and the performance required by the instrument or measurement device will result in decreased reliability and validity of the measurement process. For example, if the objective for the measurement is to ascertain the ability of practicing nurses to apply gerontological content in their work with aging clients (application level of Bloom's) and if the measure constructed to assess the objective simply requires a statement in their own words of some principles important to the care of the gerontological patient (comprehension level of the taxonomy), the outcomes of the measurement are not valid, in that this tool does not measure what is intended. When taxonomies are employed, this type of discrepancy between the level of objective and level of performance measured is less apt to occur than when taxonomies are not employed.

An example of the use of taxonomies can be found in Sheetz (2001) who employed Bloom's (1956) taxonomy of the cognitive domain, Krathwohl et al.'s (1964) taxonomy of the affective domain, and Harrow's (1972) taxonomy of the psychomotor domain in the development of a rating scale to measure students' clinical competence.

**Blueprinting**

Given a set of objectives reflecting the process or outcomes to be assessed by the measure and a content outline representative of the domain of interest, the next step is to develop a blueprint to establish the specific scope and emphasis of the measure. Table 4.4 illustrates a blueprint for a measure to assess a patient's compliance with a discharge plan. The four major content areas to be assessed appear as column headings across the top of the table and critical behaviors to be measured are listed on the left-hand side of the table as row headings. Each intersection or cell thus represents a particular content-objective pairing, and values in each cell reflect the actual number of each type of item to be included in the measure. Hence, from the table it can be seen that three items will be constructed to assess the content-objective pairing patient knowledge of the contents of the discharge plan/general health knowledge.

The scope of the measure is defined by the cells, which are reflective of the domain of items to be measured, and the emphasis of the measure and/or relative importance of each content

<table>
<thead>
<tr>
<th>Objectives</th>
<th>General Health Knowledge</th>
<th>Medications</th>
<th>Activities of Daily Living</th>
<th>Nutrition</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascertain patient knowledge of the contents of the discharge plan</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Determine patient attitudes toward the contents of the discharge plan</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Evaluate patient compliance with contents of the discharge plan</td>
<td>4</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>60</td>
</tr>
</tbody>
</table>
behavior pairing is ascertained by examining the numbers in the cells. From the blueprint, one can readily tell the topics about which questions will be asked, the types of critical behaviors subjects will be required to demonstrate, and what is relatively important and unimportant to the constructor. Tables 4.5 and 4.6 present additional examples of blueprints that vary slightly in format. In Table 4.5, the blueprint for the knowledge subscale of the measure of compliance with the discharge plan is defined by topic area and objective, but in this case, rather than listing the critical behaviors to be assessed, the performance expectations are specified using the levels of Bloom’s taxonomy. In Table 4.6, objectives are defined in terms of the steps of the nursing process, content is defined by components of the nursing conceptual model used, and numbers in the cells represent percentages of each type of item to be included rather than the actual number of items.

**TABLE 4.5** Blueprint for the Knowledge Subscale of a Measure of Compliance With the Discharge Plan

<table>
<thead>
<tr>
<th>Content</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>General health knowledge</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Medications</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Activities of daily living</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Nutrition</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td>18</td>
</tr>
</tbody>
</table>

**TABLE 4.6** Blueprint for a Measure of Clinical Performance

<table>
<thead>
<tr>
<th>(King’s Model)*</th>
<th>I Assessment</th>
<th>II Planning</th>
<th>III Implementation</th>
<th>IV Evaluation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Nurse Variables</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>20%</td>
</tr>
<tr>
<td>a. perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. goals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. expectations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Patient Variables</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
<td>10%</td>
<td>60%</td>
</tr>
<tr>
<td>a. perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. goals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. expectations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. abilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Situational Variables</td>
<td>10%</td>
<td>5%</td>
<td>2%</td>
<td>3%</td>
<td>20%</td>
</tr>
<tr>
<td>a. structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. goals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. physical resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. economic resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. climate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25%</td>
<td>20%</td>
<td>37%</td>
<td>18%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Given the blueprint, the number (or percentage) of items prescribed in each cell would be constructed. Content validity (discussed in more detail in Chapter 6) could then be assessed by presenting content experts with the blueprint and the test and having them judge (1) the adequacy of the measure as reflected in the blueprint—that is, whether the domain is adequately represented—to ascertain that the most appropriate elements are being assessed; (2) the fairness of the measure—whether it gives unfair advantage to some subjects over others; and (3) the fit of the method to the blueprint from which it was derived. Additional examples of blueprinting can be found in Toth (2003), Jalowiec (2003), and Jones (2003).

**Constructing the Measure**

The type of measure to be employed is a function of the conceptual model and subsequent operational definition of key variables to be measured. If, for example, one conceptualizes job satisfaction as a perceptual phenomenon, the measurement will require use of an affective or typical performance instrument. If, on the other hand, job satisfaction is conceptually defined as a cognitive phenomenon dependent upon one's understanding and comprehension of factors in the work setting, a maximum performance or cognitive measure is appropriate. The essential characteristics of the types of measures are presented in Chapter 1, and instrumentation and data collection methods are discussed in detail in Chapters 7–26 and will not be given further attention here. Regardless of type, every measure is composed of three components: (1) directions for administration; (2) a set of items; (3) directions for obtaining and interpreting scores.

**Administration**

Clemans (1971) presents a comprehensive set of considerations to be made in preparing instructions for the administration of a measure. More specifically, he advocates the inclusion of the following information:

1. A description of who should administer the measure
   - A statement of eligibility
   - A list of essential characteristics
   - A list of duties
2. Directions for those who administer the measure
   - A statement of the purposes for the measure
   - Amount of time needed for administration
   - A statement reflecting the importance of adhering to directions
   - Specifications for the physical environment
   - A description of how material will be received and stored
   - Specifications for maintaining security
   - Provisions for supplementary materials needed
   - Recommendations for response to subjects’ questions
   - Instructions for handling defective materials
   - Procedures to follow when distributing the measure
   - A schedule for administration
   - Directions for collection of completed measures
   - Specifications for the preparation of special reports (e.g., irregularity reports)
   - Instructions for the delivery and/or preparation of completed measures for scoring
   - Directions for the return or disposal of materials
3. Directions for respondents
   - A statement regarding information to be given to subjects prior to the data collection session (e.g., materials to be brought along and procedures for how, when, and where data will be collected)
   - Instructions regarding completion of the measure, including a request for cooperation, directions to be followed in completing each item type, and directions for when and how to record answers
4. Directions for users of results
   - Suggestions for use of results
   - Instructions for dissemination of results (p. 196)
The importance of providing this information as an essential component of any measure cannot be overemphasized. Errors in administration are an important source of measurement error, and their probability of occurrence is greatly increased when directions for administration are not communicated clearly and explicitly in writing. Those readers who desire further specifics on the topic of administration procedures will find Clemans's work extremely useful. Readers interested in examples of directions for administration are referred to Marsh (2003), Delorio and Yeager (2003), Weinert (2003), and Emerson (2001).

**Items**

Within the context of a given type of measure, there is a variety of specific item formats available, each with its own unique advantages and disadvantages in light of the specific purposes for, and characteristics of, the setting in which measurement is to occur. Most important, an item should be selected because it elicits the intended outcome, that is, the behavior specified by the objective(s). For example, if the objective of a measurement is to assess clinical performance, the item format should elicit performance by respondents in the clinical area. A written multiple-choice test or attitude survey would not be likely to elicit clinical performance on the part of subjects, and hence would not be an appropriate item format for this measurement objective. Similarly, if a cognitive measure derived from behavioral objectives at the synthesis level of Bloom's taxonomy was composed of a set of true-false items, the behavior specified by the objective and the outcome elicited would be incongruent; that is, at the synthesis level respondents are required to construct or create something new, while true-false items only require them to select one of two options on the basis of recall or comprehension.

Conditions surrounding the measurement will also establish parameters for what is an appropriate and useful item format. For example, if a measure is to be administered to diabetics with impaired vision, item formats requiring the reading of lengthy passages would be impractical. Similarly, measures to be administered to patients in acute care settings should be for the most part short, easily administered and understood so as to avoid fatigue on the part of respondents and/or to avoid conflict with ongoing care activities. The important point is that the personal characteristics of the respondents such as ability to read, ability to perform physical skills, computational skills, and communication skills must be considered, and an item format must be selected that enhances their ability to respond rather than one that hinders some or all of the subjects.

Other factors in the measurement setting are also important in selecting the format. If an instrument is to be administered by individuals without training or experience in measurement, or if it is to be employed by a variety of different people, the format should be selected with an eye to easy administration. For example, an instrument employing only one item format would be likely to require less time and less complex directions with less probability of being misinterpreted than one employing a number of different item formats. If tables or other illustrations are to be used in the tool, resources should be available for preparing them correctly and to scale; that is, incorrectly or inadequately prepared illustrative materials will increase measurement error, reduce reliability and validity, and decrease the subjects’ motivation to respond. If space is limited or reproduction of the tool is apt to be problematic, items requiring lengthy explanations or repetitions of rating scales or other content on each page of the tool are impractical. If scoring is to be undertaken by a few individuals without the advantage of computers, an item format that is automatic and requires little or no judgment on the part of the scorer is indicated, for example, multiple choice or short answers. When computer scoring is employed, attention should be paid to requirements imposed by available computer software programs.

There are as many different sets of conditions to be considered as there are varied measurement settings. For this reason, only a few of the more frequently overlooked have been included here. In all cases, it is essential that careful analysis of the measurement situation be made and an item format be selected that capitalizes on the factors inherent in a given situation. Examples of such accommodations can be found in Jansen...
and Keller (2003) and in Jalowiec (2003), who measured attitudinal demands in community-dwelling elders.

All items can be thought of as on a continuum ranging from objective to subjective. *Objective items*—those allowing little or no latitude in response and hence requiring no judgment in scoring—are often referred to as *selection-type items*.

**Examples of selection-type formats** are true-false, matching, multiple choice, and scaled response. These items are so named because they require the subjects to choose their responses from a set of options presented to them. Table 4.7 illustrates some of the more common varieties of selection-type items. The multiple-choice format is one of the most objective available and for this reason is employed widely, especially for cognitive tools. The construction of multiple-choice items is discussed in more detail in Chapter 19.

*Subjective items* allow more latitude on the part of respondents in constructing their answer and therefore require more judgment on the part of the scorers. *Supply-type items* are so named because they require the subject to respond by supplying words, statements, numbers, or symbols to best characterize subjective items. The more frequently encountered supply-type item formats are exemplified in Table 4.8.

When a norm-referenced measure is employed, one designs items that are likely to make fine distinctions between respondents with differing levels of the attribute being measured, so that the distribution of responses to the measure will resemble a normal curve with a few high and low scores and with most scores falling in the middle range. Hence, one wants to avoid items that are too easy or too difficult for most respondents.

The *difficulty* of an item is defined as the percentage of respondents answering that item correctly or appropriately. In other words, if a cognitive test item is answered correctly by 40 of 100 respondents, the item has a difficulty level of 40% or 0.40. Hence, difficulty may vary from 0, in the case where no one responds correctly to 1.00, in the case where all respondents respond correctly. When affective or performance measures are employed, the term “appropriately” or “as expected” is more meaningful than the term “correct”; that is, if subjects’ responses are to be compared with a well-defined referent group (e.g., first-level baccalaureate nursing students), one might define what is appropriate on a performance measure on the basis of the behavior one would expect to see in the comparison or referent group. Similarly, if one is measuring attitudes toward gerontology patients, one might define as appropriate those responses that reflect behaviors deemed acceptable or desirable by program planners. Item difficulties for norm-referenced measures as a whole usually range from 0.30 to 0.70 (Martuza, 1977, p. 179).

Several factors come into play in determining the optimum difficulty level for a given item, for example, the nature of the trait being measured, the item’s correlation with other items on the instrument, and the specific objectives for the measure.

Tinkelman (1971) suggested the following guidelines for determining item difficulty level:

1. In a situation in which the measure is designed to differentiate subjects’ competence in a field, there is no standard of passing or failing, scores are interpreted as percentile norms or other measures of relative standing in a group, and intercorrelations among items are low. A 0.50 level of average item difficulty and a narrow range of difficulty among items are desirable in order to increase the variance of scores and increase reliability.

2. In situations in which guessing may come into play, the optimum item difficulty level should be such that the proportion of right or appropriate answers by the average subject would be 0.50 after correction for chance; that is, the average item difficulty level before correction for chance would be halfway between the chance probability of success and 1.00 (Lord, 1952). For example, in a 4 option multiple-choice test, the chance probability of success is 0.25. The difficulty level midway between 0.25 and 1.00 would be 0.65.

3. In general, the measure’s reliability and the variance of scores increase as the variance of the item difficulties decreases. Thus, it is generally desirable that the items on a
### TABLE 4.7 Selection-Type Item Formats

<table>
<thead>
<tr>
<th>Format/Examples</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternate-Choice</strong></td>
<td>Consists of a statement to be responded to by selecting from one of two options. Format provides for presentation of a large number of items in relatively short periods of time, therefore allowing broader, more representative sampling from the domain. There is a tendency, however, to select materials out of context, resulting in ambiguity and/or measurement of trivial.</td>
</tr>
<tr>
<td><strong>1. True-False</strong></td>
<td>Consists of a declarative state that is True (T) or False (F). I usually feel in control of my life. T or F Moderate excesses of digitalis cause premature heartbeats and vomiting. T or F</td>
</tr>
</tbody>
</table>
| **2. Right-Wrong** | Consists of a statement, question, equation, or the like that is identified as Right (R) or Wrong (W) by the respondent. The formula for determining the odds of an event is: \[
\text{Odds ratio} = \frac{\text{probability of occurrence}}{\text{probability of nonoccurrence}}
\] R or W The turnover among nurses in this hospital is largely the result of their feeling undervalued by the administration. R or W |
| **3. Yes-No** | Consists of a direct question to be answered by a Yes (Y) or No (N). It is more appropriate to serve shredded wheat than Wheatena for breakfast to a patient on a 250 mg sodium diet? Y or N It is more desirable for a faculty member in this institution to spend time conducting research than consulting in that person’s specialty area? Y or N |
| **4. Cluster** | Consists of an incomplete statement with suggested completions, each of which is to be judged True (T) or False (F). Pulse pressure is the: T or F 1. difference between venous and systolic pressure 2. difference between arterial and venous pressure 3. difference between diastolic and systolic pressure 4. pressure and expansion of the artery as blood flows toward the capillaries T or F 5. all of the above T or F |
| **5. Correction** | Combines selection and supply by presenting a statement and directing the respondent to correct false statements by substituting appropriate word(s). Lightning usually occurs approximately 4 weeks before delivery. I am satisfied with policies in this college of health sciences. |
| **Matching** | Consists of a list of words or statements, a list of responses, and directions for matching responses to words or statements. Imperfect and association type are preferred because they allow assessments of higher-level behaviors. Because homogeneity is paramount in writing such items, the desire for homogeneity when heterogeneity is more appropriate may result in a shift in emphasis away from that desired. |
| **1. Perfect matching** | Each response matches one and only one word or statement. On the line before each poison, place the number of the symptoms that usually characterize it. |
TABLE 4.7 Selection-Type Item Formats (Continued)

<table>
<thead>
<tr>
<th>Format/Examples</th>
<th>Poisons</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. acids</td>
<td>1. diarrhea, garlic breath</td>
</tr>
<tr>
<td></td>
<td>b. rat poisons</td>
<td>2. restlessness, rapid pulse</td>
</tr>
<tr>
<td></td>
<td>c. cocaine</td>
<td>3. drowsiness, flushed cheeks</td>
</tr>
<tr>
<td></td>
<td>d. carbon monoxide</td>
<td>4. dyspnea, cyanosis</td>
</tr>
</tbody>
</table>

2. Imperfect matching

Some responses do not match any of the words or statements.

Match each term with its definition:

- mode 1. score that separates upper 50% of scores in the distribution from the lower 50% of the scores
- mean 2. score obtained by the largest number of respondents
- median 3. largest number of respondents selecting a given score
- 4. sum of scores in a distribution divided by the total number of scores
- 5. the average

3. Statement classification

Requires respondent to use higher-level mental operations such as analysis, evaluation.

Judge the effects of the nurse’s intervention on the patient’s physical comfort in each of the numbered situations using the following:

a. Nursing intervention would tend to reduce the patient’s physical comfort.

b. Nursing intervention would tend to increase the patient’s physical comfort.

c. Nursing intervention would tend to have little or no effect on the patient’s physical comfort.

1. A primigravida in the first stages of labor is encouraged by the nurse to walk around the corridors.

2. As labor progresses, the nurse remains with the primigravida, directing her attention to the fact that labor is progressing as expected.

3. As labor progresses, the nurse teaches the patient various breathing and relaxing techniques.

4. The nurse assesses and records the frequency, duration, and intensity of the contractions at regular intervals.

5. The nurse encourages the patient to void at regular intervals.

Multiple Choice

Components of a multiple choice item are: (1) stem—which is an introductory statement or question; and (2) responses or suggested answers. Examples of the varied types of multiple choice items follow.

1. Correct answer

Items that require or permit a correct answer are those that eliminate the need for the respondent to make a judgment regarding the correctness of his/her response, i.e., matters of fact provide a suitable basis for such items.

The basic service unit in the administration of public health is:

a. the federal government

b. the state health department

c. the local health department

d. the public health nurse

2. Best answer

For many of the important questions that need to be asked, it is impossible to state an absolutely correct answer within the reasonable limits of a
Table 4.7 Selection-Type Item Formats (Continued)

<table>
<thead>
<tr>
<th>Format/Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>multiple-choice item. Even if space limitations were not a factor, two experts would probably not agree on the precise wording of the best answer. The use of this type of item, which has one best answer, permits the item writer to ask more significant questions and frees the writer from the responsibility of stating a correct answer so precisely that all authorities would agree that the particular wording used was the best possible wording.</td>
</tr>
<tr>
<td>The primary responsibility of the instructor in health services is to:</td>
</tr>
<tr>
<td>a. provide an emotional and social environment that adds a wholesome and healthful tone to the child’s school day</td>
</tr>
<tr>
<td>b. provide emergency or first aid care when a child becomes ill or injured in school</td>
</tr>
<tr>
<td>c. provide up-to-date material about health as part of the curriculum</td>
</tr>
<tr>
<td>d. screen for abnormalities and sickness and record findings</td>
</tr>
<tr>
<td>3. Based on opinion The responses to this type of question represent generalizations on the basis of literature written by the advocates/experts relative to a preferred approach to the topic. No authoritative sanction for one particular generalization is likely to be available, yet respondents familiar with this literature would probably agree on a best answer to this item.</td>
</tr>
<tr>
<td>Advocates of the specialized approach to school nursing point out that:</td>
</tr>
<tr>
<td>a. the health of a child cannot be separated from that of the family and community as a whole</td>
</tr>
<tr>
<td>b. specialized nursing care for the child cannot be separated from that for the family and community as a whole</td>
</tr>
<tr>
<td>c. a specialized program offers greater diversity and challenge to a well-prepared community health nurse</td>
</tr>
<tr>
<td>d. specialized nursing in the school allows the nurse to function without the disadvantages of a dual channel of administrative responsibility</td>
</tr>
<tr>
<td>4. Novel question Requiring the respondent to predict what would happen under certain circumstances is a good way of measuring understanding of the principle involved.</td>
</tr>
<tr>
<td>The problem of air pollution is most likely to be reduced in the future by which of the following:</td>
</tr>
<tr>
<td>a. urban population will wear air-purifying equipment</td>
</tr>
<tr>
<td>b. cities will be enclosed to facilitate air purification</td>
</tr>
<tr>
<td>c. development of hybrid cars that will not pollute the air</td>
</tr>
<tr>
<td>d. use of nonpollutant fuels</td>
</tr>
<tr>
<td>5. Selective recall Given an item that had not been the specific object of instruction, it will function to assess learners’ ability to recall a variety of information about the content area, to select that which is relevant, and to base a generalization upon it.</td>
</tr>
<tr>
<td>The U.S. Public Health Service was reorganized in 1966 to:</td>
</tr>
<tr>
<td>a. include the UNICEF program</td>
</tr>
<tr>
<td>b. include the Agency of International Development</td>
</tr>
<tr>
<td>c. combine the Voluntary Agency Services with the official ones</td>
</tr>
<tr>
<td>d. provide leadership in control of disease and environmental hazards and manpower development</td>
</tr>
<tr>
<td>6. Descriptive response Inexperienced items writers tend to seek items having very short responses. This can seriously limit the significance and scope of the achievements measured. In an item measuring the ability to define an important term, it is usually better to place the term to be defined in the item stem and to use definitions or identifications as the responses. The same principle should be applied to other items, i.e., one-word responses need not be avoided altogether, but they should seldom be prominent in any measure.</td>
</tr>
</tbody>
</table>

(Continued)
**TABLE 4.7 Selection-Type Item Formats (Continued)**

<table>
<thead>
<tr>
<th>Format/Examples</th>
<th>The child's socialization may be defined as:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a. a behavioral process in which behavior conforms to the social practices of family and extra family groups</td>
</tr>
<tr>
<td></td>
<td>b. a process of developing an effective set of performances characteristic of self-control</td>
</tr>
<tr>
<td></td>
<td>c. the genetically determined or hereditary mechanisms that determine the individual's physical trait</td>
</tr>
<tr>
<td></td>
<td>d. all of the above</td>
</tr>
</tbody>
</table>

7. Combined response

A difficulty with four-option multiple choice items is securing four good alternatives. One solution is to combine questions with two alternatives each to give the necessary four alternatives.

A school community safety program should be concerned with:

a. teaching children how to avoid accidents

b. teaching adults and children to eliminate physical hazards that endanger them

c. eliminating physical hazards that endanger children and teaching them to avoid accidents

d. teaching children and adults to avoid accidents and eliminating physical hazards that endanger them

8. Combined question and explanation

This is a variation of the item type in which essentially two or more alternatives each are combined to give four alternatives.

When was the World Health Organization created and why?

a. 1954 to prevent the spread of disease from one continent to another

b. 1948 to achieve international cooperation for better health throughout the world

c. 1945 to structure health privileges of all nations

d. 1948 to provide for a liberated population and aid in the relief of suffering

9. Introductory sentence

The use of a separate sentence frequently adds to the clarity of the item stem if it is necessary to present background information as well as to ask the question itself. Combining these two elements into a single question-sentence probably would make it too complex.

When a group is working as a health care team, overlapping of activities may occur. What is essential if this is to be prevented?

a. auxiliaries will work within a fairly circumscribed field

b. the public health nurse will assume responsibility for all phases of the nursing team's activities

c. the functions of all personnel will be defined

d. maximum skills of each member will be used

10. Necessary qualification

If the following question were asked only about environmental health program personnel in general without qualifying urban personnel, it would be difficult for the respondent to give a firm answer to the question, given the existing differences between the environmental health programs in other than urban areas, i.e., county, state, federal.

Generally speaking, the environmental health program personnel in urban centers are:

a. persons with professional training in civil or sanitary engineering

b. sanitary inspectors or nonengineering personnel with indoctrination and orientation by the health department

c. public health engineers whose training embraces the public health aspect of both sanitary engineering and sanitary inspection

d. all of the above

(Continued)
### TABLE 4.7 Selection-Type Item Formats (Continued)

<table>
<thead>
<tr>
<th>Format/Examples</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. None of the above and/or all of the above as options</td>
<td>Whenever each of the responses can be judged unequivocally as correct or incorrect in response to the question posed in the item stem, it is appropriate to use none of the above as a response. It would be appropriate to use all of the above in a similar situation in which more than one perfectly correct answer is possible.</td>
</tr>
<tr>
<td></td>
<td>A necessary requirement for receiving funds under the Comprehensive Health Planning Act of 1966 is that:</td>
</tr>
<tr>
<td></td>
<td>a. state boards of health must have at least 10% lay representation</td>
</tr>
<tr>
<td></td>
<td>b. the council responsible for developing a comprehensive health plan for the state must have 50% consumer participation</td>
</tr>
<tr>
<td></td>
<td>c. health and welfare councils, whether or not actively involved in health planning on the state level, must have at least 25% lay representation</td>
</tr>
<tr>
<td></td>
<td>d. none of the above</td>
</tr>
<tr>
<td>12. True statements as distractors</td>
<td>It is not necessary for the incorrect options to a test item to be themselves incorrect statements. They simply need to be incorrect answers to the stem question. Judgments concerning the relevance of knowledge may be as important as judgments concerning its truth. This is particularly useful as a technique for testing achievement that is sometimes thought to be testable only by using essay measures.</td>
</tr>
<tr>
<td></td>
<td>The general purpose of parent education programs is to:</td>
</tr>
<tr>
<td></td>
<td>a. teach parents information they need to know throughout their children’s changing developmental stages</td>
</tr>
<tr>
<td></td>
<td>b. help parents reinforce their understanding and strengths in regard to themselves and their children</td>
</tr>
<tr>
<td></td>
<td>c. develop attitudes of healthy family life in parents of young children</td>
</tr>
<tr>
<td></td>
<td>d. cover a wider range of subject matter, format, and method than is possible on an individual basis</td>
</tr>
<tr>
<td>13. Stereotypes in distractors</td>
<td>Phrases such as operant behavior and homeostasis, which a respondent may have heard without understanding, provide excellent distractors at an elementary level of discrimination.</td>
</tr>
<tr>
<td></td>
<td>The particular process of interaction between the organism and its environment that results in a specifiable change in both is referred to as:</td>
</tr>
<tr>
<td></td>
<td>a. homeostasis</td>
</tr>
<tr>
<td></td>
<td>b. human behavior</td>
</tr>
<tr>
<td></td>
<td>c. operant behavior</td>
</tr>
<tr>
<td></td>
<td>d. developmental dynamism</td>
</tr>
<tr>
<td>14. Heterogeneous responses</td>
<td>When responses to an item vary widely, because of their wide differences, only an introductory knowledge of the content is required for a successful response.</td>
</tr>
<tr>
<td></td>
<td>The index of economic welfare is:</td>
</tr>
<tr>
<td></td>
<td>a. square feet of housing space</td>
</tr>
<tr>
<td></td>
<td>b. per capita national income</td>
</tr>
<tr>
<td></td>
<td>c. rate of growth of industrialization</td>
</tr>
<tr>
<td></td>
<td>d. morbidity and mortality rates</td>
</tr>
<tr>
<td>15. Homogeneous responses (harder item)</td>
<td>Homogeneity of the responses to an item requires a considerably high level of knowledge of the content and thus, makes the item difficult in comparison to an item using heterogeneous options.</td>
</tr>
<tr>
<td></td>
<td>Funds for occupational health programs were allocated to state and local health departments as a result of:</td>
</tr>
<tr>
<td></td>
<td>a. Social Security Act</td>
</tr>
<tr>
<td></td>
<td>b. Clean Air Act</td>
</tr>
<tr>
<td></td>
<td>c. Community Health Centers Act</td>
</tr>
<tr>
<td></td>
<td>d. Occupational Health Act</td>
</tr>
<tr>
<td>Format/Examples</td>
<td>Description</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>16. Multiple clues (easier item)</td>
<td>When the values of two variables fitting the specification in the item stem are used, the result is a fairly easy question. That is, the respondent need only know one of the values or know one in each of the distractors to respond successfully. The amount estimated to eliminate poverty in the U.S. is said to be which of the following: a. 2% of the gross national product and 1/5 of the cost of national defense b. 3% of the gross national product and 1/6 of the cost of national defense c. 4% of the gross national product and 1/4 of the cost of national defense d. 5% of the gross national product and 1/3 of the cost of national defense</td>
</tr>
<tr>
<td><strong>Scaled Response</strong></td>
<td>A statement or question is presented and the respondents answer by marking the area on the scale that represents their answer.</td>
</tr>
<tr>
<td>1. Number anchors</td>
<td>The use of numerical anchors facilitates analysis of data by computer as well as serves to remind respondents of the meaning of the scale steps. Rate your level of satisfaction with your present job using the following scale:</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td></td>
<td>Not Satisfied</td>
</tr>
<tr>
<td>2. Percentage anchors</td>
<td>Using the scale: A – None of the time B – 1–25% of the time C – 26–50% of the time D – 51–75% of the time E – 76–99% of the time F – All of the time</td>
</tr>
<tr>
<td></td>
<td>Rate each of the following actions performed by the nurse you observe administering medications on Unit B:</td>
</tr>
<tr>
<td></td>
<td>Rating</td>
</tr>
<tr>
<td></td>
<td>1. washes hands prior to administering medications</td>
</tr>
<tr>
<td></td>
<td>2. selects correct medication to be given at designated time</td>
</tr>
<tr>
<td></td>
<td>3. checks patient's ID prior to administering medication</td>
</tr>
<tr>
<td></td>
<td>4. stays with patient until medication taken</td>
</tr>
<tr>
<td></td>
<td>5. records administration of medication correctly</td>
</tr>
<tr>
<td>3. Degrees of agreement/disagreement</td>
<td>Indicate your degree of agreement with the following statement: Antagonistic behavior on the part of a patient indicates a need on the patient's part for additional attention and time from the nurse.</td>
</tr>
<tr>
<td></td>
<td>1  2  3  4  5  6</td>
</tr>
<tr>
<td></td>
<td>Completely Agree</td>
</tr>
<tr>
<td>4. Adjectives</td>
<td>Using the scale: A. No importance B. Little importance C. Some importance D. Importance E. A great deal of importance</td>
</tr>
<tr>
<td></td>
<td>Rate the importance you place on each of the following faculty activities:</td>
</tr>
<tr>
<td></td>
<td>Conducting clinical research</td>
</tr>
<tr>
<td></td>
<td>Consulting with nursing staff</td>
</tr>
<tr>
<td></td>
<td>Teaching students</td>
</tr>
</tbody>
</table>
TABLE 4.7 Selection-Type Item Formats (Continued)

Format/Examples

_____ practicing clinically
_____ pursuing professional development activities

5. Actual behavior

Observe the student’s intervening with the patients on Unit C and then check the behavior that best describes what you observed.

_____ Did not adapt planned intervention to meet changes in patient situation.
_____ Adapted implementation with guidance to accommodate changes in patient situation.
_____ Adapted implementation independently to accommodate changes in patient situation.
_____ Implemented independently a preplanned alternate intervention to accommodate changes in patient situation.

6. Products

Here are four care plans for confused frail elderly patients living in a long-term care facility. Indicate the one you believe is most reflective of accepted indicators of quality care for this patient population.

A. Care Plan X
B. Care Plan Y
C. Care Plan Z
D. Care Plan O

Context-Dependent

In this case, the item has meaning to the subject only in relation to other material presented, e.g., scenario, picture graph, table. Visual presentation of material, especially pictures, permits the presentation of a problem or situation in a very clear and simple manner, thus eliminating confusion due to reading or inability to adequately describe a phenomenon.

Parents are given a series of pictures portraying behaviors usually observed in children of 2–3 years of age and asked to identify those observed in their own children.

Interpretation

Consists of introductory material followed by a series of questions calling for various interpretations, thus provides for measuring ability to interpret and evaluate materials. This type of item allows one to ask meaningful questions on relatively complex topics. Disadvantages stem from the fact that such items are time-consuming to administer and difficult to construct.

<table>
<thead>
<tr>
<th>ANOVA Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
</tr>
<tr>
<td>Between groups</td>
</tr>
<tr>
<td>Within groups</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

1. How many treatments were studied in the above table?
   a. 2
   b. 3
   c. 4
   d. cannot answer from the table

2. How many subjects participated in the study?
   a. 84
   b. 92
   c. 93
   d. 94

TABLE 4.8 Supply-Type Item Formats

<table>
<thead>
<tr>
<th>Format</th>
<th>Example</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short Answer</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Question</td>
<td>What term is used to designate that portion of the infant’s body that lies nearest the internal os? (presentation)</td>
<td>For cognitive tests this format tends to measure only facts. The respondents are presented with a question or incomplete statement written in such a way that it is clear to respondents what is expected of them, followed by a blank space in which they write what is called for by the directions. Preferably short answer questions should require an answer that is a single word, symbol, or formula. See Wesman (1971).</td>
</tr>
<tr>
<td>2. Completion</td>
<td>Normal labor usually is divided into three stages: 1) ______, 2) ______, 3) ______. (dilating, expulsive, placental)</td>
<td></td>
</tr>
<tr>
<td>3. Identification/Association</td>
<td>After each event indicate the stages of labor during which it usually occurs. a. effacement __________ b. dilatation of the cervix __________ c. fetal descent __________ d. placental separation __________</td>
<td></td>
</tr>
<tr>
<td><strong>Essay</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Multiple aspects of a single topic</td>
<td>An adolescent is being discharged from the hospital on insulin and a diabetic diet regimen. When you visit his/her home one week postdischarge: (a) what observations will you make; (b) what information will you seek to elicit from the patient and family and how; and (c) what type of evaluation will you expect to make on the basis of the observation and information you are able to obtain?</td>
<td>Essays lend themselves to measuring complex phenomena, especially the ability to organize and communicate information in an area of interest. Problems lie primarily in the areas of: (1) subjectivity in scoring that can be minimized if criteria for scoring are agreed upon prior to administration; (2) time required to respond; and (3) the limited number of questions that can be handled during a given administration, hence reducing the representativeness of the domain sampled. See Coffman (1971).</td>
</tr>
<tr>
<td>2. Independent question</td>
<td>Describe your philosophy of universal health care and the resulting implications it has for access and patient care.</td>
<td></td>
</tr>
</tbody>
</table>

measure have a fairly narrow range of difficulty around the average difficulty level.

4. In the case of homogeneous measures (in which high intercorrelations exist between items) or in cases in which heterogeneous groups of subjects respond, a wider spread of difficulty is indicated.

5. In cases in which the purpose of the instrument is to serve a screening function, that is, to select a small percentage of the best, it should be a relatively difficult test for most subjects; if it is designed to screen out the weakest or least appropriate, it should be a relatively easy test for most respondents (pp. 67–69).

It should be noted that the determination of item difficulty levels occurs at the time the measure is designed and constructed, and then the expected is compared with empirical findings via item analysis procedures (which are discussed in Chapter 6).

Although the test blueprint specifies the number of items to be included in the measure during the planning stage, it is essential that test length be reconsidered during construction in light of
subsequent decisions made regarding administration and item format. Although generally the longer the test, the higher the probability of reliability and validity, there are situations in which length may become a liability. For example, if the setting in which the measure is to be given places time limits on administration, it may be necessary to reduce the number of items proportionally to accommodate the time limits. Equivalently, if the physical condition of the subject precludes lengthy testing periods, the number of items may need to be reduced or subdivided and then administered on more than one occasion. Equivalently, if the most appropriate item format is also one that is time-consuming and demanding, length may need to be traded for a format that better elicits the behavior to be assessed. The important point is that the ideal in terms of length may need to be compromised or modified because of conditions surrounding the measurement. When this occurs, it is important that the relative emphasis of the measurement be preserved by reducing the categories of items proportionally, according to the blueprint specifications.

**Scoring**

Generally, the more simple and direct the procedure used for obtaining raw scores for the norm-referenced measure, the better; that is, although a number of elaborate weighing schemes have been devised for assigning a raw score to a measure, it has been demonstrated empirically that the end result is usually consistent with that obtained by simply summing over items (Nunnally, 1967; Nunnally & Bernstein, 1994, pp. 75–82). For this reason, we recommend the use of summative scoring procedures, whenever it is appropriate, to obtain a total score or set of subscores for a measure.

To obtain a summative score, one assigns a score to each individual item according to a conceptual scheme and then sums over the individual item scores to obtain a total score. Usually, the conceptual scheme for assigning item scores derives from the conceptual model. If one designed a measure of faculty influence on nursing students’ preferences for practice, using a theory of personal influence, items would be constructed to measure key influence variables, and item responses would be constructed in such a manner that high scores represent more amenability to influence and low scores, less amenability. For example, in his theory of personal influence, Bidwell (1973) suggests a number of conditions under which the teachers’ interactions with students are more likely to influence students’ attitudes toward the content. One such condition is when the student perceives a direct positive relationship (i.e., a link) between the teachers’ attitudes and the content taught. If one presumes that teachers’ attitudes toward the content are reflected by their behavior in regard to it, then in operationalizing the theory one might choose to focus on the students’ perception of the link between the content taught by the clinical instructors and the instructors’ activities. More specifically, for illustrative purposes, suppose the key variable is defined as students’ perceptions of their clinical faculty member’s application of content to clinical performance. On the basis of the theory that the more students perceive a direct link—that is, the more they perceive that their faculty member applies the content taught to clinical performance—the more likely they are to be influenced. Students are asked to rate from 1 (not at all) to 6 (very much) the extent to which they think their clinical faculty member is involved in each of the following activities:

1. Publishing materials that relate the content taught to clinical performance
2. Speaking or in some manner presenting the content at professional meetings
3. Consulting in the content area with clinicians in the agency where the faculty member has students
4. Using the content in planning and/or developing programs for clinicians that deal with the practice discipline and/or patient care
5. Seeking continuing learning experiences that are relevant to the content taught
6. Seeking continuing learning experiences that are relevant to patient care
7. Participating in research regarding patient care and the content area
8. Using the content in providing direct patient care
Thus, the score for each of the eight items is derived in such a manner that the higher the number selected by the respondent, the more amenable to faculty influence the respondent is expected to be, on the basis of the theory underlying the tool’s development. Therefore, when individual item scores are summed to obtain a total score, scores can range from a low of 8 to a high of 48, with high scores reflecting students’ strong perception of a link between the faculty member’s content and clinical performance and, hence, being more amenable to faculty influence; low scores, on the contrary, indicate less of a link and therefore less amenability to influence. Since this is a norm-referenced measure, an individual respondent’s score, that is, the respondent’s amenability to faculty influence, would be interpreted on the basis of the scores of other respondents in the sample. To accomplish this, one would usually compute the arithmetic mean for the scores of all members of the sample and then use it to give specific meaning to the individual’s score, for example, whether an individual is more or less amenable than other members of the sample, or whether a subject’s score is above, below, or at the mean for the comparison group, which in this case is the sample. Published examples of tools whose scoring is conceptually derived as illustrated here may be found in Waltz and Jenkins (2001) and in Strickland and Dilorio (2003a, 2003b).

Hence, in the norm-referenced case, an individual’s score takes on meaning when compared with the scores of others in some well-defined referent group. The referent group might be other members of the same sample, or it might be subjects nationwide to whom the same measure was administered. In the latter case, the norm-referenced measure would most likely be a standardized test and the scores of the referent group would have been derived using an appropriate norming procedure for establishing national norms. Since standardized tests and norming procedures are discussed at length in Chapter 7, attention here will focus on those instances in which researchers construct norm-referenced measures for their own use rather than select and administer a standardized tool. It should be noted, however, that much of what is discussed here holds true in the case of standardized measures as well.

### TABLE 4.9 Ungrouped Frequency Distribution of Scores on a 10-Item Measure of Anxiety (n = 30)

<table>
<thead>
<tr>
<th>Score</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### TABLE 4.10 Grouped Frequency Distribution of Subjects’ Scores on a 150-Item Cognitive Measure (n = 30)

<table>
<thead>
<tr>
<th>Score</th>
<th>Number of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>150–141</td>
<td>1</td>
</tr>
<tr>
<td>140–131</td>
<td>2</td>
</tr>
<tr>
<td>130–121</td>
<td>1</td>
</tr>
<tr>
<td>120–111</td>
<td>4</td>
</tr>
<tr>
<td>110–101</td>
<td>3</td>
</tr>
<tr>
<td>100–91</td>
<td>1</td>
</tr>
<tr>
<td>90–81</td>
<td>1</td>
</tr>
<tr>
<td>80–71</td>
<td>5</td>
</tr>
<tr>
<td>70–61</td>
<td>3</td>
</tr>
<tr>
<td>60–51</td>
<td>3</td>
</tr>
<tr>
<td>50–41</td>
<td>1</td>
</tr>
<tr>
<td>40–31</td>
<td>2</td>
</tr>
<tr>
<td>30–21</td>
<td>1</td>
</tr>
<tr>
<td>20–11</td>
<td>1</td>
</tr>
<tr>
<td>10–0</td>
<td>1</td>
</tr>
</tbody>
</table>

To facilitate the interpretation of norm-referenced scores, the distribution of raw scores is tabulated using a table, graph, or polygon. In each case, each score is paired and its frequency of occurrence in the set of scores is noted. For example, if the same 10-item measure of ability was administered to 30 subjects, the distribution of their scores could be represented as shown in Table 4.9. This table is called an ungrouped frequency distribution and is useful because it clearly displays how many subjects obtained each score. When there is a wide range of scores in a distribution or a number of scores are not received by
subjects, it is more desirable and economical to group scores according to size in a **grouped frequency distribution**. Table 4.10 illustrates the use of a grouped frequency distribution to tabulate the scores of 30 subjects on a 100-item cognitive measure. Each group in Table 4.10 is called a score class, and the width of each score class interval in this case is 10. Although there are no fixed rules for when a grouped frequency distribution is preferred to an ungrouped one, Glass and Stanley (1970) suggest that the grouped frequency distribution be used when there is a large number of scores, 100 or more, and that it is usually best to construct not fewer than 12 nor more than 15 score classes. They state that with fewer than 12 classes one runs the risk of distorting the results, whereas with more than 15 classes the table produced is inconvenient to handle.

In lieu of a frequency distribution, one might opt to present scores using a graph such as that presented in Figure 4.4. The graph in Figure 4.4 is a histogram. It not only displays all the information in the frequency distribution, but it has the advantage of making information regarding the shape of the distribution more accessible to the reader (Glass & Stanley, 1970). The histogram is a series of columns, each having as its base one score or class, and as its height the frequency or number of subjects in that class. A column is centered on the midpoint of the score/class interval.

A **frequency polygon** is yet another way that one may choose to represent the scores. A polygon is very similar to a histogram. In the histogram, the top of each column is represented by a horizontal line, and the length of one score or class placed at the proper height represents the number of subjects in that class. In the polygon, a point is located above the midpoint of each score or class and at the height that represents the frequency at that score. These points are then joined by straight lines. Figure 4.5 illustrates a polygon for the data represented by the histogram in Figure 4.4. The main advantage of the polygon over the histogram is that it allows one to superimpose up to three distributions with a minimum of crossing of lines (Glass & Stanley, 1970). Thus, the polygon facilitates comparisons among distributions.

Standards for constructing tables, graphs, and polygons were first published in 1915 by Brinton and have changed little through the years. That report still covers most of the points required for the proper representation of data; thus the following rules are cited from it:

1. The general arrangements of a diagram should proceed from left to right.
2. The horizontal scale should usually read from left to right and the vertical scale from bottom to top.
3. Whenever practical, the vertical scale should be selected so that the zero line appears on the diagram.
4. In diagrams representing a series of observations, whenever possible the separate observations should be clearly indicated on the diagrams.
5. All lettering and figures on a diagram should be placed so they can be read easily from the base as the bottom, or from the right-hand edge of the diagram as the bottom.

6. The title of a diagram should be as clear and complete as possible. (pp. 790–797)

Additional information regarding the tabulating of data can be found in Walker and Durost (1936), Arkin and Colton (1936), Kelley (1947), or Grier and Foreman (1988). Summary statistics, described in Chapter 3, are then employed to facilitate interpretation of an individual’s score and to communicate information about the characteristics of the distribution of scores.

Since in norm-referenced measurement the meaning of an individual’s score is dependent upon how it compares with the scores of the other members of the referent group, it is necessary to obtain a measure of central tendency for the distribution of scores and then consider an individual’s performance in light of it. The mean of the distribution represented in Figure 4.5 is 5.3, the mode is 5, and the median is approximately 5.5. Hence, one knows that an individual with a score of 3 is below the mean, received an anxiety score lower than most members of the group, and had an anxiety score falling in the lower half of the score distribution. Furthermore, by determining the variance and standard deviation for the distribution, interpretation of the individual’s score can be enhanced by referring to how many standard deviations an individual’s score lies above or below the mean.

If a norm-referenced measure performs in the intended manner, the resulting distribution of scores ought to display a wide range, large variance, and a shape resembling that of a normal distribution. The normal distribution (Figure 4.6) is a symmetric distribution. Symmetric means the left half of the distribution is a mirror image of the right half. The normal curve will always be symmetric around its mean; it is bell-shaped, begins and ends near the baseline, but never quite touches it, and therefore is unbounded, meaning there is no beginning and no end. The normal curve is a mathematical construct first used as a model for distributions that closely approximate its characteristics, or would if a very large sample were used. The distributions of scores on the anxiety measure in Figures 4.4 and 4.5 do in fact resemble a normal curve, and their measures of central tendency illustrate another property; that is, in a normal distribution the mean, median, and mode are equal in value.

Because empirical distributions vary in terms of the extent to which they approximate the theoretical normal curve and because there are a number of normal curves, that is, as many different forms as there are combinations of different means and standard deviations, the use of raw scores for the interpretation of norm-referenced measures can be very problematic. For example, if a tool were administered to two groups of 20 subjects and the distribution resulting from the first administration had a mean of 10 and a standard deviation of 5 and the distribution in the second case had a mean of 20 and a standard deviation of 15, an individual with a score of 15 in the first group would be above average in his or her group, while a subject with a score of 15 in the second would be below average when compared with his or her group. Furthermore, because the standard deviation in the second group is considerably higher than that of the first, more error is present in the first set of scores and, hence, they are less accurate indications of subjects’ true amount of the attribute being measured. Therefore, it would be meaningless at best to attempt to compare subjects’ scores across groups. For this reason, it is often useful for a norm-referenced measure to transform raw scores to a set of standard scores that allows comparison among different groups of subjects on the same measure as well as facilitates comparison within groups.

Standard scores allow one to describe the position of a score in a set of scores by measuring its deviation from the mean of all scores in standard deviation units. This can be accomplished by converting the raw scores of each subject to a standard score. Any set of raw scores with a known mean and standard deviation can be transformed into a different set of scores with mean 0 and standard deviation.
so that the transformed score immediately tells one the deviation of the original score from the mean measured in standard deviation units. This is accomplished by subtracting the mean from the raw score and dividing the difference by the standard deviation. The resulting scores are Z scores (Waltz and Bausell, 1981).

**Example 4.1:** Determination of Z scores.

Given the following raw scores: 5, 10, and 18 with a mean and standard deviation of 11 and 5.11, respectively, the resulting Z scores are −1.17, −0.19, and +1.36. Specifically,

For raw score = 5

\[ 5 - 11/5.11 = -6/5.11 = -1.17 \] (Z score)

For raw score = 10

\[ 10 - 11/5.11 = -1/5.11 = -0.19 \] (Z score)

For raw score = 18

\[ 18 - 11/5.11 = 7/5.11 = 1.36 \] (Z score)

Aside from being a convenient means for communicating the position of a subject’s score, Z scores are a step toward transforming a set of raw scores into an arbitrary scale with a convenient mean and standard deviation. There are many possible scales to which raw scores can be transformed (arbitrary means and standard deviations). For example, intelligence test scores are often transformed to a scale with mean 100 and standard deviation 15 or 16. Similarly, t scores with a mean of 50 and standard deviation of 10 are used widely. A Z score can be transformed to any scale of measure by multiplying the desired standard deviation with the Z score and adding the result to the value of the desired mean.

**Example 4.2:** Transforming a Z score to a t score with mean 50 and standard deviation 10

To transform a Z score = 1.36 to a t score with mean of 50 and standard deviation of 10:

\[ t = (10) (1.36) + 50 = 13.60 + 50 = 63.60 \] (t score)

A distribution of Z scores is referred to as a *unit normal curve*, which is illustrated in Figure 4.7. It is a unit normal curve because the area under the curve is 1. Its mean and standard deviation are 0 and 1, respectively, and any other normal curve can be moved along the number scale and stretched or compressed by using a simple transformation. As stated earlier, there is an infinite number of normal curves, a different one for each different pair of values for the mean and standard deviation.
The most important property they have in common is the amount of the area under the curve between any two points expressed in standard deviation units. In any normal distribution, approximately:

1. 68% of the area under the curve lies within (+ or –) one standard deviation of the mean.
2. 95% of the area under the curve lies within (+ or –) two standard deviations of the mean.
3. 97.7% of the area under the curve lies within (+ or –) three standard deviations of the mean.

It is useful if all references to normal distributions are in terms of deviations from the mean in standard deviation units; that is, when the normal curve is employed, one wants to know how many standard deviations a score lies above or below the mean. The deviation of a score from its mean is the result of the score minus the mean. The number of standard deviations the score lies from its mean is determined by subtracting the mean from the score and dividing the result by the standard deviation and is called the unit normal deviate. The shape of the normal curve does not change when one subtracts the mean and divides by the standard deviation.

**Example 4.3:** What portion of the area lies to the left of a score of 30 in a normal distribution with mean 35 and standard deviation of 10?

It is the proportion of the area that lies to the left of \((30 - 35)/10 = -0.5\) in the unit normal distribution.

Using a table of areas of the unit normal distribution found in most research and statistics books, one can further determine that the area that lies to the left of \(-0.5\) in the unit normal distribution is 0.3085. A table of areas of the unit normal distribution can be found in Waltz and Bausell (1981, Appendix 1, pp. 338–340).

The Z score is sometimes referred to as a derived score. Two additional derived scores obtained from a raw-score distribution using specific arithmetic operations are percentage scores and percentile ranks. Percentage scores are appropriate for criterion-referenced measures rather than norm-referenced; because they are frequently confused with the percentile rank, which is appropriate for norm-referenced measures, they will be briefly discussed here. A percentage score is the percentage of the total number of points available that have been earned by the subject.

The percentage score indicates where the individual’s performance is in relation to the minimum and maximum possible values on the raw-score scale. The percentage score is a measure of absolute performance; that is, the percentage score obtained by one subject is completely independent of the percentage scores of all other subjects in the group. Therefore, it is a useful measure of performance in a criterion-referenced context.

In contrast, the percentile rank of a particular raw score is the percentage of area in the histogram located to the left of the raw score in question. To determine the percentile rank:

1. Determine how many subjects obtained scores exactly equal to the subject’s raw score value.
2. Divide the number obtained in step 1 by half.
3. Count the number of subjects who obtained scores less than the subject’s raw-score value.
4. Add the results obtained in steps 2 and 3.
5. Divide the result of step 4 by the total number of scores in the distribution.
6. Multiply the resulting value by 100.

**Example 4.4:** Determining the percentile rank of a raw score in a distribution:

Given the following raw scores and the frequency (in parenthesis) with which each score occurred: 5(0), 4(3), 3(2), 2(4), 1(1), find the percentile rank of the raw score 2.

1. Four subjects obtained scores exactly equal to 2.
2. One-half of 4 is 2.
3. Exactly one subject had a raw score less than 2.
4. Adding the results from steps 2 and 3, $2 + 1 = 3$.
5. Because there are 10 scores in the distribution, $3/10 = 0.30$.
6. Multiplying $0.30 \times 100 = 30$, indicating 30% of the area of the distribution is located to the left of the raw score 2.

The percentile rank is an indicator of relative performance. The percentile rank of a subject is totally dependent upon the quality of the subject’s performance as compared with the performances of the other subjects in the group. Thus, it is an excellent measure in a norm-referenced context, but totally inappropriate for use with criterion-referenced measures.

A percentile is simply a point on the raw score continuum. The $n$th percentile is the point or value on the raw-score scale that separates the leftmost $n\%$ of the histogram area from the remainder of the graph. If a subject scored at the $n$th percentile, the subject’s performance was better than or equal to exactly $n\%$ of the performances in the group. Selected percentiles are sometimes referred to as quartiles. That is, the 25th percentile may be called the first quartile, the 50th percentile the second quartile, and the 75th percentile the third quartile. The first, second, and third quartiles are symbolically designated as $Q_1$, $Q_2$, and $Q_3$, respectively. $Q_2$ is the median of the distribution. Quartiles are useful for summarizing data, because simply reporting that $P_{50}$ is 10 and $P_{25}$ is 15 tells the reader immediately that 50% of the observations are less than 10, and 25% of them lie between 10 and 15. For large groups of data, knowing the quartile values may enable the reader to readily envision the entire collection of observations.

Once the scores resulting from a norm-referenced measure have been transformed to sets of comparable values (e.g., standard scores), a profile can be plotted to demonstrate the comparability of two or more scores for the same subject or the comparability of two or more scores for groups of subjects. More specifically, profiles may be used to:

1. Obtain a visual representation of the relative performance of subjects in several different areas.
2. Compare the performance of a single group of subjects on several variables and with a set of norms (e.g., national norms).
3. Provide sample-by-sample comparisons in terms of common variables and with a set of norms (e.g., national norms).

For example, Grover et al. (2007) conducted a study to determine whether showing physicians and patients the patient’s calculated coronary
risk can improve the effectiveness of treating dyslipidemia in a primary care setting in which they developed a coronary risk profile using the Cardiovascular Life Expectancy Model and Framingham equations.

Usually a profile is constructed as a chart on which one axis represents the tools and the other axis the scores as standard scores, percentile ranks, or stanines. It must be emphasized that a profile must be based on the scores of subjects from the same or strictly comparable populations to whom the tools were administered at the same time. Because profiles are most often employed with standardized measures, which are a special type of norm-referenced measure, the development of profiles is discussed and illustrated in more depth in Chapter 7.

Additional examples of the use of norm-referenced measures can be found in the work of Ellenbecker and colleagues (2008) who employed a norm-referenced framework to examine the level of job satisfaction and test a theoretical model of the direct and indirect effects of job satisfaction, and individual nurse and agency characteristics on intent to stay and retention of home health nurses; Glaister (2007) who employed norm-referenced measures to determine if presence of mathematical and computer anxiety in nursing students affects learning of dosage calculations; and Whiting and Mallory (2007) who conducted a study of 5th and 6th graders in which students mentored by college students were tested using multiple instruments including standardized instruments, the Achenbach (Achenbach & Rescorla, 2001) System of Empirically Based Behavior (ASEBA), to identify and develop a profile of behavior and attitudinal outcomes.

**DESIGNING CRITERION-REFERENCED MEASURES**

In the preceding sections, the development of norm-referenced measures was discussed. At this point, we turn our discussion to the development of criterion-referenced measures. We will begin by differentiating the nature of criterion-referenced measurement from norm-referenced measurement and discussing how criterion-referenced measures are fundamentally different from norm-referenced measures. Next we will discuss the place of criterion-referenced measurement in measuring health and nursing concepts. This will be followed by the specification of the similarities and differences in the approach to designing criterion-referenced measures in comparison to norm-referenced measures. In the past, criterion-referenced and norm-referenced measures were regarded as competing approaches to measurement. However, recently works in the area of instructional diagnostics have recognized that the same test may allow for both norm- and criterion-referenced interpretation (Glaser, 1994; Hambleton, 1994; Watermann & Klieme, 2002).

**The Meaning of Criterion-Referenced Measurement**

In criterion-referenced measurement the emphasis is on determining what a person can or cannot do or knows or does not know, not on how the person compares with others (Bond, 1996). For illustrative purposes, suppose that a nursing instructor wants to know if a student can apply the principles of sterile technique while catheterizing a patient. This is quite a different concern from how well the student can perform this task when compared with classmates. The former concern has a criterion-referenced measurement focus, and the latter is an example of the focus of norm-referenced measurement.

Criterion-referenced measures are used to determine an object’s domain status, usually with respect to some predetermined criterion or performance standard. In one sense, criterion refers to the specified knowledge or skills in performing a task that a test or measure was designed to assess. However, in another sense, it means the level of performance that is required to pass a test (Brown & Hudson, 2002; Mertler, 2007). Criterion-referenced measures are used whenever you want a person to demonstrate that he or she is capable of performing a specific skill or ability (Shrock & Coscarelli, 2007).
The domain refers to the variable or content area that is the focus of measurement. In criterion-referenced measurement the objective of the test or measure specifies the domain that is being measured, and the emphasis is on the determination of the object’s or person’s domain status. In the example cited above, the criterion or performance standards guide the instructor in determining whether the student can perform the expected set of target behaviors independent of reference to the performance of others. When the criterion-referenced framework is applied to a testing situation, whether an individual passes or fails the test would be defined by a preset standard of performance or cut score. If the student scores above the cut score, the student would pass the test regardless of how many peers scored above or below the cut score. Such tests may be referred to as mastery-referenced tests. Standards-referenced assessment is used to refer to criterion-referenced measurement related to large-scale performance assessments (Young & Yoon, 1998). When the content of a criterion-referenced test is based on specific objectives, it may be called an objectives-referenced test. The term “domain-referenced” test or measure refers to those circumstances when a well-established domain has been clearly identified and representative items have been selected from the domain for a test (Brown & Hudson, 2002; Hashway, 1998). The phrase “criterion-referenced” refers to the general family of measurement strategies used for criterion-referenced interpretation of scores.

Use of criterion-referenced measurement is not limited to testing achievement skills or other similar behaviors, but it also is used to determine an object’s status in relation to some specific attribute or property. The criterion-referenced measurement framework is applied when individuals are classified or categorized by sex or social class or when the nurse specifies fetal position during labor. These are some examples of nominal-level use of criterion-referenced measurement, since the results will serve to simply classify an object in relation to a specified attribute rather than imply quantitative value. In this type of criterion-referenced measurement, an object’s domain status is determined by distinguishing characteristics or features that have been clearly identified, described, and explicated in terms of the nature of the domain. Such distinguishing characteristics serve as the criterion or standard(s) for measurement.

The primary feature of criterion-referenced measurement is its use of an interpretive frame of reference based on a specified domain rather than on a specified population or group (Popham, 1978). The principle difference between criterion-referenced and norm-referenced measurement lies in the standard used as a reference for interpretation of results (Glaser, 1994). In contrast to norm-referenced measurement, in which results are interpreted in terms of those obtained by others on the same measuring device, interpretation of criterion-referenced measurements is based on a predetermined criterion or standard of performance, that is, on specific tasks or performance behaviors.

**Comparison of Criterion-Referenced and Norm-Referenced Measures**

Although criterion-referenced and norm-referenced measures are developed so that scores will be interpreted differently, they have characteristics in common as well as distinct differences. Common characteristics include the following according to Gronlund (1988, p. 4).

1. Both require specification of the achievement domain to be measured.
2. Both require a relevant and representative sample of test items.
3. Both may use the same types of test items.
4. Both have the same rules for item writing (except for item difficulty).
5. Both are judged by the same qualities of goodness (reliability and validity), although there are sometimes differences in statistical methods employed.
6. Both are useful in the measurement of health variables and in educational measurement.

Table 4.11 delineates some of the differences between criterion-referenced and norm-referenced measures.
Utility in Health and Nursing Measurement

The use of criterion-referenced measurement in the health fields is a common approach to measurement and has been increasing within the last two decades. The application of criterion-referenced measurement is usually best suited for testing basic skills, such as the ability to do manipulative procedures or to demonstrate simple cognitive skills. However, this should not be taken to de-emphasize the importance and usefulness of criterion-referenced measurement in testing domains that include advanced levels of knowledge. It is the intended use of the results of measurement that should determine whether a criterion-referenced measure should be used rather than the complexity of the content domain. For example, the nursing board licensing examination is an example of a criterion-referenced test with a domain characterized by advanced levels of knowledge. Boards of nursing only want to license those who have the competence and skill to function as a nurse.

Health Research

Criterion-referenced measurement is amenable for use in the measurement of variables in health and nursing research, and in many instances it may be the most appropriate measurement framework to use in the operationalization of concepts (Strickland, 1994). Suppose a nurse

| TABLE 4.11 Differences Between Criterion-Referenced and Norm-Referenced Measures |

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Criterion-Referenced</th>
<th>Norm-Referenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type of interpretation</td>
<td>Absolute interpretation. Amount of attribute measured is specified based on known placement in a category or by percent.</td>
<td>Relative interpretation. Amount of attribute measured is compared to others for interpretation.</td>
</tr>
<tr>
<td>2. Primary uses</td>
<td>Used to categorize attributes or for mastery testing.</td>
<td>Used primarily to obtain scores for purposes of comparison.</td>
</tr>
<tr>
<td>3. Type of measurement</td>
<td>Focuses on a delimited domain or subdomains with a relatively large number of items measuring each task, objective, category, or subscale.</td>
<td>Typically focuses on a large domain, with a few items measuring each task, objective, category, or subscale.</td>
</tr>
<tr>
<td>4. Purpose of testing</td>
<td>To assess the amount of an attribute or material known by each in isolation of others.</td>
<td>To spread out objects or persons across a continuum on the attribute measured.</td>
</tr>
<tr>
<td></td>
<td>Emphasizes description of objects or individuals on the attribute measured or what a person can or cannot do.</td>
<td>Emphasizes discrimination of objects or individuals on the attribute measured in terms of amount or level of learning.</td>
</tr>
<tr>
<td>5. Distribution of scores</td>
<td>Distribution of scores vary, often are not normally distributed.</td>
<td>Normal distribution of scores is expected around the mean.</td>
</tr>
<tr>
<td>6. Structure of measure or test</td>
<td>Homogeneous, well-defined item content matched to each domain, subdomain, or subscale.</td>
<td>More heterogeneous and relatively long subtests or subscales.</td>
</tr>
<tr>
<td>7. Knowledge of nature of questions if testing</td>
<td>Students know the content to expect test questions to address.</td>
<td>Students have little or no idea of nature of content to expect in questions.</td>
</tr>
</tbody>
</table>

researcher is conducting a study to determine if adjustment to the parental role by parents who have a child with meningomyelocele is related to their acceptance of the child’s condition. In this example both the independent variable (adjustment to the parental role) and the dependent variable (acceptance of the child’s condition) can be conceptualized so that the criterion-referenced measurement framework would be the more appropriate framework to use for measurement of the variables. If the conceptualization of the variables indicates that parents either adjust to their role or do not adjust, and the parents either accept their child’s condition or do not accept it, the criterion-referenced framework is the better framework to use in the measurement of the variables. This is the case because the variables are conceptualized in a criterion-referenced manner. Crucial in the measurement of the variables would be the specification of critical behaviors that each parent must exhibit in order for the researcher to make the determination that adjustment to the parental role had occurred or not occurred or that acceptance of the child’s condition had occurred or not.

Whether a nurse researcher should choose a measuring tool that uses the criterion-referenced measurement framework depends on the conceptualization of the variables under study and the nature of the research questions addressed. However, some researchers have a bias toward using norm-referenced measurement when operationalizing variables, because criterion-referenced measures usually yield nominal and ordinal data. Many variables are best operationalized through the use of criterion-referenced measurement. For example, self-care agency is a concept that is likely to be a focus of study in nursing research. The definition of the concept indicates the need to use a criterion-referenced tool to measure the concept because the focus is on determining one’s capabilities that enable performance of self-care (Orem, 1985). Denyes’s Self-Care Agency Instrument (Denyes, 1988) was designed so that one could determine strengths and limitations in an individual’s abilities to make decisions about and to accomplish self-care. Therefore, the focus of measurement is on specifying the individual’s degree of ability related to self-care.

Clinical Practice

In the clinical practice setting, criterion-referenced measures are sometimes used to determine client ability to perform specific tasks and skills and to categorize clients in regard to their health status or diagnosis. The criterion-referenced measurement framework is used to classify attributes related to client conditions that may be assessed through direct clinical observation or by laboratory tests. For example, pelvic floor muscle strength has been a clinical variable of interest for nurses who care for women with urinary incontinence as well those who care for obstetrical patients. The Pelvic Muscle Strength Rating Scale (Sampselle, Brink, & Wells, 1989) and the Circumvaginal Muscles Rating Scale (Worth, Dougherty, & McKey, 1986) are two similar instruments that have been developed to rate or categorize the strength of pelvic floor muscles in women. Also, the results of pregnancy tests are interpreted as either positive or negative; the intensity of a heart murmur may be classified as grade 1, 2, 3, 4, 5, or 6; the measurement of reflexes during a neurological exam may be recorded as 0, 1+, 2+, 3+, or 4+; a test of the presence of albumin in the urine may be interpreted as either negative, trace, or 1+, 2+, or 3+; and a patient may be categorized as either hypotensive, normotensive, or hypertensive based on his or her blood pressure level. Such criterion-referenced measurements are used on numerous occasions daily in the clinical setting. In most cases, criterion-referenced measures that are used in the clinical milieu provide a means for classifying data for descriptive purposes and to facilitate diagnoses. The criterion standards applied during the classification process have been explicated and incorporated into these procedures so that results will be as accurate as possible. Figure 4.8 illustrates the use of the criterion-referenced framework for the classification of primary skin lesions. Types or classes of lesions have been specified and defined in descriptive terms so that the approach to classification is clear and unambiguous. These
criterion standards guide the classification process by the examiner.

**Educational Programs**

Criterion-referenced measures are particularly useful when the purpose of testing is to ascertain whether an individual has attained critical clinical competencies (Gilje, Klose, & Birger, 2007) or minimum requirements, such as for practice or for admission to a specific educational program or course. The NCLEX examination is probably the most commonly used criterion-referenced test in nursing. A standard is set and each individual must score at that level or above in order to be considered safe to practice and to receive nursing licensure. In educational programs, criterion-referenced measurement is best applied when there is a need for tests to examine student progress toward the attainment of a designated skill or knowledge level. Criterion-referenced measurement is better suited for such functions than norm-referenced measures. Instruction and evaluation of nursing students in the clinical setting is highly amenable to the use of criterion-referenced measures because of the emphasis placed on the application of knowledge and skills. Clearly the focus of evaluation in the assessment of clinical skills in nursing and other practice disciplines should be on what a person is able to do rather than on how the person compares with others. The application of criterion-referenced measurement for ascertaining clinical skills would require each student to demonstrate critical behaviors before performance would be considered satisfactory.

Mastery testing is used to classify students as masters or nonmasters of a single learning objective. Mastery testing yields an all-or-none score (i.e., pass or fail) that indicates whether a person has attained the predetermined level of skills or knowledge. When basic skills are tested, it is not unusual for nearly complete mastery to be expected. Items on the mastery test should be highly instructionally sensitive and discriminate between those who do and do not master the objective tested. Scores are reported separately in terms of the student’s performance in relation to each objective, since students may have adequate skills and knowledge related to some objectives but not others. The methods for setting performance standards or cut scores for mastery are particularly important and involve the identification of critical behaviors related to each objective assessed.

When advanced content is tested, it is virtually impossible to set the cut score or level of mastery completely in terms of critical requisite skills, but this often must be done partly in a normative manner. The mastery level is often determined in a normative manner based on the performance of previous groups or through the judgment of the instructor who is teaching the course.

**Developing Criterion-Referenced Measures**

Given that the primary goal of criterion-referenced measurement is to accurately determine the status of some object in terms of a well-defined domain, two major assumptions regarding a criterion-referenced measure become apparent. First, the items included in the measure should sample the specified content domain carefully. Second, the preset criteria or standards of performance must estimate the object’s domain status accurately. These assumptions encourage one to consider several key points that are crucial for the development of criterion-referenced measures, among which are the need for (1) a clear definition or explication of the content domain tested; (2) the inclusion of a relatively homogeneous collection of items or tasks that accurately assess the content domain as the focus of measurement; and (3) the determination of criteria or performance standards that define an object’s domain status accurately. These assumptions encourage one to consider several key points that are crucial for the development of criterion-referenced measures, among which are the need for (1) a clear definition or explication of the content domain tested; (2) the inclusion of a relatively homogeneous collection of items or tasks that accurately assess the content domain as the focus of measurement; and (3) the determination of criteria or performance standards that define an object’s domain status. Figure 4.9 presents the various steps for developing and validating criterion-referenced measures. Attention for the remainder of this chapter is concentrated on steps 2 through 6, which focus on the construction of measures. The need to delineate a conceptual model as a basis for tool development is discussed in Chapters 1 and 2. Concerns related to establishing reliability and validity will be discussed in detail in Chapters 5 and 6.

**Specifying the Purpose(s) of the Measure**

In order to ensure that a test will optimally address the needs for which it is developed, the
purposes of the measure should be clearly specified. As indicated in Chapter 2, the conceptual model that serves as the basis for the development of the measure helps to clarify its purpose and guides the manner in which it is developed. However, when the major purposes are clarified and the priorities among probable uses of the measure are identified, the likelihood increases that the final form of the measure will meet the most important purposes it is intended to serve. When specifying the purposes of the measure, the developer should consider the population with whom it will be used, the circumstances in which it is most likely to be employed, and how the scores that will ultimately result will be applied. For example, a measure of knowledge of diabetic care might be needed by a nursing instructor who wants to test the knowledge of nursing students or by a clinician who needs to assess the knowledge of patients with diabetes. Although both potential users need to measure the same variable, it would not be appropriate in most circumstances to use the same tool for both. The reason for this is obvious. The nursing instructor would want a test that clearly identifies the knowledge level of nursing students who ultimately will be expected to use that knowledge to make decisions about the care of patients. Most likely, such a test would be administered in a classroom setting to a group of students who are reasonably well educated. Knowledge areas to be addressed by such a measure that would be used with nursing students would be broad and include rather detailed scientific information. In this circumstance, a test with many items that uses high-level terminology would be appropriate. However, in a situation where the focus is on the measurement of patient knowledge of
1. Specify the conceptual model of the measure.
2. Specify the purpose(s) of the measure.
3. Explicate objective(s) or the domain definition.
4. Prepare test specifications including:
   a. Method of administration
   b. Number or proportion of items that will focus on each objective or subscale
   c. Type of items and how they will be created
   d. Test restrictions and givens
   e. General scoring rules and procedures
5. Construct the measure including:
   a. Develop a pool of items or tasks matched to the objective(s) or subscales
   b. Review items or tasks to determine content validity and their appropriateness
   c. Select items after editing or deleting poorly developed items from the item pool
   d. Assemble the measure (including preparation of directions, scoring keys, answer sheets, etc.)
6. Set standards or cut score for interpreting results.
7. Field-test or administer the measure.
8. Assess reliability and validity of measure (including determining the statistical properties of items, and deleting and revising items further based on empirical data).

FIGURE 4.9 Stages in the development and validation of criterion-referenced measures.

diabetic care, the test developer would have to be sensitive to the broad range of educational levels of patients, many of whom would not understand highly technical and advanced terminology. Also, test length in this situation would be important since it is not likely that circumstances under which patients would be administered such a measure would allow for a long test with many items. Keep in mind that the nature of a student’s performance to be assessed needs to be considered. Performance can be in relation to performance speed, performance quality, or performance precision (Mertler, 2007). Performance speed refers to the amount of time a student requires to complete a task. Performance quality refers to the level at which the student performs based on ratings. Performance precision addresses the degree of accuracy with which the student completes the task. Therefore, clarifying the primary purposes for which a measure will be used will influence the characteristics of the items or indicators of the variable in the tool as well as other aspects of the tool, such as its length, reading level, and the manner in which it is to be administered and scored.

Explicating Objectives or Domain Definition

Criterion-referenced measures are developed using an objectives-based approach (Shrock & Coscarelli, 2007). A precise and rigorous domain definition is necessary to maximize the interpretability of the results of measurements. It is the objective of the measure that defines and specifies the domain that is to be assessed. The specific objective(s) for the measure, therefore, must be explicated prior to its construction. Methods for stating behavioral objectives were discussed previously in this chapter during the discussion of norm-referenced measures, and also apply in the construction of criterion-referenced measures.

Preparation of Test Specifications

It has been noted previously that the objective of a measure defines the content domain that is the focus of measurement. However, the objective, in most instances, is not sufficiently constraining to guide the specifics of the construction of the measure such as method of administration, number or proportion of items testing each objective or subscale, test-item format, test restrictions and givens, or test scoring. That is the purpose of test specifications, which serve a similar function as the test blueprint in the norm-referenced case. When the test constructor has provided a description of all of these components, then the major components of test specifications have been explicated. The approach to developing each of these parts of test specifications is the same as described for norm-referenced measures.
If a measure includes subobjectives that relate to the overall objective, the test developer should make sure that each subobjective is adequately represented on the instrument. This can be done by using a blueprinting approach as described earlier in this chapter.

Popham (1978, 1980) has specified a general format for test specifications and suggests that they generally consist of (1) a general description, (2) a sample item, (3) stimulus attributes (item characteristics), (4) response attributes, and (5) specification supplement.

**General Description**

The general description specifies what it is that the test measures through a succinct overview of the set of target behaviors. In most criterion-referenced test specifications, this is the test objective. Although succinct, the general description provides information about the form of the test and the approach to administration of the measure. The following is illustrative of the general description for a measure of knowledge of fluid and electrolyte balance.

Given a written test of knowledge relevant to the care of clients at risk for fluid and electrolyte imbalance, the student will respond to at least 80% of the items correctly.

**Sample Item**

A sample item, similar to those offered in the measure, is provided along with complete directions to the examinee or respondent. Usually, it is rather simple to provide a sample item, because most measures consist of relatively short items. Sometimes it becomes difficult to supply a sample item if items are lengthy and complicated. In any case, an illustrative item is provided for two reasons. First, for many measures the general description statement along with the illustrative item can provide enough information about the test to further clarify the purpose, scope, and intended use for the measure. The second reason is that the illustrative item can provide format cues for those who will assist in the generation of items that will constitute the test. It should be noted that criterion-referenced test items may consist of most of the item forms discussed for norm-referenced measures. Below is an example of a sample item that is compatible with the general description provided above.

**Example of a Sample Item**

*Directions:* This test presents situations that are followed by sets of related test items. Read each situation carefully and answer the multiple-choice items that follow it, based on the information in the situation. Select only one answer. Write the letter of the answer you select in the designated space on the answer sheet provided.

*Situation:* Mr. Johnson is a 65-year-old retired farmer who has come to the Rural Health Clinic complaining of weakness, frequent episodes of diarrhea of 5 days’ duration, and abdominal pains. He says he has not been able to eat and drink fluids well because they “make my stomach hurt.” Mr. Johnson has a temperature of 102°F, a thready pulse of 92, and a respiratory rate of 18. His blood pressure is 124/70. Mr. Johnson’s skin is dry with poor turgor. There have been no episodes of vomiting.

1. In addition to a deficit of water (fluids), which of the following problems should the nurse be most concerned about in observing Mr. Johnson?
   A. Sodium deficit
   B. Chloride deficit
   C. Potassium deficit
   D. Bicarbonate deficit

**Stimulus Attributes**

*Stimulus attributes* (item characteristics) are the factors that constrain or limit the composition of the set of items included in the measure. Generally, the items within a measure are designed to yield a response that is used in the measurement of the phenomenon of interest. Therefore, the attributes of the stimulus materials (i.e., the items) are set forth and described. This means that careful thought must be given to the nature of items in an attempt to identify significant factors associated with the desired item characteristics. Attention must be focused upon content considerations that may influence item characteristics. A decision must be made about how the range of eligible content can be most effectively circumscribed through test items. The following is illustrative of stimulus attributes that might be developed for a nursing test.
that is to measure knowledge requisite for the care of clients at risk for fluid and electrolyte imbalance and that is to consist of multiple-choice items.

**Example of Response Attributes**

1. A set of four short one- or two-word responses or single-sentence response alternatives will follow each item stem. All responses within an item should be approximately the same length and must plausibly relate to the item stem.
2. An item will contain only one correct or clearly best answer. All response alternatives will be grammatically consistent with the stem of the item.
3. The three incorrect response alternatives will lack accuracy or appropriate scope.
4. An incorrect response alternative exemplifies a lack of accuracy when it makes a statement contradicted by information in the textbook or makes a statement incapable of verification.
5. An incorrect response alternative exemplifies the lack of appropriate scope when it does not include all of the important details to fully answer the item stem or when it is too general to account for all of the important details needed to clearly answer the item stem.
6. The correct response alternative must be entirely accurate and have appropriate scope, in that it includes all the important information to answer the stem and is verifiable by agreement of experts in the area.

**Response Attributes**

*Response attributes* make up the final component of a set of test specifications and focus on the nature of the examinee’s or subject’s response to items within the measure. Two types of responses are possible. The subject may either select from a collection of response options presented in the measure (e.g., in multiple-choice or true-false questions), or the respondent may construct a response (e.g., in oral presentations, essay items, short-answer items, or behavioral skills tests). It is within the response-attributes section of the test specifications that rules regarding the two response possibilities are specified.

If the response attribute is the selected response, then specific rules are provided that determine the nature of the correct response and also the nature of the incorrect options. For example, if multiple-choice items are to be used in the measure, guidelines for creating not only the correct response but also the wrong answer options must be carefully explicated. Incorrect responses usually reflect common errors encountered in meeting the objective. Hence, by looking at the wrong answers, diagnostic information may be obtained. Illustrated below is a set of response attributes that are complementary to the set of stimulus attributes.

**Example of Stimulus Attributes**

1. Each multiple-choice item will relate to a nursing situation that describes a client at risk for fluid and electrolyte imbalance. The client’s diagnosis, pertinent lab results, physical condition, treatment regimen, and significant history will be presented in each situation.
2. Each item will focus on prevention, assessment, or treatment/care related to clients at risk for fluid and electrolyte imbalance.
3. The item stem will not include irrelevant material. Neither should a negatively stated stem be included, except when significant learning outcomes require it. Item stems will consist of complete sentences.

**Specification Supplement**

This involves listing supplemental material that is needed to clarify the previous elements of test specifications. This could include a list of vocabulary items, or other information from which the item writer can draw (Brown & Hudson, 2002).
Similar test specifications would need to be developed for a measure of proficiency for performing a skill. Figure 4.10 provides an illustrative set of criterion-referenced test specifications for a measure of skill for inserting a nasogastric tube, which is provided in Figure 4.11. This example presents an illustration of response attributes for the constructed response required in this situation.

Finally, in some cases, the nature of the content domain or items may be such that a full description of stimulus attributes or response attributes may be too voluminous to include in a focused presentation of the test specifications. In such cases, key statements could be emphasized within an abbreviated description for these sections, and the detailed specifications would be included in a manual, supplement, or appendix. This approach should be taken when lengthy content citations might distract the reader from focusing on important specification statements.

Clearly, one of the major purposes of test specifications is to facilitate the creation of a measure with items that are homogeneous. Since criterion-referenced measures are supposed to assess one content domain, homogeneity of items within a measure is an important indicator of this desirable characteristic. The more homogeneous the items, the more likely it is that the items within the measure are representative of one domain. On the other hand, the more heterogeneous the items, the greater the likelihood that the measure assesses factors outside the

---

**General Description**

Given a conscious adult, the nurse will insert a nasogastric tube. All necessary actions for safe insertion must be performed.

**Sample Item**

Directions: You are to insert a nasogastric tube from the nostrils into the stomach of an adult client. You must employ the necessary materials and proceed sequentially through each requisite step of the procedure.

Step 1. Gather necessary equipment. (i.e., Levine type lumen tube, large 30 cc syringe and stethoscope, cup of drinking water)

**Stimulus Attributes or Item Characteristics**

1. Each item will consist of a necessary step in the procedure and describe the behaviors required of the nurse to complete the step. Each item will be stated in behavioral terms.
2. Each item should be listed sequentially (i.e., will follow the item that should be completed immediately prior to it).
3. Where appropriate, more than one descriptive behavior will be included in an item (step), if either may be correctly employed for the completion of that item.

**Response Attributes**

1. A correct response to an item occurs if both of the following are observed:
   a. The nurse performs the behaviors as described in the item.
   b. The nurse performs the item in its proper sequence.
2. An incorrect response to an item occurs if any one of the following is observed:
   a. Nurse’s behavior is not consistent with behaviors described in the item.
   b. Nurse does not perform the item in its proper sequence.
   c. Nurse omits the item.

---

**FIGURE 4.10** An illustrative set of criterion-referenced test specifications for a measure of skill for inserting a nasogastric tube.
behaviors (steps) | correct | incorrect
---|---|---
1. gathers necessary equipment. (i.e., levine type lumen tube, large 30 cc syringe and stethoscope, cup of drinking water). | | |
2. marks distance on tube as measured from the tip of the nose, around the ear, to the xiphoid. | | |
3. places client in a sitting position (or as near to sitting as possible). | | |
4. maintains position throughout procedure. | | |
5. advances tube firmly but gently through the client's nostril to the pharynx. | | |
6. has the patient swallow sips of water to carry the tube down the esophagus until tube is in the predetermined distance (see step 2). | | |
7. checks to determine if tube is in the stomach by aspirating gastric juices up the tube. -or- putting 20 ml of air into the tube by syringe while listening with a stethoscope over the stomach for a gurgling noise. | | |

scoring key: pass = correctly performs all steps (1–7) in procedure. fail = incorrectly performs at least one step in the procedure.

figure 4.11 a measure of skill for inserting a nasogastric tube.

domain. precise and rigorous test specifications help to delimit the domain and thereby facilitate the inclusion of homogeneous items that measure the same domain, even though items may be of various levels of difficulty. however, ambiguous and fuzzy test specifications most often lead to incongruent and heterogeneous test items, which reduce the interpretability and, hence, the validity of results.

test restrictions and givens
the restrictions and givens of the test conditions should be spelled out. often these are incorporated into the statement of the objective. restrictions may be placed on resources or aids that can be employed or on the amount of time that may be taken to perform a task or behavior. in some instances, time may be an important indicator of the quality of performance, such as in the administering of medications or certain treatments. for example, the time specification in the objective “the student administers medications within 30 minutes of the scheduled time of administration” is strongly related to quality of performance. however, in most situations, time is not usually an important indicator of the quality of performance. time restrictions may be placed on some skill or achievement tests. such restrictions should include a long enough period of time to allow those who normally would have mastered the domain to have a sufficient opportunity to exhibit mastery. in addition to resources that a subject may be prohibited from using, there may be a variety of resources that the subject may use during a testing period. such resources are referred to as givens. any givens or restrictions in resources, aids, or time used during the measurement procedure should be clearly communicated.

scoring rules and procedures
once the items have been constructed and matched to objectives, scoring rules should be
spelled out. In most instances, the item format dictates the general scoring procedure. If any items must be reverse-scored, those items should be clearly identified in the scoring procedure. The test developer must be careful to specify which items measure which objectives when more than one objective is measured within the context of a single tool. Within the criterion-referenced framework, a separate score should be derived for each objective measured by the instrument in order to interpret the result appropriately.

In most instances, the same rules of scoring used for norm-referenced measures will also be relevant for the criterion-referenced case. However, with criterion-referenced measures, a cut score that indicates mastery or nonmastery of an objective will often need to be determined. Methods for setting cut scores or standards for interpreting scores derived from criterion-referenced measures are discussed in a later section of this chapter.

In summary, the purpose of test specifications is to communicate the specifics related to the construction of the measure. This includes explication of not only what the items on the measure will assess but also the rules that govern the creation and administration of the measure and scoring procedures. The goals of the developer of test specifications are to be sufficiently specific to communicate the scope and constraints to potential users of the measure; and to be sufficiently targeted and explicit to guide those who might be involved in the construction and development of the measure.

**Constructing the Measure**

After items are constructed, a preliminary review of all test items (or tasks) should be done once the generation of items has been completed. Items are reviewed by content specialists and those that are not well formulated or congruent with objectives are identified, revised, or discarded in a manner similar to that described for norm-referenced measures. Population representatives should be asked to complete the tool and then specify (1) which items they had difficulty responding to and why, (2) which items they have questions about, (3) revisions they believe should be made, and (4) suggestions for items that should be included. Appropriate revisions should then be made in the measure prior to having it field tested.

In some instances a fairly large number of items may be generated to test one content domain. When a large sample of items is developed to test one objective, a predetermined number may be selected for inclusion in the measure by random sampling. Any sampling method that maintains the domain-referenced status of the test would be appropriate. Once items have been selected, the measure should be assembled including directions for administration, scoring keys, answer sheets, and any other materials necessary for administration and scoring of the tool.

**Setting Standards for Interpreting Results**

Once the domain of a measure has been defined and items to measure the domain have been generated and selected, the next step in the construction of a criterion-referenced measurement tool often is to establish standards or cut score(s). However, standards or cut scores are not a necessary feature of all criterion-referenced measures, for example, those that assess domain status by percentage scores only. Criterion-referenced scoring can be based on state or continuum models (Cizek & Bunch, 2007). State scoring models yield categorical scores, such as “master” or “nonmaster” or “pass” or “fail.” Continuum models acknowledge that competency exists in degrees, such as is represented by competency scores ranging from 0, reflecting a low level of competency to 100, representing a high degree of competency. A standard or cut score is a point along the scale of test scores that is used to classify a subject to reflect level of proficiency relative to a particular objective. Sometimes several cut scores may be established so that a subject may be assigned to one of several levels of proficiency.

As noted previously in the section on scoring, if a test or measure consists of items that assess more than one objective, different standards will be set in relation to sets of items that measure the different objectives. In other words, items that measure different objectives are separated
out and used like individual tests, and cut scores are established to make criterion-referenced interpretations of the results. This is done because one cannot make criterion-referenced interpretations of results when performance on different objectives is reflected in one score. The use of one score to represent performance on a number of different objectives does not communicate what a subject can actually do, because the pooling of results will mask performance relative to each specific objective.

Whenever possible, the domain score is computed for each objective, since it represents knowledge, skills, or attitudes in relation to the specified content domain. A percentage score is a domain score. Whereas the percentile rank is used in norm-referenced measurement as an indicator of relative performance, the percentage score often is used in criterion-referenced measurement as a measure of absolute performance. The percentage score is the proportion of the maximum raw-score points that have been earned by the subject and is calculated by the formula below.

**Formula 4.1**

To convert a raw score to a percentage score:

\[
\text{Percentage score} = \frac{\text{subject’s raw score on the measure}}{\text{the maximum possible raw score on the measure}} \times 100
\]

That is, the percentage score is the subject’s raw score on a measure divided by the maximum possible raw score on the measure times 100.

**Example**

A raw score of 10 on a 20-item test is equivalent to a percentage score of:

\[
\text{Percentage score} = \frac{10}{20} \times 100 = 0.50 \times 100 = 50
\]

The percentage score represents the proportion of a content domain that an individual has mastered or responded to appropriately. Hence, it indicates an individual’s level of performance in relation to the possible minimum and maximum raw scores on a measure.

How are standards or cut scores determined? The answer to this question will depend on the nature of the measure and the content domain that is the focus of measurement. The key idea in criterion-referenced measurement is to determine critical behaviors that distinguish those objects that possess the attribute in question from those that do not. In some situations it is quite a simple matter to make these distinctions. However, in other situations, these distinctions are not clear. It also is apparent that the standard level will vary from measure to measure depending upon the nature of the objective assessed and the critical behaviors or attributes that must be observed in order to make a criterion-referenced interpretation. For instance, it is easier to determine if a child possesses the psychomotor skills to jump double Dutch than to determine if the child possesses the psychomotor skills appropriate for his age and stage of development. In the former case, 100% mastery of the domain would likely be required in order to make the judgment that the child could indeed jump double Dutch. However, making a criterion-referenced judgment in the latter case is not so simple, nor is 100% mastery of the items that might be used to measure psychomotor development for a particular age and stage of development a likely expectation.

Because the determination of standards for making criterion-referenced interpretations is often not a simple matter, a number of approaches to standard setting have been suggested, and Cizek and Bunch (2007) have dedicated a whole book to presenting more than 30 different standard-setting approaches. However, most standard-setting methods can be categorized as judgmental, empirical, or combination. Judgmental methods subject the individual items on the measure to the inspection of judges who are asked to assess how a person who is minimally competent would perform on each item. When empirical methods are used, data are collected and cut scores are based on the results of data analysis. Some blend of both judgmental and empirical methods is used in combination methods for setting cut scores.

No matter what standard-setting method is used, judgment is involved, and the standard in
that regard is arbitrary. As with any process where judgment is used, the setting of standards is likely to involve some degree of error (Bandaranayake, 2008). If a standard is set too high, the chances of making false-negative criterion-referenced interpretations and decisions are increased; that is, there will be increased chances of wrongly classifying persons or objects as not meeting the standard when they in actuality do meet it. Similarly, false-positive classifications are made when persons or objects are categorized as having met the standard when in actuality they have not. When standards are set too low, the chances of false-positive results are increased. Figure 4.12 illustrates groups that have been classified as masters and nonmasters of a content domain. The area designated “masters incorrectly classified” represents false-negatives, and the area specified “nonmasters incorrectly classified” indicates false-positive classifications. The optimal outcome in establishing a standard is to set cut scores in a manner whereby chances of false-positive and false-negative results are at a minimum. However, depending on the use that will be made of the results, standards may electively be set high by the user to reduce the chances of making false-positive interpretations at an increased expense of making more false-negative interpretations, and vice versa.

Several authors have suggested judgmental methods that provide a means for setting a standard or cut score. The judgmental methods offered by Martuza (1977), Nedelsky (1954), and Ebel (1979) will be presented here, because they are rather clear-cut approaches that are recognized and used by measurement specialists.

Martuza (1977, p. 270) suggests a rather simple three-step process to the establishment of cut scores. First, content specialists examine each item and carefully rate its importance relative to the objective on a 10-point scale ranging from “of little importance” to “extremely important.” The second step involves averaging each judge’s ratings across all items in the test. Finally, the averages are converted into a proportion. The proportion could then be used as a cut score for the test. If more than one judge independently rated the items, the mean of the averages from all judges would be used to calculate the proportion that would be used as a cut score. If the proportion that resulted was 85%, then this would be

FIGURE 4.12 Frequency polygons of criterion-referenced test scores for masters and nonmasters.
Chapter 4 Strategies for Designing Measurement Tools and Procedures

137

by the total number of test items to obtain the standard (cut score). Figure 4.13 presents an example of Ebel’s method.

Nedelsky (1954) has offered a method to establish cut scores for tests with multiple-choice items. Judges are asked to review each item and to identify distractors for each item that D-F students or students who are minimally competent should be able to eliminate as incorrect. The reciprocal of the remaining alternatives is the minimum passing level (MPL) on that item for the student who is minimally competent. It is the probability of a correct response as a function of remaining answer choices. For instance, if an item had five options from which the student could select an answer and the judges determined that the minimally competent student could eliminate one distractor as incorrect, this would leave four alternatives from which the student would really have to select. The minimum passing level for that item would be 1/4, or 0.25. If 3, 2, and 1 items remained, the minimum passing level for the items would be 0.33, 0.50, and 1.00, respectively. Once the minimum passing level for each item has been determined by the judges, the

<table>
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<tr>
<th>Relevance</th>
<th>Essential</th>
<th>Important</th>
<th>Acceptable</th>
<th>Questionable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>1,20,21</td>
<td>4,15,27,28</td>
<td>3,10</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Medium</td>
<td>5,14,22,23</td>
<td>2,7,19,16,30</td>
<td>8,13,18</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>60%</td>
<td>33.3%</td>
<td>0%</td>
</tr>
<tr>
<td>Hard</td>
<td>9,26</td>
<td>11,25,29</td>
<td>12,24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>33.3%</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Standard} = \frac{\sum \text{No. of items in cell} \times \text{cell percentage}}{\text{Total no. of test items}}
\]

\[
\text{Standard} = \frac{300 + 400 + 200}{30} = \frac{400 + 300 + 100 + 200 + 100 + 100}{30}
\]

\[
\text{Standard} = \frac{2200}{30}
\]

\[
\text{Standard} = 73.3\%
\]

FIGURE 4.13 An example of Ebel’s grid for standard setting.
minimum passing levels are summed across the test items to obtain a standard. All of the judges’ standards are then averaged to obtain a standard or cut score for the test.

Nedelsky recommends a method for adjusting cut scores in order to reduce the chances of false-negative or false-positive interpretations, depending on the user’s needs. He assumes that if the standard deviation of the individual judges’ standards is computed, a distribution synonymous with the hypothesized distribution of scores of borderline students will result. This standard deviation is then multiplied by a constant $K$, which is subtracted from or added to the standard. The constant is decided upon by the test user and would regulate the approximate number of borderline students who will pass or fail the test.

Two combination methods for setting standards on classroom tests suggested by Zieky and Livingston (1977) have applicability for other nursing situations as well. They are the borderline-group and the contrasting-group methods. In both methods, experts are used as judges, and standards are based on subjects rather than items. For illustrative purposes, assume that a nursing supervisor is trying to establish a cut score for acceptable performance on a rating scale of staff-nurse team leadership. In the contrasting-group method, the supervisor identifies those staff nurses exhibiting definite acceptable and unacceptable teamwork behavior after defining minimally acceptable performance. The distributions of scores obtained by the two groups are then plotted. The point of intersection of the two groups is taken as the standard. (Refer to Figure 4.12 for an illustration of the point of intersection.) Another example was the use of the contrasted-group method by Tudor-Locke and colleagues (2008) to identify age- and gender-specific cut points for steps per day related to body mass index (BMI) cut points for normal weight and overweight/obesity. These cut points for steps per day can be used to identify persons at risk for overweight/obesity and to set intervention goals.

In the borderline-group method, the evaluator defines the minimally acceptable performance on the content domain assessed, after which a list is made of a group of subjects who are borderline in performance; that is, their performance is so close to being both acceptable and unacceptable that they cannot be classified into either group. The median of the test scores from this borderline group is taken as the cut score.

As can be noted from the methods presented here, the rigor and applicability of the standard-setting methods vary. Different approaches are required from measure to measure, depending on the purpose, content domain, and intended use of the results. The decision-making context and the resources available to aid in the standard-setting process also need to be taken into consideration. Analysis of the decision-making context consists of viewing the short-term and long-term implications of decisions or conclusions that will be made using the measure. Possible psychological, social, financial, and educational consequences that may result and the number of people that might be affected must be given careful thought before making a final decision about the approach to establishing a standard for a measure.

The actual resources that will be needed to implement a standard-setting method also need consideration. The degree to which resources (e.g., personnel, time, effort, money, material, and expertise) are expended would best be determined by the decision context for which the measure will be used and the availability of such resources to carry out the task. The actual number of judges needed for the standard-setting process, when they are used, is usually the decision of the user. However, approximately three or four content specialists should be employed when a high degree of precision is needed in the estimation of the cut score. Several suggestions and insights that are particularly pertinent for the standard-setting process have been noted (Bandaranayake, 2008; Hambleton, 1980). Regardless of how technically sound or how content valid the test is, considerable care and attention must be given to the standard-setting process. The best test can be sabotaged by an inappropriate standard. Therefore, Hambleton (1980, p. 114) notes that the test developer should:

1. Select a standard-setting method that can be efficiently and effectively handled by judges.
2. Ensure that all relevant groups have an opportunity to be involved in standard setting.
Chapter 4 Strategies for Designing Measurement Tools and Procedures

3. Train the judges so that they understand their tasks during the standard-setting process.
4. Ensure that the judges understand the purpose of the testing program, know the characteristics of the group of subjects to be tested or assessed, and have the same perspective or definition of a master and a nonmaster of test content.
5. Pilot-test the measure. Decision-validity information should be provided for several standards of test performance. Decision validity as used in this instance refers to the accuracy with which objects are classified into specific groups based on the set of standard(s) for categorization. Both test results from subjects and independently derived standards from judges can be used to set a revised standard.
6. Review standards occasionally.

Construction of Criterion-Referenced Measures With Descriptive Domains

In nursing, many of the criterion-referenced measures that are used assess physical attributes or purely descriptive domains. Specificity and precision in the measurement of descriptive domains are needed in clinical nursing and in nursing research as a means to facilitate precise measurement of client conditions and states. Nominal- and ordinal-level measurements are often employed for descriptive purposes in these situations. A number of examples of such descriptive domains were cited earlier in this chapter—for example, the results of pregnancy tests, which are interpreted as either positive or negative, and the measurement of acetone in the urine, which is given as negative, trace, or 1+, 2+, or 3+. Although such measures appear rather simple and easy to construct and use, the reader is reminded that these criterion-referenced measures must adhere to the same measurement principles as are required in the measurement of behavioral domains. In addition, the same principles that undergird the construction of measures to test behavioral domains also apply for descriptive domains, although the approach varies somewhat.

As noted previously, the goal of criterion-referenced measurement is to assess a specified domain and to determine the domain status of some object in regard to the attribute of interest. The outcome or result of criterion-referenced measurement is that the object is classified or categorized according to the attribute that is the focus of measurement. When the attribute is a cognitive or psychomotor skill, the person is classified on a pass/fail basis or is categorized in some other relevant manner in terms of the specified content domain. When an object is assessed in regard to a descriptive content domain, the major difference is that a number of items or tasks are not generated in order to determine the domain status of the object. A woman is either pregnant or not. The breath sounds of the lungs are described and categorized by level of intensity, pitch, and duration as vesicular, bronchovesicular, or bronchial, because no clinical measurement equipment exists that can measure this variable as a continuous variable at the interval level of measurement. There is no pool of items or tasks that can be generated to facilitate measurement of these descriptive domains. However, it is desirable that they be assessed in a way that provides an accurate classification of an object’s status within the domain.

There are a number of important steps that must be followed in the development of measures with descriptive domains that are similar to those required in the construction of measures that test behavioral domains. When considering the steps, one will notice the marked similarity to those presented in Figure 4.9.

1. Clearly define the conceptual basis of the domain.
2. Formulate the purpose of the measure.
3. Prepare specifications for the formulation of classes or categories.
4. Determine content validity of classes or categories with the assistance of content specialists.
5. Revise classes or categories, if indicated.
6. Administer the measure.
7. Assess the reliability and validity of the measure.

The initial step in the construction of a criterion-referenced measure with a descriptive
content domain, as with any other type of measure, is to provide conceptual clarity about what is being measured. Therefore, a clear definition of the central concept or variable that is the focus of the measurement is obtained. The definition must provide conceptual clarity about the scope and limitations in conceptualization of the variable. The purpose of the measure is stated in terms of this definition and thereby further clarifies the content domain of the measure.

The next step is to specify and define the non-overlapping categories within which phenomena may be classified. The goal is to describe accurately and specifically the distinguishing attributes or dimensions of each category in order to provide a basis for the classification process. Figure 4.8 presents a sample measure for the classification of primary skin lesions. In this example, the descriptions of the categories are based on several dimensions: size, shape, color, and configuration of skin lesions. Descriptions must be precise and unambiguous so that no entity can be classified in more than one category.

The content validity of the classes or categories is judged by content specialists who review each category to determine if there are overlapping categories or one or more categories in which the same object might be classified. The judges also determine if the dimensions used in the categorization scheme are appropriately followed and if there are missing categories. A missing category would be indicated if the categories that had been identified and described did not provide for the categorization of an object or phenomenon that is included in the content domain according to the domain definition. Additional revisions of the classes are made, if indicated, prior to administering the measure. Reliability and validity data can then be investigated.

SUMMARY

The first step in the design of any nursing measure is to clarify the purposes for the measurement. This is facilitated greatly when the measure is derived from a conceptual model. Objectives for the measure should be stated using good form. When taxonomies are employed in writing objectives, action verbs and critical behaviors to be observed are specified, hence decreasing the possibility that the same behavior will be assessed differently by different people.

Specifications regarding the scope, emphasis, and length of the norm-referenced measure are explicated by the process of blueprinting. The blueprint facilitates the construction of items and the assessment of content validity of the resulting measure. When a criterion-referenced measure is employed, test specifications serve the same function as a blueprint and include a general description of the measure, sample item, stimulus attributes, response attributes, and test givens and restrictions that explicate what the items on the measure will assess as well as the rules that govern the creation and administration of the measure and scoring procedures. The type of measure to be employed is a function of the conceptual model and subsequent operational definitions of key variables to be measured. Regardless of type, every measure has three components: (1) directions for administration, (2) a set of items, and (3) directions for obtaining and interpreting scores. Within the context of a given type of measure, there are a variety of specific item formats available, each with its own unique advantages and disadvantages in light of the specific purposes for and characteristics of the setting in which measurement is to occur. A variety of selection and supply-type formats are presented and exemplified within the chapter.

Summative scoring procedures are advocated whenever it is appropriate to obtain a total score or set of subscores for a measure. A conceptual scheme should be employed for assigning scores and this scheme should derive from the conceptual model for operationalizing key variables. Various procedures for obtaining, tabulating, and summarizing norm-referenced and criterion-referenced scores are presented.

REFERENCES


Measurement Reliability

The use of sound measurement practices and procedures must be a salient concern during the design, implementation, and evaluation of a research study, especially in regard to assessing the quality of research results for use as a basis for practice. Thus, pretesting the measures and data collection methods employed in a research study is an essential component that enables the researcher to assess the appropriateness of the type of data collection method employed, identify needed revisions, and evaluate reliability and validity. Rubin, Pronovost, and Diette (2001) in their article regarding the development and testing of quality indicators emphasize the dangers of not pretesting when using hospital records as a sole source for measuring whether left ventricular function has been assessed as a measure for congestive heart failure. Specifically, they note that in some settings this assessment is usually performed by an outpatient physician and transmitted to an attending physician in the hospital and thus is often missing from the inpatient medical record (p. 494).

A pretest is a trial run of a measure and data collection methods that is undertaken to provide information regarding the method’s reliability and validity and to reveal problems relating to its content, administration, and scoring. The measure must be pretested, usually on a small sample of subjects for whom it was designed under conditions that approximate as nearly as possible the conditions expected to exist when it is employed. For example, Kip and colleagues (2009) in a study of patients’ adherence to Anti-Retroviral Therapy in Botswana pretested their face-to-face structured interview using a number of approaches. Specifically, (1) each item on the interview schedule was judged by two researchers and four HIV/AIDS clinicians to ascertain if it measured the theoretical construct it purported to measure, (2) Cronbach’s alpha coefficient was employed to determine if there was evidence that items within each subscale were internally consistent, (3) administration procedures and potential problems with items were assessed by interviewing 10 patients who were excluded from participation in the actual study, and (4) 12 faculty members, 2 experienced nurse researchers, and 1 statistician reviewed the interview schedule for content and construct validity. Another example can be found in the work of Glaister (2007) who, in a study to determine if the presence of mathematical and computer anxiety in nursing students affects learning of dosage calculations, pretested her dosage competency instrument with a group of six students who had successfully completed studies in the content area the preceding semester.

During the conduct of the pretest, it is important to be attentive to the reactions, comments, and nonverbal communication of respondents that might give clues to problems with the measure. Similarly, observations and concerns during the administration that may suggest needed improvements should be recorded. For example, problems related to maintaining interest, questions raised by respondents, adequacy of the time provided to respond, test length, and the like may come to light during the pretest. It is also most beneficial after the pretest data have been collected to ask respondents to identify difficulties they have encountered in completing the measure, suggestions they may have for improving it, and possible discrepancies between the purpose for which items were constructed and how subjects understood and responded to the items. In the above study, Glaister (2007) conducted focus groups after completion of the dosage competency instrument with eight randomly selected participants from each intervention group in her study.
In addition, scores should be computed and data compiled and tabulated for interpretation, including the preparation of tables and graphs, so that any difficulties with scoring, interpretation, or preparation of the data for analysis will be evident. Appropriate procedures for estimating the method’s reliability and validity should be employed, including item-analysis procedures using the pretest data. On the basis of the information obtained from the pretest, especially the resulting evidence for the measure’s reliability and validity, a decision should be made concerning whether the method will be used as is or needs modification before it can be employed. If it is determined that the method needs modifications for improvement, these should be made and the method pretested again prior to its use.

When sufficient evidence for reliability and validity is obtained as a result of the pretest, the measure may then be employed for data collection, but its reliability and validity should still be monitored each time it is employed, using less extensive and more economical procedures than required for the pretest. Should monitoring of the measure suggest that reliability and/or validity are not holding up with use, it is necessary to scrutinize the measure using more rigorous and extensive reliability and validity studies to ascertain needed changes, to make the modifications required, and then to pretest again (Waltz & Bausell, 1981, pp. 84–85). Another example of pretesting can be found in the work of Blood-Siegfried and associates (2008) who developed an evaluation rubric to measure quality in a graduate online curriculum and conducted a pretest to assess its utility and applicability in five online core master’s level courses that resulted in revision. Attention now turns to the determination of the reliability of norm-referenced measures.

Norm-referenced measures are derived from classical measurement theory. In Chapter 3, it was noted that in this view, every observed score (O) is composed of a true score (T), which represents the precise amount of the attribute possessed by the subject at measurement time, and an error score (E). If a large number of subjects are measured on the attribute in question and their observed scores plotted, reliability would be conceptualized as the proportion of the variance in the observed score distribution that is due to true differences in subjects’ possession of the attribute being measured. Unreliability would be conceptualized as the proportion of variance in the observed score distribution that is due to error. Hence, in this view every measurement involves some error that, although it can never be eliminated in total, can be reduced.

Measurement error may be random or systematic. If the nurse had only one thermometer and it was accurate, but she misread it while obtaining different measures, the error would be random. Random errors limit the degree of precision in estimating the true scores from observed scores and therefore lead to ambiguous measurement and decreased reliability of the measure. In practice, reliability concerns the extent to which measurements are repeatable by the same individual using different measures of the same attribute or by different individuals using the same measure of an attribute. Thus, research and evaluation efforts are limited by the reliability of measuring instruments and/or reliability with which they are employed. More specifically, sources of random error include, but are not limited to, imprecision in the measure itself, temporal factors, individual differences at measurement time, and/or imprecision in the administration or scoring of the measure.

If, in the preceding example, the nurse employed the thermometer correctly, but the thermometer itself was inaccurate and always registered 0.5 points higher than it should, the error in the nurse’s measurement would be systematic. This systematic or constant error would contribute to the mean score of all subjects equally and thus would become part of the true score of each individual. Since validity is defined as the extent to which an instrument measures what it purports to measure, systematic errors, because they affect the true scores of all subjects, would decrease the validity of the measure rather than its reliability.

In Chapter 3, it was noted that reliability is a necessary but not sufficient condition for validity; that is, a measure that demonstrates evidence for reliability will not necessarily demonstrate evidence for validity as well. The amount of random error places a limit on measurement validity, but even in the complete absence of random errors there is no guarantee of measurement validity;
scores in means, standard deviations, and correlations because of random errors in the sampling of items. Thus, in this view, the preferred way to estimate the reliability of a measure is to correlate one measure with a number of other measures from the same domain of content. Since in practice this is often impractical, usually one measure is correlated with only one other measure to obtain an estimate of reliability. The domainsampling model suggests that the reliability of scores obtained on a sample of items from a domain increases with the number of items sampled. Thus, one item would be expected to have a small correlation with true scores, a 10-item measure a higher correlation, and a 100-item measure an even higher correlation.

CONCEPTUAL BASIS FOR RELIABILITY

The determination of reliability in the norm-referenced case is conceptualized using the domain-sampling model. As noted in Chapter 3, this model views any particular measure as composed of a random sample of items from a hypothetical domain of items. For example, an adjective checklist designed to measure anxiety in presurgical patients would be thought of as containing a random sample of adjectives from all possible adjectives reflective of anxiety in that patient group. Obviously, the model does not hold strictly true empirically, because it is usually not practical or feasible to explicate all possible items defining a domain of interest, thus items are actually randomly sampled for a specific measure. The model does, however, lead to principles and procedures for determining evidence for reliability that have much utility in practice.

On the basis of the domain-sampling model, the purpose for any measure is to estimate the measurement that would be obtained if all the items in the domain were employed. The score that any subject would obtain over the whole domain is his or her true score. To the extent that any sample of items on a given measure correlates highly with true scores, the sample of items is highly reliable. In other words, specific measures are viewed as randomly parallel tests that are assumed to differ somewhat from true

NORM-REFERENCED RELIABILITY PROCEDURES

In the norm-referenced case, reliability is usually estimated using a test-retest, parallel form, and/or internal consistency procedure.

The test-retest procedure is appropriate for determining the quality of measures and other methods designed to assess characteristics known to be relatively stable over the time period under investigation. For this reason, test-retest procedures are usually employed for investigating the reliability of affective measures. Since cognitive measures assess characteristics that tend to change rapidly, this procedure is not usually appropriate for estimating their reliability.

When a test-retest procedure is employed, the concern is with the consistency of performance one measure elicits from one group of subjects on two separate measurement occasions. To estimate test-retest reliability for a given measure, one would:

1. Administer the instrument or method under standardized conditions to a single group of subjects, representative of the group for which the measure was designed.
2. Readminister the same instrument or method under the same conditions to the same group of subjects. Usually the second administration occurs approximately 2 weeks after the first, although the time
may vary slightly from setting to setting. It should be noted that it is important to ascertain that no activities have occurred between the first and second administration that may have affected the stability of the characteristic being measured.

3. Determine the extent to which the two sets of scores are correlated. When data are measured at the interval level, the Pearson product–moment correlation coefficient \( r_{xy} \) that is discussed in Chapter 3 is taken as the estimate of reliability. When data are measured at the nominal or ordinal level, a nonparametric measure of association, such as Chi square–based procedures or Spearman rho, is used. Discussion of the conditions under which specific correlation coefficients are appropriately used, as well as their computation, may be found in Waltz and Bausell (1981), Nunnally and Bernstein (1994), Munro (2001), Polit and Beck (2008). An example of test-retest reliability can be found in Whiting and Mallory (2007) who conducted a longitudinal study to determine the effects of mentoring on middle school students by nursing and other college students. The correlation coefficient, \( r_{xy} \), was employed to compare mean item scores on the Child Behavior Checklist (CBCL) and Teachers Report Form (TRF) on two occasions. Examples of test-retest reliability also can be found in Hall, Rayens, and Peden (2008) and Wang and Chiou (2008).

The value of the reliability coefficient resulting from a test-retest procedure reflects the extent to which the measure rank orders the performances of the subjects the same on the two separate measurement occasions. For this reason, it is often referred to as the coefficient of stability. The closer the coefficient is to 1.00, the more stable the measuring device is presumed to be.

When it is desirable to employ a more stringent index of test-retest reliability, that is, to determine the absolute agreement between the two sets of scores, the percentage of agreement index is calculated. Engstrom (1988, pp. 383–389) advocates the percentage of agreement as an essential index for describing the reliability of physical measures because it reflects both the precision of measurement and frequency of error and has direct and useful clinical meaning. That is, in most clinical situations, some measurement error is acceptable, but there is a limit on the amount of error that can be tolerated without jeopardizing patient safety. This limit, she notes, can be used as an index of agreement. More specific discussion regarding the assessment of the reliability and validity of physical measures is presented in Chapter 18. For example, Arozullah and colleagues (2007) employed percentage of agreement in developing and validating a short-form, rapid estimate of adult literacy in medicine for assessing patient literacy in diverse research settings for use when designing interventions for clinical contexts. Chang and Roberts (2008) employed percentage of agreement between the investigator and a nurse with research and clinical experience with older adults concerning the amount of food eaten by residents in an observational study undertaken to investigate factors related to feeding difficulty that is shown in interaction between nursing assistants and elderly residents with dementia.

Whenever two forms of an instrument can be generated, the preferred method for assessing reliability is the parallel form procedure. In parallel form reliability, the interest is in assessing the consistency of performance that alternate forms of a measure elicit from one group of subjects during one administration. Two measures are considered alternate or parallel if they have (1) been constructed using the same objectives and procedures, (2) approximately equal means, (3) equal correlations with a third variable, and (4) equal standard deviations.

Prior to assessing parallel form reliability, it is necessary to obtain empirical evidence that the two measures meet these four criteria. To provide empirical evidence for equal means and standard deviations, both measures are administered to the same group of subjects on the same occasion, and a test of the significance of the difference between the means and a homogeneity of variance test is employed. If the resulting means are not statistically significantly different and the variances are homogeneous, evidence that the two measures are parallel is said to exist. Similarly, to obtain empirical evidence that both measures have equal correlations with a third
variable, a measure of a third variable believed to be highly correlated with the phenomena being assessed by the parallel measures, which has demonstrated evidence for reliability and validity, is administered to the same group of subjects on the same occasion as the two measures believed to be parallel. Evidence that the two measures are parallel is said to exist if the scores resulting for each of the two measures correlate significantly with the scores resulting from the measurement of the third variable.

Given evidence for parallel forms, to estimate parallel form reliability one would:

1. Administer two alternative forms of a measure to one representative group of subjects on the same occasion or on two separate occasions.
2. Determine the extent to which the two sets of scores are correlated, using an appropriate parametric or nonparametric correlation coefficient as an estimate of reliability.

If both forms of the measure are administered on the same occasion, the value of the resulting reliability coefficient reflects form equivalence only. If the measure is administered on two occasions, stability as well as form equivalence is reflected. Values above 0.80 are usually taken as evidence that the forms may be used interchangeably. An example of the parallel measures model can be found in Finke and colleagues (2003).

Internal consistency reliability is most frequently employed for cognitive measures where the concern is with the consistency of performance of one group of individuals across the items on a single measure. To estimate the internal consistency of a measure, one would administer the measure under standardized conditions to a representative group on one occasion. The alpha coefficient, KR 20, or KR 21, would be calculated as the estimate of reliability.

The alpha coefficient is the preferred index of internal consistency reliability because it (1) has a single value for any given set of data, and (2) is equal in value to the mean of the distribution of all possible split-half coefficients associated with a particular set of data. Alpha represents the extent to which performance on any one item on an instrument is a good indicator of performance on any other item in the same instrument. An example of determination of the alpha coefficient follows.

**Example 5.1**

Five newly diagnosed diabetics are given a 10-item multiple-choice test to assess their knowledge and understanding of diabetic food exchanges and the scores in Table 5.1 are obtained.

Using the information in Table 5.1:

1. There are 10 items on the tool, the number of items −1 = 9.
2. The variance of the test score distribution is 2.64
3. The sum of the variances for each of the 10 items is 2.04, that is (0.24 + 0.4 + 0.4 + 0.4 + 0.2 + 0.2 + 0 + 0 + 0 + 0.2).
4. \(\alpha = (\text{the number of items}/\text{the number of items} - 1) \times \left[1 - \left(\frac{\text{sum of the item variances}}{\text{variance of the test score distribution}}\right)\right]\)

<table>
<thead>
<tr>
<th>TABLE 5.1</th>
<th>Scores Obtained on a Hypothetical Test of Diabetic Food Exchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient</strong></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Variance</strong></td>
<td>0.24</td>
</tr>
</tbody>
</table>
5. \[
\text{alpha} = \frac{9}{10} \left[ 1 - \frac{2.04}{2.64} \right] \\
= (1.11) (0.77) \\
= (1.11) (0.23) \\
= 0.2553, \text{ rounded to 0.26}
\]

The resulting alpha value of 0.26 indicates the test has a very low degree of internal consistency reliability, that is, that the item intercorrelations are low. As a result, performance on any one item is not a good predictor of performance on any other item. A high alpha value is usually taken as evidence that the test as a whole is measuring just one attribute, for example, knowledge of diabetic food exchanges, which in the example is not the case. When tests are designed to measure more than one attribute (e.g., those with subscales or components), alpha should be determined for each scale or subset of homogeneous items in addition to the test as a whole.

A number of factors surrounding the measurement situation may affect the alpha value obtained, and for this reason, it is wise to consider the following when alpha is employed:

1. Alpha is a function of test length. The longer the test, that is, the more items included, the higher the resulting alpha value.
2. A spuriously high alpha may be obtained in a situation in which it is not possible for most respondents to complete the test or measure. As a rule of thumb, Martuza (1977) suggests that if less than 85% of the subjects respond to all items on the test, alpha should not be used as an estimate of reliability. Equivalently, alpha should not be used when speeded tests are employed.
3. As with all reliability estimates, alpha should be determined each time a test is employed.
4. From the example, it is apparent that alpha is dependent upon the total test variance; that is, the higher the value of the total test variance, the greater the alpha value obtained.
5. Alpha is dependent upon the shape of the resulting distribution of test scores. When a skewed test-score distribution results, variance is usually less than that obtained when the distribution approximates a normal curve, and hence, alpha may be lower in value. Similarly, when alpha is employed with a group of subjects homogeneous in the attribute being measured, alpha will be lower than when a heterogeneous group is measured.

KR 20 and KR 21 are special cases of alpha used when data are dichotomously scored, that is, when each item in a test is scored 1 if correct and 0 if incorrect or missing.

**Example 5.2**

Using the data from Table 5.1, KR 20 is determined as follows:

1. There are 10 items on the tool, the number of items \(-1 = 9\).
2. The variance for item one = the proportion of correct responses to the item \((2/5\) or 0.4) multiplied by the proportion of incorrect responses \((3/5\) or 0.6), that is \((0.4)(0.6) = 0.24. The variances for the remaining 9 items are 0.24, 0.24, 0.24, 0.16, 0.16, 0, 0, 0, and 0.16, respectively.
3. The sum of the item variances is 1.44.
4. The variance for the test-score distribution is 2.64.
5. \[
KR 20 = \frac{9}{10} \left[ 1 - \frac{1.44}{2.64} \right] \\
= (1.11) (0.54) \\
= (1.11) (0.46) \\
= 0.51
\]

If one can assume that the difficulty level of all items is the same, that is, that the proportion of correct responses is the same for all items, KR 21 may be employed. Since this is not the case for the items in Table 5.1, that is, the item \(p\) levels are not the same, the determination of KR 21 is best exemplified using a different data set.

**Example 5.3**

A 20-item tool is used to assess six students’ scores on a research pretest. Items are scored 1 if correct, and 0 if incorrect. The mean of the resulting
scores to the same objects or responses. Thus, interrater reliability is determined when two or more raters judge the performance of one group of subjects at the same time.

To determine interrater reliability, one would:

1. Employ two or more competent raters to score the responses of one group of subjects to a set of subjective test items at the same time.
2. Use an appropriate correlation coefficient to determine the degree of agreement between the different raters in assigning the scores. If only two raters are used, the Pearson product–moment correlation coefficient ($r_{xy}$) may be used as an index of agreement among them. When more than two raters are employed, coefficient alpha may be used, with the column headings representing the judges and the row headings representing the subject's performance ratings. Table 5.2 presents an example of alpha employed for the determination of the interrater reliability of six judges of five subjects' performance on a subjective tool.

Additional examples of internal consistency reliability can be found in the studies of Blackwood and Wilson-Barnett (2007), Lavoie-Tremblay and associates (2008), Hatfield (2008), and Rew, Grady, Whitaker, and Bowman (2008).

When a subjectively scored measure is employed, two types of reliability are important, interrater reliability and intrarater reliability.

**Interrater reliability** refers to the consistency of performance (i.e., the degree of agreement) among different raters or judges in assigning scores to the same objects or responses. Thus, interrater reliability is determined when two or more raters judge the performance of one group of subjects at the same time.

To determine interrater reliability, one would:

1. Employ two or more competent raters to score the responses of one group of subjects to a set of subjective test items at the same time.
2. Use an appropriate correlation coefficient to determine the degree of agreement between the different raters in assigning the scores. If only two raters are used, the Pearson product–moment correlation coefficient ($r_{xy}$) may be used as an index of agreement among them. When more than two raters are employed, coefficient alpha may be used, with the column headings representing the judges and the row headings representing the subject’s performance ratings. Table 5.2 presents an example of alpha employed for the determination of the interrater reliability of six judges of five subjects’ performance on a subjective tool.

An interrater reliability coefficient of 0 indicates complete lack of agreement between judges; a coefficient of 1.00 indicates complete agreement. It should be noted that agreement does not mean that the same scores were assigned by all raters.

**Table 5.2** Example of Alpha Employed for the Determination of Interrater Reliability for Six Judges’ Rating of Five Subjects’ Performances

<table>
<thead>
<tr>
<th>Judges</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>10</td>
<td>10</td>
<td>43</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>47</td>
<td>23</td>
<td>23</td>
<td>21</td>
<td>47</td>
<td>43</td>
<td>204</td>
</tr>
<tr>
<td>Mean</td>
<td>9.4</td>
<td>4.6</td>
<td>4.6</td>
<td>4.2</td>
<td>9.4</td>
<td>8.6</td>
<td>40.8</td>
</tr>
<tr>
<td>Variance</td>
<td>0.64</td>
<td>0.24</td>
<td>0.20</td>
<td>0.20</td>
<td>0.70</td>
<td>0.64</td>
<td>1.44</td>
</tr>
</tbody>
</table>

\[
\text{alpha} = \frac{6}{5} \left[ 1 - \left( \frac{3.86}{8.56} \right) \right] \\
= (1.2) (1 - 0.45) \\
= (1.2) (0.55) \\
= 0.66
\]
but rather that the relative ordering or ranking of scores assigned by one judge matches the relative order assigned by the other judges. Interrater reliability is especially important when observational measures are employed as well as when other subjective measures are used, such as free responses requiring categorization, essays, and case studies. Raters are often trained to a high degree of agreement in scoring subjective measures using the intrarater reliability procedure to determine when the raters are using essentially the same criteria for scoring the responses. Examples of intrarater reliability can be found in the studies of Valentine and Cooper (2008), Immers, Schuurmans, and van de Biji (2005), and Arnold (2003).

**Intrarater reliability** refers to the consistency with which one rater assigns scores to a single set of responses on two occasions. To determine intrarater reliability:

1. A large number of subjects are asked to respond to the same subjective tool.
2. Scores are assigned to the responses using some predefined criteria.
3. Answers are not recorded on the respondents’ answer sheets and anonymity of respondents is protected as much as possible.
4. Approximately 2 weeks after the first scoring, response sheets are shuffled and rescored a second time by the same rater who scored them on occasion one, using the same predefined criteria.
5. The Pearson correlation coefficient \( r_{xy} \) between the two sets of scores is determined as a measure of agreement.

A 0 value for the resulting coefficient is interpreted as inconsistency, and a value of 1.00 is interpreted as complete consistency. Intrarater reliability is useful in determining the extent to which an individual applies the same criteria to rating responses on different occasions and should be employed for this purpose by those who use subjective measures. This technique, because of the time lapse between the first and second ratings, also allows one to determine to some extent the degree to which ratings are influenced by temporal factors. An example of intrarater reliability can be found in Burge (2003).

### ESTIMATING THE RELIABILITY OF CHANGES IN TEST LENGTH

In many instances, as a result of item analysis that is discussed in Chapter 6, it appears that a measure might be improved either by shortening its length, by eliminating faulty items, or by adding more items. Similarly, when a measure is being developed and tested, the test constructor often will include more items than the number desired for the final form in order to assess by item analysis the performance of individual items with the intent to retain the best items and eliminate faulty items. In these cases, it is important to remember that reliability is a function of test length; that is, a longer test tends to demonstrate a higher reliability than a shorter test and vice versa. For this reason, following an item analysis, it is often useful to estimate what the reliability of the measure would be if test length were also varied from the form tested. The Spearman-Brown formula permits one to estimate the reliability of a shortened or lengthened measure with known reliability. The assumption, when this approach is used, is that while test length is changed, the nature of the test is not.

**Example 5.4**

An original 100-item measure has a known reliability of 0.80 and as a result of item analysis is to be reduced to half its original length or 50 items. The reliability of the shortened version is determined in the following manner. The reliability of the shortened version = the length of the shortened test \((1/2)\) multiplied by the original reliability \((0.80)\) divided by \(1 + (the\ length\ of\ the\ shortened\ test –1)\) multiplied by the original reliability. Specifically,

1. the length of the shortened test is \(1/2\) multiplied by the original reliability \((0.80) = 0.40\)
2. \(0.40/1 + (1/2 – 1) (0.80) =\)
3. \(0.40/(1/2 – 1) (0.80) =\)
4. \(0.40/1 – (0.40) =\)
5. \(0.40/0.60 =\)
6. \(0.66\)

The reliability of the shortened version is estimated to be 0.66.
Example 5.5

To estimate the reliability of a measure 3 times as long as the original measure, with an original reliability of 0.20, the reliability of the lengthened test =

1. multiple the increased length of the test (3) by the original reliability (0.20) = 0.60
2. divide 0.60 by 1 + (3 – 1) (0.20) =
3. \( \frac{0.60}{1.40} = \)
4. 0.42

The reliability of the lengthened test is estimated to be 0.42.

It should be noted that whenever a test is to be lengthened, it is important to consider the potential negative effects of increased test length; that is, extreme increases in test length may introduce unwanted factors such as boredom, fatigue, diminished response rate, and other variables that may actually serve to decrease rather than increase reliability.

CRITERION-REFERENCED RELIABILITY PROCEDURES

In criterion-referenced measurement, reliability is concerned with the consistency or dependability with which a measuring device classifies or categorizes phenomena. For this reason, some researchers use the terms dependability or agreement to refer to reliability of criterion-referenced tests or measures (Brown & Hudson, 2002). In the case of criterion-referenced results, the range of variability is often quite reduced, particularly when scores have been divided into gross categories, such as master and nonmaster. In the norm-referenced case, scores are usually highly variable and reliability is calculated on the basis of parametric correlational analyses. With criterion-referenced measurement the resulting scores are generally less variable than in the norm-referenced case, so reliability is often determined with nonparametric procedures. However, when criterion-referenced scores are reported as percentages, their variability may be similar to those in the norm-referenced case, and most of the procedures used to estimate reliability in the norm-referenced case also are appropriate to assess the reliability of a criterion-referenced measure (Popham, 1978).

In some cases, a criterion-referenced measure may yield scores that are quite variable as far as the actual scores are concerned, but the interpretation of the range of scores would have reduced variability. For example, if a nursing instructor uses a test to determine if a student has mastered the requisite knowledge in a maternity nursing course, the potential score range might be 0 to 100%. However, assume that the cut score for mastery is set at 80%. If the student scores 75% on the test, the student has not mastered the content. Based on the way in which the scores on the test are interpreted and used, the concern for testing reliability is on the consistency with which the measure classifies the subjects within the specified categories of the content domain. Even if a whole class of 20 students is tested by the measure, with the scores reflecting marked variability, the primary concern would be the consistency with which the measure classifies each student as master or nonmaster in terms of the stated criterion standard, the cut score. This brings to mind another very important point. In the case of criterion-referenced measurement, unless the standard or cut score has high validity, the computation of a reliability index has little significance. A high reliability index in a situation in which the standard has been improperly set may mean only that the measure consistently classifies objects or phenomena incorrectly.

In the criterion-referenced framework, reliability is usually estimated by employing test-retest, parallel forms, and intrarater and interrater agreement procedures.

Criterion-Referenced Test-Retest Procedure

The focus of the test-retest procedure for criterion-referenced measures is on the stability over time of the classification of phenomena by a measure on two separate measurement occasions. In other words, the focus is on the ability of a measure to consistently classify objects or persons into the same categories on two separate occasions. The extent to which a criterion-referenced measure is able to reflect stability of results over
time is an indication of the degree to which it is free from random measurement error.

To estimate test-retest reliability for a given criterion-referenced measure, an investigator would follow the same general guidelines in administering the measure as described for the norm-referenced case. However, the calculation of the reliability index would be different because of the difference in the way criterion-referenced test results are interpreted and used.

Two statistics have been identified that may be employed to assess the stability of criterion-referenced test procedure, regardless of the number of categories established by the measure: \( P_o \), also termed percent agreement or the coefficient of agreement, is the proportion of observed agreements in classifications on both occasions and is the simplest index of agreement (Portney & Watkins, 2009). \( K \) or kappa also referred to as Cohen’s \( K \), is the proportion of persons consistently classified in the same category on both occasions beyond that expected by chance. Hence, \( K \) is \( P_o \) corrected for chance agreements.

**Computation of \( P_o \) (Percent Agreement or the Coefficient of Agreement)**

\( P_o \) is the number of exact agreements divided by the number of possible agreements. According to Subkoviak (1980), \( P_o \) is best computed by the following formula.

\[
P_o = \frac{m}{\sum_{k=1}^{m} P_{kk}}
\]

where \( m \) = the number of classification categories

\( P_{kk} \) = the proportion of objects or persons consistently classified in the \( k \)th category

For illustrative purposes, assume that a criterion-referenced measure designed to assess a nurse’s attitudes toward elderly clients is administered to 30 nurses at 2-week intervals to determine test-retest reliability. Results are illustrated in Table 5.3.

The \( P_o \) would be the proportion of student nurses consistently classified with positive/positive and negative/negative attitudes on both testing occasions. Thus, \( P_o \) would be the total proportion of the values in cells A and D. Hence:

\[
P_o = \frac{15/30 + 12/30}{16/30 + 14/30} = \frac{0.50 + 0.40}{0.53}
\]

Therefore, in this example 0.90 or 90% of the classifications made by the measure on both testing occasions were in agreement. However, some small portion of this estimate can be attributed to chance and 0.90 is, therefore, an overestimate of the stability of the test.

The proportion of chance agreements (\( P_r \)) for data in Table 5.3 can be computed by the product of the corresponding row and column totals as indicated by Formula 5.1.

### TABLE 5.3 Hypothetical Test Results Matrix for 30 Nurses for Computing \( P_o \) and \( K \) on a Measure of Nurse Attitudes Toward Elderly Clients

<table>
<thead>
<tr>
<th>First Administration</th>
<th>Positive</th>
<th>Negative</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second Administration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>15</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Negative</td>
<td>1</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
</tbody>
</table>
**Computation of the Proportion of Chance Agreements**

Chance agreement is reflected by the number of expected agreements divided by the number of possible agreements. Subkoviak (1980) provides the following formula for calculating chance agreements.

**Formula 5.2**

Calculating one proportion of chance agreements ($P_c$) (Subkoviak, 1980)

\[
m \quad P_c = \sum P_k P_k
\]

\[
k = 1
\]

where $m$ = the number of classification categories

$P_k P_k$ = the proportion of objects or persons assigned to category $k$ on each measurement occasion, respectively

In this situation $P_c$ would be computed by the proportions for $(A + B)$, $(A + C)$, and $(C + D)$, $(B + D)$. Thus,

\[
P = (17/30) (16/30) + (13/30) (14/30)
\]

\[
= (0.57 \times 0.53) + (0.43 \times 0.47)
\]

\[
= 0.30 + 0.20
\]

\[
= 0.50
\]

**Computation of Cohen’s kappa ($K$)**

The proportion of nonchance agreements is provided by kappa ($K$) (Cohen, 1960). $P_o$, observed agreements, and $P_c$, chance agreements, are used to calculate $K$ as follows:

**Formula 5.3**

Calculating the proportion of nonchance agreements ($K$) (Martuza, 1977; Subkoviak, 1980)

\[
K = P_o - P_c / 1 - P
\]

In the present example, $K$ is computed by:

\[
K = 0.90 - 0.50 / 1 - 0.50
\]

\[
= 0.40 / 0.50
\]

\[
= 0.80
\]

**Computation of $K_{\text{max}}$**

An upper-bound $K$ value of 1.00 will result only when the marginal distributions for the two administrations have the same shape or proportions in them, for example, when the proportions in the right upper cell ($A + B$) and in the bottom left cell ($A + C$) of the table are the same. One can determine the maximum possible value of $K$ for a specific situation by adjusting the values within the cells of the table (cells $A$, $B$, $C$, and $D$) to reflect the maximum number of possible agreements or consistent test classifications that could be congruent with the observed marginal proportions (marginal proportions are not changed) and by calculating a revised version of $K$ using the adjusted values. When this is done, the resulting value is $K_{\text{max}}$, which represents the upper limit value that $K$ could take on with the particular distribution of results. The $K_{\text{max}}$ value provides information that can facilitate a better interpretation of a specific $K$ value. When the $K/K_{\text{max}}$ ratio is calculated, it provides a value that can be interpreted on a standard scale. The

**TABLE 5.4 Data From Table 5.3 Expressed as Proportions**

<table>
<thead>
<tr>
<th>First Administration</th>
<th>Positive</th>
<th>Negative</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second Administration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>0.50</td>
<td>0.07</td>
<td>0.57</td>
</tr>
<tr>
<td>(A)</td>
<td></td>
<td>(B)</td>
<td>(A + B)</td>
</tr>
<tr>
<td>Negative</td>
<td>0.03</td>
<td>0.40</td>
<td>0.43</td>
</tr>
<tr>
<td>(C)</td>
<td></td>
<td>(D)</td>
<td>(C + D)</td>
</tr>
<tr>
<td>Totals</td>
<td>0.53</td>
<td>0.47</td>
<td>1.00</td>
</tr>
<tr>
<td>(A + C)</td>
<td></td>
<td>(B + D)</td>
<td>(A + B + C + D)</td>
</tr>
</tbody>
</table>
since significant events may occur during the between-testing interval that might interfere with results on the second administration. Also, administration of the test on the first occasion might influence the results on the second testing, particularly if the same measure is used. The use of parallel forms of a measure could help remedy such situations. However, a major concern in instances in which parallel forms of a measure are used is whether the two forms produce a substantial degree of agreement or consistency in the classification of subjects in a specified group.

Two criterion-referenced measures are considered parallel if they assess the same content domain, that is, if they were constructed with the same set of test specifications and if items are relatively homogeneous. Parallel forms of a criterion-referenced measure may be created through random item selection from a pool of items constructed with the same test specifications or the same item-generation rules (Popham, 1978).

The approach to the estimation of the reliability of parallel forms involves administering the two alternate forms of the measure to one specified group on the same measurement occasion. If it is not possible to administer the two forms of the test at the same time, they should be administered under similar circumstances within a short period of time. After the two versions of the measure are administered, and would be calculated in the same manner used in the test-retest case. Data from the two forms would be compiled and placed in a matrix as shown in Table 5.3. However, the label “First Administration” should be changed to “Form 1,” and “Second Administration” to “Form 2.” If the two forms have high parallel-form reliability, there will be a high consistency in the classification of subjects.

**TABLE 5.5 Adjustments Required in Table 5.4 for the Calculation of $K_{max}$**

<table>
<thead>
<tr>
<th>First Administration</th>
<th>Positive</th>
<th>Negative</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second Administration</strong></td>
<td>0.53 (A)</td>
<td>0.04 (B)</td>
<td>0.57 (A + B)</td>
</tr>
<tr>
<td>Positive</td>
<td>0.53 (A)</td>
<td>0.04 (B)</td>
<td>0.57 (A + B)</td>
</tr>
<tr>
<td>Negative</td>
<td>0.00 (C)</td>
<td>0.43 (D)</td>
<td>0.43 (C + D)</td>
</tr>
<tr>
<td>Totals</td>
<td>0.53 (A + C)</td>
<td>0.47 (B + D)</td>
<td>1.00 (A + B + C + D)</td>
</tr>
</tbody>
</table>
into categories. In the parallel-forms procedure, high $P_o$ and $K$ values reflect consistency between the alternate forms of a measure.

**Criterion-Referenced Interrater and Intrarater Agreement Procedures**

As with the test-retest and the parallel-forms procedures, $P_o$ and $K$ can be employed to estimate interrater and intrarater agreement, which also may be referred to as interjudge and intrajudge agreement (Tindal & Marston, 1990). The focus of interrater agreement in the criterion-referenced case is on the consistency of classifications of two (or more) different raters who classify a specified group of objects or persons using the same measurement tool on the same measurement occasion. For example, if a rating tool designed to measure the environmental safety of nursing units is used, two nurse raters could be employed to independently classify a group of nursing units as either safe or unsafe one at a time. Once results are obtained, $P_o$ and $K$ could be calculated to determine interrater agreement for the classification of the safety of the nursing units. The values of $P_o$ and $K$ are computed in the same manner as indicated previously and used as the index of interrater agreement. Prior to computing $P_o$ and $K$, the data would be set up in a matrix table similar to Table 5.3, but with the appropriate label changes, that is, changing “First Administration” to “Rater 1,” “Second Administration” to “Rater 2,” “Positive” to “Safe,” and “Negative” to “Unsafe.”

Intrarater agreement for criterion-referenced measurement situations is the consistency with which a single rater classifies a group of persons or objects, using a specified measuring tool after rating each person or object on two separate occasions. In instances when intrarater agreement is used, there is a danger that the two separate rating situations are not consistent with each other unless the situation has been captured by a recording device, such as video or audio recordings or written documents from which both ratings can be made. Another danger is that the first rating might affect the second rating. Steps would be taken to minimize this problem by using such techniques as obscuring the identification of the persons or objects being rated, altering the order in which ratings are done, and reordering the pages of the rating tool if appropriate. Data are arrayed in a matrix in the manner discussed previously, with the proper labeling changes. $P_o$ and $K$ are then calculated to provide an index of intrarater agreement (Martuza, 1977).

In cases where criterion-referenced measurement is based on ratings by observers, there are several types of rating errors that can negatively impact the reliability and, thus the validity of ratings. These include error of standards, halo error, logic error, similarity error, and central tendency error (Shrock & Coscarelli, 2007).

- **Error of standards** result when numerical and descriptive rating scales fail to provide definitions of behaviors specific enough to prevent raters from using their own standards to rating items differently from those intended by the developer of the measure. Hence, different raters would be more likely to rate the same items differently, thereby reducing reliability of ratings between raters.

- **Halo error** occurs when raters allow their opinion of the performer to influence their performance ratings. This may be done subconsciously and may be in a negative or positive direction. Therefore, halo error can affect scores negatively or positively.

- **Logic error** results when a rater rates one characteristic of a performer when another characteristic is supposed to be the focus of the rating. This occurs when the rater is not fully aware of the independence of two performance characteristics. For example, suppose a clinical instructor assumes that a student who takes longer to perform a procedure is less knowledgeable about the procedure. In actuality, speed of conducting the procedure may have nothing to do with the amount of knowledge about the procedure.

- **Similarity error** occurs when a rater has the tendency to rate a performer that he or she perceived to be similar to him or her more highly than those whom he or she perceives are “different.” This error also is referred to as “similarity-to-me error.”

- **Central tendency error** is associated with rating scales that allow raters to choose points along a continuum, such as with behaviorally anchored, descriptive, or numerical scales. Raters will often avoid rating performers on the extreme anchors of rating scales and tend to group ratings more in the middle of the scale.
This behavior is so consistent that for most Likert-type scales the extreme positions are often lost; thus, a seven-point scale is responded to as if it is a five-point scale during ratings. For this reason, some psychometricians recommend using only an even number of categories on rating scales (Shrock & Coscarelli, 2007).

**Weighted Kappa (\(K_w\))**

When Cohen's kappa is calculated, the frequencies along the agreement diagonal are used. This approach assumes that all disagreements are of equal seriousness, although this could not in actuality be the case. In some instances, the researcher may want to assign greater weights to some disagreements in relation to others due to the differential risks of some disagreements. For example, when criterion-referenced scores are assigned using ordinal categories with more than two categories such as 0, +1, +2, or +3, a disagreement between ratings of 0 and +3 is much more serious than a disagreement between 0 and +1. In the former situation, there is a difference of 3 categories of disagreement and in the latter, a difference of only 1 category. Therefore, the disagreement in the former case is much more serious than the latter. In situations where disagreements can be differentiated in this way, a weighted kappa, \(K_w\), can be used to estimate reliability (Cohen, 1968; Portney & Watkins, 2009). Weighted kappa gives more credits to the more serious disagreements than those that are less serious by assigning different weights to the off-diagonal cells based on the seriousness of disagreements. The assignment of weights is basically a judgmental process (Cohen, 1968), but should be consistent with a hypothesis that defines the relative seriousness of the misclassifications or disagreements. The assignment of weights can be incremental, asymmetrical, or symmetrical weights. *Incremental weights* assume that the categories are on an ordinal scale with equal weights; *asymmetrical weights* are based on the assumption that disagreements do not fit a uniform pattern but that the direction of disagreement is important; and *symmetrical weights* assume that the direction of disagreement is unimportant.

Weights for incremental disagreements can be assigned by using the formula: \(w = (r_1 - r_2)^2\); where \(w\) = the assigned weight; and \(r_1\) and \(r_2\) = scores assigned by rater 1 and rater 2 to a cell (Fleiss & Cohen, 1973). Hence, \(r_1 - r_2\) indicates the deviation from agreement for each cell in the agreement matrix. Weights of zero would automatically be assigned to all cells on the diagonal where there is no disagreement.

When assigning asymmetrical weights, the evaluation of weights does not fit a uniform pattern. It is important to consider if the direction of the disagreement is important for assigning weights for disagreements and the amount of weight. For example, let’s assume two raters have the task of rating the developmental behaviors of 2-year-old boys as either “below normal,” “normal,” or “advanced.” Assigning a rating of “advanced” to a child who is “below normal” would be considered a more serious disagreement than assigning a rating of “normal” to a child who is “advanced.” This would be the case because needed corrective intervention may not be given to the child who is “below normal” that has been misclassified as “advanced.” It also would be of concern if there was a misclassification of a child who was “below normal” as “normal.” On the other hand, the misclassification of a child who was “advanced” as “normal” would not be quite as serious. Therefore, the more serious the hypothesized misclassification, the more heavily the misclassification would be weighted.

In the case of assignment of symmetrical weights, the direction of disagreement is considered unimportant. For example, one might argue that any disagreement between “below normal” and “advanced” is twice as serious as a disagreement between “below normal” and “normal,” and that a disagreement between “normal” and “advanced” is only minimally important. Therefore, disagreements between “below normal” and “advanced” might be assigned a weight of 6 while a disagreement between “below normal” and “normal” would be given a score of 3, and a weight of 1 might be assigned to disagreements between “normal” and “advanced.”

Calculation of \(K_w\) would proceed with the use of the assigned weights to each cell in the agreement matrix. A limitation of this procedure is that if weights are assigned in an arbitrary manner and are not based on a sound hypothesis, then the value of \(K_w\) would be arbitrary also. Therefore, the rationale for the assignment of
weights must be clear and scientifically defensible. Hence, when $K_w$ is calculated, the research report should specify the weighting procedure and the rationale for the assignment of weights.

**Interpretation of $P_o$ and $K$ Values**

Several points should be kept in mind regarding the interpretation of $P_o$ and $K$ values. The value of $P_o$ can range from 0 to 1.00. Total disagreement in observed test classifications is reflected by a $P_o$ value of 0, while “total agreement” in observed results is reflected by a $P_o$ value of 1.00. As indicated by the formula for $K$, the value of $K$ is always less than or equal to $P_o$. The size of the difference between $P_o$ and $K$ is always a function of the size of $P_o$ or chance agreements. The value of $K$ always lies within an interval between $-1.00$ (which represents complete inconsistency of test results) and 1.00 (which reflects total consistency of results) (Hashway, 1998). The upper limit of 1.00 for $K$ is fixed; however, the lower-bound value may fluctuate from one situation to another depending upon several influencing factors. Landis and Koch (1977) proposed the standards for interpretation of the strength of agreement for $K$ as follows: Kappa values above 0.80 indicate near perfect reliability; values between 0.61 and 0.80 imply substantial reliability; values between 0.41 and 0.60 indicate moderate reliability; kappas between 0.21 and 0.40 reflect fair reliability; and values equal to or less than 0.21 indicate slight reliability. Both $P_o$ and $K$ are affected by factors such as test length, number of response alternatives (e.g., when items are multiple choice), the value of the cut score used to classify subjects, sample size, and the homogeneity of the group of subjects. For example, as the number of response categories increases, the extent of agreement will usually decrease; and homogeneous samples often lead to a high percentage of agreements. Small samples can result in misleading results due to rater bias (Portney & Watkins, 2009). At this time, guidelines related to these factors (which would facilitate further interpretation of $P_o$ and $K$ values) have not been explicated. Whenever $P_o$ and $K$ are used to describe the reliability of a criterion-referenced test, these influencing factors should be clearly described because of their impact on the values of $P_o$ and $K$. However, it should be noted that the size of the difference between $P_o$ and $K$ represents the amount of susceptibility of the decision process to chance factors (Martuza, 1977). It is possible to use kappa with more than two raters or more than two test-retest administrations (Fleiss, 1971), however, it is best to use separate kappas computed for pairs of raters or pairs of test-retest administrations to facilitate ease of interpretation of results.

**SUMMARY**

Every measurement involves some error that cannot be eliminated but can be reduced by using sound approaches to measurement. Random errors of measurement affect reliability. Reliability must be assessed every time a given measure is employed. The domain-sampling model is the conceptual basis of choice for the determination of reliability in the norm-referenced case. Norm-referenced reliability is usually estimated using a test-retest, parallel form, and/or internal consistency procedure. In addition, when a subjectively scored measure is used, it is important to consider interrater and/or intrarater reliability as well. When variations in the length of a measure result from item analysis, estimations of reliability using the Spearman-Brown formula should be considered prior to actually making such modifications.

Each of the types of reliability procedures is applicable in both norm-referenced and criterion-referenced measurement. The principles for each type of reliability assessment are the same regardless of the measurement framework employed. However, the approach to calculation of the reliability coefficient depends upon the nature of the score that results from the measurement effort. As noted previously, since norm-referenced measures result in scores that are at the interval level of measurement, parametric statistical procedures are used. In the criterion-referenced case, nonparametric statistics are employed when categorical scores or classifications result, and parametric statistics are permissible when percentage scores result and the distribution of scores is not highly skewed. Table 5.6 summarizes the types of reliability procedures and related statistics.
that can be applied in the norm- and criterion-referenced cases.

When the criterion-referenced measurement framework is used, reliability procedures follow the same general principles as in the norm-referenced case. However, scores are often not as variable since, in many cases, criterion-referenced measures result in classifications or the placement of the objects that are the focus of measurement into categories. In this instance, percent agreement ($P_o$) and/or Kappa ($K$) are typically used as approaches

### TABLE 5.6 Types of Norm-Referenced and Criterion-Referenced Reliability Procedures and Related Statistics

<table>
<thead>
<tr>
<th>Reliability Procedure</th>
<th>Norm-Referenced Statistic(s)</th>
<th>Criterion-Referenced Statistic(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test-Retest:</strong> Concerned with consistency of measurements that one instrument or tool elicits from one group of subjects on two separate measurement occasions. (Stability assessment)</td>
<td>Correlation of the two sets of scores using Pearson product–moment correlation.</td>
<td>The percent agreement ($P_o$) of classification of subjects on the two separate measurement occasions is calculated. Kappa ($K$), which is ($P_o$) adjusted for chance agreements, also can be computed. Pearson product–moment correlation can be used with percentage scores that are not highly skewed. Nonparametric correlation procedure, i.e., Spearman rho, can be computed if data are highly skewed.</td>
</tr>
<tr>
<td><strong>Parallel Forms Procedure:</strong> Concerned with assessing the consistency of measurements that alternate forms of an instrument or tool elicit from the same group of subjects during a single administration. (Equivalence assessment)</td>
<td>Correlation of two sets of scores obtained from each tool using Pearson product–moment correlation. Two norm-referenced measures are considered parallel if: (1) they were constructed using the same objectives and procedures; (2) have approximately equal means; (3) have equal standard deviations; and (4) have equal correlations with any third variable.</td>
<td>The percent agreement ($P_o$) in the classification of subjects by the two parallel measures is computed. Kappa ($K$) also can be computed. Two criterion-referenced measures are considered parallel if: (1) they were constructed with the same set of test specifications; and (2) items are relatively homogenous in nature. Pearson product–moment correlation or Spearman’s rho can be used with percentage scores as appropriate.</td>
</tr>
<tr>
<td><strong>Interrater Reliability:</strong> Concerned with consistency of performance (i.e., degree of agreement) among different raters or judges in assigning scores to the same objects or behaviors in the same tool and/or the same predefined criteria. (Equivalence assessment)</td>
<td>Correlation of the two sets of scores obtained from each rater or judge using Pearson product–moment correlation.</td>
<td>The percent agreement ($P_o$) of the classification of subjects by the two raters or judges is computed. Kappa ($K$) also can be computed. Pearson product–moment correlation or Spearman’s rho can be used with percentage scores as appropriate.</td>
</tr>
<tr>
<td><strong>Intrarater Reliability:</strong> Refers to the consistency with which one rater assigns scores to a set of behaviors on two occasions (observed under the same conditions) using the same instrument and/or the same predefined criteria. (Stability assessment)</td>
<td>Correlation of the two sets of scores obtained from one rater or judge for the two occasions using Pearson product–moment correlation.</td>
<td>The percent agreement ($P_o$) of the two sets of classifications obtained from a single rater or judge is computed. Kappa ($K$) also can be calculated. Pearson product–moment correlation or Spearman’s rho can be used with percentage scores as appropriate.</td>
</tr>
</tbody>
</table>
to the calculation of the various types of reliability. When percentage scores are used with criterion-referenced measures, it may be appropriate to use the same statistical approaches as in the norm-referenced case if scores are not highly skewed.

REFERENCES


Validity is defined as “the degree to which evidence and theory support the interpretation entailed by proposed use of tests” (American Educational Research Association [AERA], American Psychological Association [APA], National Council on Measurement in Education [NCME], 1999, p. 9). The type of validity information to be obtained depends upon the aims or purposes for the measure rather than upon the type of measure per se. Hence, it is not appropriate to speak of a valid tool or measurement method, but rather of accruing evidence for validity by examining the scores resulting from a measure that is employed for a specific purpose with a specified group of respondents under a certain set of conditions. For any given measure, different aspects of validity will be investigated depending upon the measure’s purpose(s). That is, “when test scores are used or interpreted in more than one way, each intended interpretation must be validated” (AERA, APA, & NCME, 1999, pp. 9–11).

Standards for measurement validity changed substantially in the Standards for Educational and Psychological Testing published by AERA, APA, and NCME in 1999. These changes resulted from concern that the focus on only the three types of validity (content, criterion-related, and construct) tended to narrow thinking and lead to the misconception that validity is a property of a test or measure per se. In the 1999 Standards the definition of validity was expanded to emphasize that validity should be viewed as a unitary concept. Validity is not a property of a tool. It is a property of the scores obtained with a measure when used for a specific purpose and with a particular group of respondents.

Thus, for any given measure, one or more types of evidence will be of interest. Evidence for the validity of a newly developed measure requires extensive, rigorous investigation using a number of different approaches depending upon the purpose(s), subjects, and the conditions under which it will be used, prior to employing the measure clinically and/or within a research study. In addition, evidence for validity should be obtained within the context of each study in which the measure is used for the collection of data. Therefore, for any given tool or measurement method, validity will be investigated in multiple ways depending upon the purpose(s) for measurement and evidence for validity will be accrued with repeated use of the measure. The Standards focus on five distinct types of evidence based on: (1) test content, (2) response processes, (3) internal structure, (4) relations with other variables, and (5) the consequences of testing. Two important points are emphasized: First, “these sources of evidence may illuminate different aspects of validity, but they do not represent distinct types of validity . . . it is the degree to which all of the accumulated evidence supports the intended interpretation of test scores for the intended purpose” (AERA, APA, & NCME, 1999, p. 11). Second, “A sound validity argument integrates various strands of evidence into a coherent account of the degree to which existing evidence and theory support the intended interpretation of test scores for specific uses . . . encompasses evidence gathered from new studies and evidence available from earlier reported research . . . indicates the need for refining the definition of the construct, may suggest revisions in the test or other aspects of the testing process, and may
indicate areas needing further study” (AERA, APA, & NCME, 1999, p. 17).

Five types of evidence to be considered when investigating the validity of a measure are described in the Standards:

1. Evidence based on test content: The extent to which content, including specific items or tasks and their formats, represent the content domain. Evidence for relevance of the content domain to the proposed interpretation of scores might include:
   • Extent to which content represents the content domain (Content Validity)
   • Experts review of sufficiency, relevance, and clarity of items (Content Validity, Item Analysis), extent to which the intended construct is measured (Construct Validity)
   • Extent to which items or subparts match the definition of the construct and/or purpose of the measure (Construct Validity)
   • Evidence that construct underrepresentation or construct-irrelevant components may give unfair advantage to subgroups of subjects (Construct Validity)

2. Evidence based on response processes: The fit between the type of performances or responses in which respondents engage and the intended construct. Evidence that the construct of interest is assessed and criteria applied as intended and responses are not the result of irrelevant or extraneous factors like social desirability may include:
   • Interviewing subjects to assess the basis for their responses
   • Observing subjects as they engage in task performances
   • Studying the way in which judges or observers employ criteria to record and score performances

3. Evidence based on internal structure: The extent to which relationships among items and components match the construct as operationally defined. Evidence based on internal structure might include:
   • Factor analysis, especially Confirmatory Factor Analysis (CFA)
   • Differential item function (DIF) studies to detect item bias
   • Item analysis to examine interrelationships

4. Evidence based on relations to other variables: The nature and extent of the relationships between scores and other variables that the measure is expected to correlate with or predict, as well as variables that the measure is not expected to relate with. Extent to which these relationships are consistent with the construct that serves as the basis for the proposed interpretation of scores. Evidence based on relations with other variables may include:
   • Correlation with scores from another measure of the same construct (Criterion-related Validity)
   • Extent to which scores correlate with data obtained at a later date (Criterion-related Validity)
   • Differential group prediction studies
   • Validity generalization studies (Meta-analysis)
   • Convergent and divergent validity studies (Multitrait-multimethod)
   • Experimental and known group comparison studies

5. Evidence based on consequences of testing: Extent to which anticipated benefits of measurement are realized and/or unanticipated benefits (positive and negative) occur. Extent to which differential consequences are observed for different identifiable subgroups. Evidence based on consequences of testing may include:
   • Descriptive studies
   • Focus groups (AERA, APA, & NCME, 1999; Goodwin, 2002, pp. 100–106).

A number of validation frameworks have been proposed that are based on these Standards. Readers interested in learning more regarding these frameworks are referred to Slaney and Maraun (2008) who provide an overview and evaluation of validation frameworks proposed by others and propose a framework for test analysis based upon the Standards that addresses some of the limitations in existing frameworks, and Baldwin and colleagues (2009)
who developed and implemented a process to validate the 75 Core National Association of Clinical Nurse Specialists (NACNS) clinical nurse specialist (CNS) competencies among practicing CNSs.

**NORM-REFERENCED VALIDITY PROCEDURES**

**Content Validity**

Validation of the extent to which content represents the content domain is important for all measures and is especially of interest for instruments designed to assess cognition. The focus is on determining whether the items sampled for inclusion on the tool adequately represent the domain of content addressed by the instrument and the relevance of the content domain to the proposed interpretation of scores obtained when the measure is employed. For this reason, content validity is largely a function of how an instrument is developed. When a domain is adequately defined, objectives that represent that domain are clearly explicated, an exhaustive set of items to measure each objective is constructed, and then a random sampling procedure is employed to select a subset of items from this larger pool for inclusion on the instrument, the probability that the instrument will have adequate content validity is high.

When investigating content validity, the interest is in the extent to which the content of the measure represents the content domain. Procedures employed for this purpose usually involve having experts judge the specific items and/or behaviors included in the measure in terms of their relevance, sufficiency, and clarity in representing the concepts underlying the measure's development. To obtain evidence for content validity, the list of behavioral objectives that guided the construction of the tool, a definition of terms, and a separate list of items designed to specifically test the objectives are given to at least two experts in the area of content to be measured. These experts are then asked to (1) link each objective with its respective item, (2) assess the relevancy of the items to the content addressed by the objectives, and (3) judge if they believe the items on the tool adequately represent the content or behaviors in the domain of interest.

When only two judges are employed, the content validity index (CVI) is used to quantify the extent of agreement between the experts. To compute the CVI, two content specialists are given the objectives and items and are asked to independently rate the relevance of each item to the objective(s) using a 4-point rating scale: (1) not relevant, (2) somewhat relevant, (3) quite relevant, and (4) very relevant. The CVI is defined as the proportion of items given a rating of quite/very relevant by both raters involved. For example, suppose the relevance of each of 10 items on an instrument to a particular objective is independently rated by two experts using the 4-point scale, and the results are those displayed in Figure 6.1. Using the information from the figure, the CVI equals the proportion of items given a rating of 3 or 4 by both judges: CVI = 8/10 or 0.80. If all items are given ratings of 3 or 4 by both raters, interrater agreement will be perfect and the value of the CVI will be 1.00. If one-half of the items are jointly classified as 1 or 2, while the others are jointly classified as 3 or 4, the CVI will be 0.50, indicating an unacceptable level of content validity (Martuza, 1977).

When more than two experts rate the items on a measure, the alpha coefficient, discussed in Chapter 5, is employed as the index of content validity. Figure 6.2 provides an example of alpha employed for the determination of content validity for six experts’ rating of the relevance of each of five items on a measure. In this case, column headings represent each of the six experts’ ratings (A–F), and the row headings represent each of the five items (1–5) rated. The resulting alpha coefficient quantifies the extent to which there is agreement between the experts’ ratings of the items. A coefficient of 0.00 indicates lack of agreement between the experts and a coefficient of 1.00 indicates complete agreement. It should be noted that agreement does not mean that the same rating was assigned by all experts, but rather that the relative ordering or ranking of scores assigned by one expert matches the relative order assigned by the other experts. When
Part II  Understanding Measurement Design

FIGURE 6.1  Two judges’ ratings of 10 items.

<table>
<thead>
<tr>
<th>Judge 1</th>
<th>(1 or 2) not/somewhat relevant</th>
<th>(3 or 4) quite/very relevant</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judge 2</td>
<td>(1 or 2) not/somewhat relevant</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3 or 4) quite/very relevant</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

FIGURE 6.2  Example of alpha employed for the determination of content validity for six judges’ rating of a five-item measure.

sufficiency and/or clarity of the specific item and/or behavior included in the measure in representing the concept underlying the measure’s development is of interest, the same procedure is employed.

Content validity judgments require subject matter expertise and therefore careful attention must be given to the selection, preparation, and use of experts, and to the optimal number of experts in specific measurement situations. Readers interested in more information in this regard are referred to Berk (1990), Davis (1992), and Grant and Davis (1997). Content validity judgments are different from the judgments referred to in determining face validity. Face validity is not validity in the true sense and refers only to the appearance of the instrument to the layperson; that is, if upon cursory inspection, an instrument appears to measure what the test constructor claims it measures, it is said to have face validity. If an instrument has face validity, the layperson is more apt to be motivated to respond, thus its presence may serve as a factor in increasing response rate. Face validity, when it is present, however, does not provide evidence for validity, that is, evidence that the instrument actually measures what it purports to measure.

For example, Ganz et al. (2009) examined content validity of a survey instrument employed...
in a study undertaken to describe the oral-care practices of ICU nurses to compare those practices with current evidence-based practice and to determine if the use of evidence-based practice was associated with personal demographic or professional characteristics. Brodsky and Dijk (2008), when examining the validity of their questionnaire designed to evaluate Israeli nurses’ and physicians’ attitudes regarding the introduction of new nursing roles and the expanding scope of nursing practice, employed a panel of experts with theoretical knowledge and practical experience in the fields being analyzed. Specifically, the panel was asked to independently review the measure’s content, face validity, and to scrutinize each item regarding its appropriateness, comprehensiveness, and relevance to the target population. Similarly, Blackwood and Wilson-Barnett (2007) distributed their questionnaire to assess nurses’ knowledge and principles regarding protocolized-weaning from mechanical ventilation to a panel of international experts in critical care with research experience to comment on its content and face validity. Other examples of content validity can be found in Glaister (2007); Schnall et al. (2008); Gatti (2008); Kearney, Baggs, Broome, Dougherty, and Freda (2008); and Hatfield (2008).

Construct Validity

Construct validity is important for all measures especially measures of affect. The primary concern in assessing construct validity is the extent to which relationships among items included in the measure are consistent with the theory and concepts as operationally defined. The importance of consistency between theory and operationalization is exemplified in the work of Fouladbachsh and Stommel (2007) who address the need for conceptual and operational consistency in discussing the development of a Complementary Alternative Medicine Health Care Model.

Activities undertaken to obtain evidence for construct validity include:

- Examining item interrelationships
- Investigations of the type and extent of the relationship between scores and external variables
- Studies of the relationship between scores and other tools or methods intended to measure the same concepts
- Examining relationships between scores and other measures of different constructs
- Hypothesis testing of effects of specific interventions on scores
- Comparison of scores of known groups of respondents
- Testing hypotheses about expected differences in scores across specific groups of respondents
- Ascertaining similarities and differences in responses given by members of distinct subgroups of respondents

Construct validity is usually determined using (1) the contrasted groups approach, (2) hypothesis testing approach, (3) the multitrait-multimethod approach (Campbell & Fiske, 1959; Martuza, 1977), and/or (4) factor analysis (Rew, Stuppy, & Becker, 1988).

**Contrasted Groups Approach**

In the contrasted groups approach, the investigator identifies two groups of individuals who are known to be extremely high and extremely low in the characteristic being measured by the instrument. The instrument is then administered to both the high and low groups, and the differences in the scores obtained by each are examined. If the instrument is sensitive to individual differences in the trait being measured, the mean performance of these two groups should differ significantly. Whether the two groups differ is assessed by use of an appropriate statistical procedure such as the t test or an analysis-of-variance test.

For example, to examine the validity of a measure designed to quantify venous access, the nurse might ask a group of clinical specialists on a given unit to identify a group of patients known to have good venous access and a group known to have very poor access. The nurse would employ the measure with both groups, obtain a mean for each group, then compare the differences between the two means using a t test or other appropriate statistic. If a significant
difference is found between the mean scores of the two groups, the investigator may claim some evidence for construct validity, that is, that the instrument measures the attribute of interest. Since the two groups may differ in many ways in addition to varying in the characteristic of interest, the mean difference in scores on the instrument may be due to group noncomparability on some other variable that was not measured. Hence, a claim for validity using the contrasted groups approach must be offered in light of this possibility. If no significant difference is found between the means of the high and low groups, three possibilities exist: (1) the test is unreliable; (2) the test is reliable, but not a valid measure of the characteristic; or (3) the constructor’s conception of the construct of interest is faulty and needs reformulation.

**Hypothesis Testing**

When the hypothesis testing approach, also referred to as the experimental manipulation approach, is employed, the investigator uses the theory or conceptual framework underlying the measure’s design to state hypotheses regarding the behavior of individuals with varying scores on the measure, gathers data to test the hypotheses, and makes inferences on the basis of the findings regarding whether the rationale underlying the instrument’s construction is adequate to explain the data collected. If the theory or conceptual framework fails to account for the data, it is necessary to (1) revise the measure, (2) reformulate the rationale, or (3) reject the rationale altogether.

For example, Bidwell (1973) in his theory of personal influence suggests a set of conditions under which a faculty member’s interactions with students are more likely to affect or influence students’ attitudes toward the content. One such condition is that a faculty member will positively affect students’ attitudes toward the content when the student perceives a direct positive relationship or link between the teachers’ attitudes and the content taught. This theory, and more specifically, the set of conditions, are used as a conceptual framework for identifying variables that may explain variations in students’ attitudes toward the content at the completion of a course in clinical nursing. The condition regarding the link is operationalized into a set of questionnaire items that assess students’ perceptions of the link between the content taught and faculty activities.

For example, students rate from 1 (not at all) to 6 (very much) how much they thought their clinical faculty member or members were involved in the following activities:

- Applying the content they teach to their own clinical performance
- Speaking or in some manner presenting the content at professional meetings
- Consulting with nurses in the agency where they have students, regarding nursing and/or patient care problems in the content area
- Planning and/or developing programs for other nurses that deal with nursing and/or patient care in the content area
- Seeking continuing learning experiences that are relevant to the content they are teaching
- Participating in research in their content area

It is hypothesized that students who respond to the questionnaire items in a manner that indicates they are aware of a positive link (i.e., record higher scores) will demonstrate more positive attitudes toward the clinical content upon completion of the course than will students who respond to the items in a manner that indicates they do not perceive a positive link between faculty activities and the content (i.e., record lower scores). To test this hypothesis, a random sample of students is selected from the available population of students and is administered the questionnaire along with a second measure to assess their attitudes toward the clinical content upon completion of the course. The significance of the differences in attitudes between those students who perceive a positive link and those who do not is assessed using an appropriate statistical technique. If a significant difference is found in the expected direction (i.e., those with high scores on the questionnaire and high scores on the attitude measure, and vice versa), one can say some evidence has been obtained for the construct validity of the measure. It should be noted
that this is a simplified example and that in actually designing such a study it would be necessary to control variables such as students’ past exposure to faculty in order to test the research hypothesis more precisely.

**Factor Analysis**

Factor analysis is a useful approach to assessing construct validity when the investigator has designed, on the basis of a conceptual framework, a measure to assess various dimensions or subcomponents of a phenomenon of interest and wishes to empirically justify these dimensions or factors. When factor analysis is employed, the investigator administers the tool to a large representative sample of subjects at one time. An appropriate parametric or nonparametric factor-analysis procedure is then employed. The result of this factoring process is a group of linear combinations of items called factors, each of which is independent of all other identified factors. Once constructed, each factor is then correlated with each item to produce factor loadings. Waltz and Bausell (1981, p. 301) note that it might be helpful to conceptualize these factors as “lumps” of variance taken from items that tend to measure something in common, and the loadings as correlations between these lumps and the items they comprise. Usually, the next step is a process referred to as rotation, in which the factors are repositioned in such a way as to give them more interpretability. Rotated factors are interpreted by examining the items loading upon each, over and above a certain preset criterion (usually 0.30 is the minimum that will be considered). If evidence for construct validity exists, the number of factors resulting from the analysis should approximate the number of dimensions or subcomponents assessed by the measure, and the items with the highest factor loadings defining each factor should correspond with the items designed to measure each of the dimensions of the measure.

All factor analyses do not result in such easily interpretable factors; thus, one of the most difficult aspects of this approach is to objectively name or interpret factors without allowing original conceptualization to bias the interpretation, since the interpretation of factors or analyses always involves a certain amount of subjectivity. Some rules of thumb suggested by Waltz and Bausell (1981, p. 304) to avoid such biases include: (1) choosing a minimum loading to interpret, probably no less than 0.30, perhaps as high as 0.50, before the analysis is attempted; (2) in naming a factor, consider the relevant items in descending order with respect to the magnitude of their loadings; and (3) never ignoring an item meeting a predetermined loading criterion simply because it does not “conceptually” fit with the rest of the items loading on a factor. It should also be noted that factors can be notoriously unstable, particularly with small samples, so that the results of factor analysis should be cross-validated. Rew, Stuppy, and Becker (1988) in their article provide a useful discussion of the limitations noted in published studies employing factor analysis for the determination of construct validity (pp. 10–22). Readers are referred to Lauri and Sanna (2002) for another example of the use of factor analysis to obtain evidence for validity for an instrument designed to measure and describe decision making in different nursing fields (pp. 93–100). Additional examples of the use of factor analysis for the estimation of construct validity can be found in Herr, Spratt, Mobily, and Richardson (2004); Schnall et al. (2008); Svavarsdottir and Orlygsdottir (2008); Gatti (2008); and Byrne, Deane, and Caputi (2008).

**Confirmatory Factor Analysis**

One of the common methods for assessing the construct validity of an instrument is exploratory factor analysis (EFA), a technique that decomposes the variance of a measure into variance that is shared by the items (common factors) plus variance that is not shared (i.e., uniqueness). The outcome of this process is the identification of a group of linear combinations of the items that are called factors. These underlying factors are defined in mathematical terms so the process is considered data-driven. The ultimate goal is to explain the most variance in the set of variables or items with the fewest number of factors as determined using a statistical criterion such as having an eigenvalue greater than 1 or explaining a certain percent of the variance. It is possible using EFA for the researcher to move
away from a strictly exploratory perspective by specifying a priori the number of factors to be extracted. In EFA all items load on or reflect all the extracted factors, with some factor loadings being insignificant. That is, the researcher is not able to specify which items load on which factors, and some items should not load on some factors. In addition, if more than one factor emerges in the analysis, factors are allowed to correlate or not correlate in an all-or-none fashion. Either all factors are permitted to correlate with one another, or all are independent of one another. Finally, EFA does not permit correlated measurement errors. In areas where little is known, EFA can be valuable in suggesting an underlying structure. However, if the structure can be hypothesized, as would be the case for a test developer or a researcher seeking to support the construct validity of a scale, the constraints of EFA are inappropriate.

The test construction process requires an operational definition of the construct so that items reflecting the construct can be written or selected. As a result, one is able to hypothesize not only how many factors there are, but also what the factors are and which specific items belong to or load on each factor. Items need not load on each factor and, in fact, often are considered to reflect only one or maybe two factors. In that case, the item loadings on other factors can be set to 0. The developer might also hypothesize that some factors correlate with one another, while other factors are thought to be independent of one another. Finally, the test developer might speculate that some errors in measurement are correlated, for example, because of a bias in answering negatively worded items or because of the response format. For example, the revised Caregiver Reciprocity Scale II (CRSII) was hypothesized to consist of four factors that correlated with each other: warmth and regard, intrinsic rewards of caregiving, love and affection, and balance within family caregiving (Carruth, Holland, & Larsen, 2000). Each factor consisted of three to seven items, with no item loading on more than one factor. EFA would not permit a direct test of the hypothesis regarding construct validity given that the number of factors was specified along with which item loaded on which factor. However, confirmatory factor analysis (CFA) permits each of the above situations, thereby allowing the test developer to use theoretical knowledge in testing the construct validity of the instrument. The intent of CFA is to hypothesize or define the factors directly and then determine how well the defined measurement model fits the observed data. CFA, then, is theory-driven rather than data-driven.

CFA can be thought of as having several steps. In the first step, the hypothesized measurement model is specified and the relationships among variables and constructs are made explicit. Second, the researcher must determine whether the model is identified, that is, whether it is theoretically possible to estimate every parameter in the model. Third, the model is analyzed and parameters are estimated. Finally, the fit of the model is evaluated. Several computer software programs are available for CFA, including the following widely used programs: AMOS (Arbuckle, 2005), EQS (Bentler, 1995), LISREL, which stands for Linear Structural RELations (Jöreskog & Sörbom, 2004), PROC CALIS in SAS® and MPlus (Muthén & Muthén, 2006).

**Specifying the Model**

In order to apply CFA, the researcher must explicitly state the hypothesized measurement model using a diagram or a set of equations. In the context of CFA, measured variables or scale items are called indicators or manifest (observed) variables. Measured variables are represented in a diagram by squares or rectangles. Constructs or factors are referred to as latent variables or unobserved variables, represented by circles in the diagram. Relations among constructs or between constructs and indicators are depicted with arrows (→) that indicate the direction of the relationship. Curved lines that may have arrows at each end are unanalyzed relationships or associations that have no implied direction.

Consider the measurement model in Figure 6.3 showing one construct with four indicators.

Constructs are denoted by ξ (pronounced “ksi”), and the indicators are represented by X. Not all computer programs for CFA require Greek notation, but the notation does provide a useful way of referring to and speaking about the
model. Lambda (λ) is a coefficient denoting the effect of ξ on X. These λ are sometimes referred to as the factor loadings because they indicate which item “loads” on which factor. A change in the latent variable ξ has an effect on the observed variables X₁, X₂, X₃, and X₄. In fact, lambda is the magnitude of the expected change in the observed variable for one unit of change in the latent variable or factor. In other words, lambda is a measure of the validity of the item as an indicator of the construct. Finally, delta (δ) refers to error in the measurement of X. Each indicator can be expressed in the form of an equation showing its relationship with the construct plus as an error term:

\[
\begin{align*}
X_1 &= \lambda_1 \xi + \delta_1 \\
X_2 &= \lambda_2 \xi + \delta_2 \\
X_3 &= \lambda_3 \xi + \delta_3 \\
X_4 &= \lambda_4 \xi + \delta_4 \\
\end{align*}
\]

All four equations simultaneously can be expressed using vectors:

\[X = \Lambda \xi + \delta\]

In this form x is a vector of the Xᵢ, Λ is a vector that contains the factor loadings, and the vector δ contains the error terms. (CFA is one application of structural equation modeling or SEM because of the structural equation system.

![Figure 6.3](image1)

**FIGURE 6.3** Measurement model showing one construct with four indicators.

![Figure 6.4](image2)

**FIGURE 6.4** Measurement model with two constructs, each with four indicators.
that combines factor analysis and regression-type models.)

The measurement model can be expanded to include multiple factors with a varying number of indicators for each. For example, Figure 6.4 depicts a measurement model with two constructs, each with four indicators or items. In addition, the curved line between δ_i and δ_j tells us that the two constructs are correlated with each other.

**Identification**

Once the model is specified, it is clear which parameters need to be estimated. They are the factor loadings (λ_i), the variances of the measurement errors (δ_i), the variances and, if correlated, the covariances of the factors and, if the model includes correlated measurement errors, then the covariances of the errors. In Figure 6.4 there are 19 parameters to be estimated: 8 factor loadings, 8 variances of the measurement errors, 2 variances of the factors, and 1 covariance between the factors. However, each latent variable must have a measurement scale set. This is necessary because the latent variables are not observed and therefore they have no scale. Usually the scaling is accomplished by setting the loading of one indicator for each factor to equal 1.0. This means that a one-point increase in the factor is reflected in a one-point increase on the reference indicator. This process of “setting the scale” reduces the number of parameters that will be estimated; in this example, scaling reduces the number of parameters to 17. An alternative approach to scaling is to fix the variance of each factor to 1.0, in essence standardizing the factor. Using the latter approach, the unit of measurement is equal to the population standard deviation.

In CFA parameters can be of three types: free, fixed, and constrained. *Free* parameters have unknown values that must be estimated while *fixed* parameters are set to a constant value by the researcher and are not estimated. For example, the loading of X_1 on ξ_i is a free parameter that must be estimated; the loading of X_1 on ξ_j is fixed to 0, that is, X_1 does not load on ξ_j. *Constrained* parameters are restricted in that they are hypothesized to be equal to one another and must be estimated. For example, a test developer might hypothesize that all the loadings on a factor are equal to one another, a so-called *tau-equivalent* measure. Or, in the case of multiple factors, the developer might hypothesize that the correlations between all pairs of factors are equivalent. Constrained parameters are not completely fixed since they must be estimated, but they are not completely free either since they have some restrictions placed on them.

The issue of *identification* is critical in CFA. A model is identified if it is theoretically possible to derive a unique estimate for every parameter. You might recall from algebra that one equation with two unknowns such as \(a + b = 5\) does not have a unique solution, but a set of two equations with two unknowns can be solved. The same principle applies in CFA. There must be enough information available to determine unique estimates for the parameters. In CFA the available information comes in the form of the variance-covariance matrix of the observed variables, so there must be enough unique terms in the variance-covariance matrix to be able theoretically to estimate the parameters. (The SEM analysis is sometimes referred to as *analysis of covariance structures* given the dependence on the variance-covariance matrix.) The example includes 8 indicator variables so the variance-covariance matrix will have \((8 \times 9)/2 = 36\) observations, more than the 17 parameters to be estimated. Note that the use of the term “observation” here refers to an element of the covariance matrix and not to the sample size. As an aside, there is no agreement among researchers as to a desired sample size in CFA. One suggestion offered is a 10:1 subject-to-parameter ratio, or 10 subjects for each parameter estimated while others recommend at least 200 subjects (Kline, 2005; Raykov & Marcoulides, 2000). However, no rule of thumb applies to all cases. Rather, based on simulated data, the recommended sample size depends on the anticipated measurement quality, that is, on the number of factors and the expected magnitude of the loadings (see Gagné & Hancock, 2006, for a review and tables of recommended sample sizes).

With \(p\) indicators, there will be \(p(p + 1)/2\) unique elements in the variance-covariance
matrix, the diagonal consisting of variances and half of the off-diagonal elements that are the covariances. If there are more parameters to be estimated than there are observations, there is insufficient information and the model is underidentified. If there is more information than is necessary, the number of observations exceeds the number of parameters and the model is overidentified, indicating that theoretically the parameters can be estimated. Similarly, if there is just enough information, that is, the number of observations equals the number of parameters, then the model is just identified or saturated. Saturated models will always fit the data perfectly so the hypothesized model can never really be tested. The model presented in Figure 6.4 is overidentified.

Having enough observations given the number of parameters to be estimated, the so-called $t$-rule is a necessary condition for identification, but by itself this condition is not sufficient to determine whether the model is identified. Several necessary conditions or rules exist to help determine whether a model is identifiable. For example, a single factor model with at least three indicators is identifiable. A two-factor model in which each indicator loads on one factor, measurement errors are uncorrelated, and factors correlate, is identifiable if each factor has at least two indicators. It should be noted, that while it may be theoretically possible to estimate every parameter in a model, there may be other difficulties that keep it from actually happening. (For further discussion of the “rules” or necessary conditions related to identifiability, see, for example, Bollen [1989], Kline [2005], or Raykov & Marcoulides [2000].)

Parameter Estimation

Estimation refers to the process by which the unknown model parameters are estimated. There are four main approaches to estimation: maximum likelihood estimation, unweighted least squares, generalized least squares, and weighted least squares. Each is based on minimizing a fit function. The most widely used approach is maximum likelihood estimation (ML). In ML all parameters in the model are estimated simultaneously so that if they are assumed to be the population values, they maximize the likelihood or probability that the observed data (the covariance matrix) comes from the population. The process is iterative, meaning that an initial solution is derived, and then through subsequent steps the estimates are improved. At each step the parameter estimates are used to compute the relationships among the measured variables. This computed matrix is called the implied covariance matrix—implied by the measurement model that has been imposed on the data. The process continues iteratively until the implied covariance matrix comes as close as possible to the sample covariance matrix.

As a rule, with continuous multivariate normally distributed variables, the maximum likelihood procedure has desirable characteristics. Although ML can handle slight to moderate departures from normality, the overall test of the model in the next step is sensitive to violations of the normality assumption. If there are large departures from normality, then other methods for parameter estimation are more appropriate although they require large sample sizes. Another strategy for addressing nonnormality is to transform the data to improve the normality. In the case of a Likert-type response scale, which many instruments tend to use, the data can be treated as ordinal and the polyserial correlation (one ordinal and one continuous variable) or polychoric correlation (two ordinal variables) computed and analyzed.

The resulting parameter estimates are unstandardized covariances between factors and unstandardized regression coefficients (i.e., factor loadings) of the direct effect of the factor on the indicator. Using the standard error for each parameter estimate, one can test for the statistical significance of each estimate. Standardized estimates also are presented giving the correlations between factors and the correlation between the factor and the indicator, that is, the factor loading or validity coefficient for the indicator. If an item loads on only one factor, then the standardized estimate can be squared to give the proportion of variance in the indicator explained by the factor, a measure of the reliability of the indicator. Another value given
is the $R^2$ for each item, an indication of the proportion of variance in the item explained by all the constructs/factors.

**Assessing the Fit of the Model**

Evaluation of whether a measurement model fits is not necessarily a simple and straightforward procedure, in part because there is not just one statistical test with a corresponding level of significance. Rather a number of statistical measures of fit have been proposed to evaluate whether the hypothesized measurement model is consistent with the data. Some are measures of overall model fit, while others examine components of the model or the parameter estimates; some can be tested for significance, while others are descriptive; and some are affected by sample size or complexity of the model, while others are not.

The first step in assessing model fit, however, involves looking at the estimates to determine whether they make sense. For example, are the signs (directions) of the estimates what one would expect, and are the sizes (magnitudes) of the estimates reasonable? You might find a correlation between factors that is greater than 1.0 or a variance estimate that is negative—both impossible values. This would be an improper solution known as a Heywood case, and it might occur, for example, if the sample size were too small or if the model were not correctly specified.

As a test of the overall model fit, we obtain a $\chi^2$ statistic that tests whether the model-implied covariance matrix is consistent with the sample covariance matrix. Our goal is to accept the null hypothesis that our model is consistent with the data versus the alternative that it is not consistent. There are some reasons for using caution with the $\chi^2$ test, however. For one, as noted above, multivariate skewness can result in a large $\chi^2$ statistic that would lead to rejection of the null hypothesis. Also, with large samples small differences between the actual and implied covariance matrices can be magnified, leading to a significant $\chi^2$ test statistic. For that reason, the recommendation is to look at the $\chi^2/df$ ratio with the goal of having the ratio be less than 3.0. In the example of the Caregiver Reciprocity Scale mentioned above, the $\chi^2 = 193.89$ with 146 df and $p < .01$ that would suggest the model does not fit, but the $\chi^2/df = 1.32$, well within the acceptable range.

Other fit indices are less sensitive to sample size. One common index is the Goodness-of-Fit Index (GFI) that indicates the proportion of observed covariances explained by the model-implied covariances. The Adjusted Goodness-of-Fit Index (AGFI) adjusts for the complexity of the model. These indices range from 0–1 with values more than 0.90 recommended, preferably 0.95 or greater (Hu & Bentler, 1999).

Another useful measure is the Normed Fit Index (NFI) that is based on the difference of the chi-square value for the proposed model to the chi-square value for the independence model. Although there are no strict guidelines for what supports the model, values greater than 0.95 are desired (Hu & Bentler, 1999). The Standardized Root Mean Squared Residual (SRMR) is based on the average covariance residuals or differences between the observed and model-implied covariances. Values less than 0.10 are desired (Kline, 2005). There are still other fit indices that focus on different aspects such as adjusting for sample size or for degrees of freedom and indices that are normed versus nonnormed. The ones mentioned are probably the most common. At any rate, researchers are advised to report more than one of the fit indices to support the fit of the hypothesized model. (See Kline, 2005, for other fit measures.)

**Model Modification**

Often an initial model does not fit well, generally because it has not been correctly specified. An indicator may have been incorrectly included or linked with the wrong factor. Perhaps an indicator should load on more than one factor. Included in the analysis results are modification indices (MI) that are statistical suggestions of how changes to the model would improve the fit. These suggested changes include which items load on which factors as well as whether some error variances or factors should be permitted to correlate. It is important to remember that if the model is modified based on these indices, the analysis has become more exploratory and
Chapter 6  Validity of Measures  175

In another study (McDonald, Hartman, & Vrana, 2008), researchers used CFA to support a hierarchic structure of fears that had been identified previously. They hypothesized that 16 fear situations represented four first-order fear factors and one higher-order general fear factor that is common to all fears.

In other situations, the researcher may want to demonstrate that a measurement model or factor structure holds across multiple groups. This is called testing the invariance of the measurement model and requires analyzing two variance-covariance matrices simultaneously, one from each sample or group. Parameters are constrained to be equivalent across the samples to determine whether the same model fits both groups. The simplest analysis involves testing the model form or pattern only to determine whether the number of factors is the same in each group with the items loading on the same factors in each group. Knowing that the general model is invariant, one might want to test whether the factor loadings are the same in each group. In this situation the factor loadings for the first group are constrained to be equivalent to the factor loadings for the second group. The correlations among factors or the

OTHER USES OF CFA FOR TESTING MEASUREMENT MODELS

So far the focus has been on what are called first-order factors—factors reflected directly by the items or indicators. It is possible that if the factors are correlated, then the factors themselves may reflect a more global or higher-order factor. For example, Sousa & Chen (2002) hypothesized that quality of life is explained by a second-order general factor and four first-order factors. A diagram for this model is shown in Figure 6.5.

To assess a second-order factor structure, keep in mind that a second-order structure can never fit better than a first-order structure since it attempts to explain the correlations among the first-order factors with fewer parameters. If the model holds, then quality of life can be conceptualized as being explained by the four first-order factors. In another study (McDonald, Hartman, & Vrana, 2008), researchers used CFA to support a hierarchic structure of fears that had been identified previously. They hypothesized that 16 fear situations represented four first-order fear factors and one higher-order general fear factor that is common to all fears.

In other situations, the researcher may want to demonstrate that a measurement model or factor structure holds across multiple groups. This is called testing the invariance of the measurement model and requires analyzing two variance-covariance matrices simultaneously, one from each sample or group. Parameters are constrained to be equivalent across the samples to determine whether the same model fits both groups. The simplest analysis involves testing the model form or pattern only to determine whether the number of factors is the same in each group with the items loading on the same factors in each group. Knowing that the general model is invariant, one might want to test whether the factor loadings are the same in each group. In this situation the factor loadings for the first group are constrained to be equivalent to the factor loadings for the second group. The correlations among factors or the

![FIGURE 6.5 Hypothesized second-order factor structure (indicators and errors not represented).](image-url)
equivalence of error variances could also be tested.

In one study, for example, researchers tested the invariance of the Computer Anxiety Scale across two groups of college students, one attending a traditional lecture course and the other using Web-based tools (Marcoulides, Emrich, & Marcoulides, 2008). In another study researchers used CFA to assess whether the EURO-D Scale that measures late-life depressive symptoms was invariant across 10 European countries (Castro-Costa et al., 2008). Another use of CFA is testing whether a scale has the same factor structure in populations speaking different languages. Yet another application is determining whether a measurement model is invariant across time. Using a sample of 2,400 adolescents who completed the CES-D at three times, researchers applied CFA to support longitudinal as well as gender invariance of the measure (Moti, Dishman, Birnbaum, & Lytle, 2005).

In summary, confirmatory factor analysis is a flexible procedure that directly assesses the link between the theoretical assumptions for a measure and the operational definition of the construct. Because it is theory-driven, CFA can be used to test the hypothesized construct validity of a measure. Individual parameters in a measurement model are tested as well as the overall model. In addition, CFA can be used to test invariance of a model across groups and time.

Examples of construct validity estimation can be found in Weston (2009) who reviewed the psychometric properties and evaluated estimates of validity of instruments for measuring autonomy and control over nursing practice published in English peer-reviewed journals between 1990 and 2007, and Jackson, Gillaspy, & Pure-Stephenson (2009) who reviewed and compared reporting practices with established reporting guidelines in 194 Confirmatory Factor Analysis articles published in the American Psychological Association journals from 1998 to 2006. As a result of this effort, they offer recommendations for reporting and provide a checklist to help editors, reviewers, and authors improve reporting practices in studies employing Confirmatory Factor Analysis. Additional examples can be found in Fouladbakhsh and Stommel (2007), Pion and Cordray (2008), Houston and Smith (2008), Valentine and Cooper (2008), Al-Mahroos (2009), and Kalish, Landstrom, & Williams (2009).

**Criterion-Related Validity**

When one wishes to infer from a measure an individual’s probable standing on some other variable or criterion, criterion-related validity is of concern. It is important to distinguish between two types of criterion-related validity: predictive validity and concurrent validity. **Predictive validity** indicates the extent to which an individual’s future level of performance on a criterion can be predicted from knowledge of performance on a prior measure. **Concurrent validity** refers to the extent to which a measure may be used to estimate an individual’s present standing on the criterion. Predictive validity, unlike concurrent validity, involves a time interval during which events may occur; for example, people may gain experience or be subjected to some type of learning experience.

Thus, concurrent and predictive validity differ in the timing of the related criterion measures. For concurrent validity, the measure being tested for validity and the related criterion measure are given within a short period of time and their results compared to make statements regarding present standing in regard to the criterion. With predictive validity the criterion measure is administered much later than the measure being tested for validity, and the results are compared to assess the ability of the measure being tested to predict future standing in regard to the criterion.

Activities undertaken to obtain evidence for criterion-related validity include:

- Correlation studies of the type and extent of the relationships between scores and external variables
- Studies of the extent to which scores predict future behavior, performance, or scores on measures obtained at a later point in time
- Studies of the effectiveness of selection, placement, and/or classification decisions on the basis of the scores resulting from the measure
• Studies of differential group predictions or relationships
• Assessment of validity generalization

In each of the following questions, the interest is in determining the extent to which performance on a criterion measure can be estimated using information obtained by the measure being tested (the predictor measure).

1. Is performance on a computer-simulated measure of empathy a good predictor of empathetic performance in a patient care situation?

2. Are scores on a confidence index obtained at the completion of an educational experience good predictors of participants’ incorporation of skills learned during the program into their future practice?

The criterion against which the predictor measures are to be validated in both questions are higher-order operationalizations of the same construct that the predictor measure is attempting to assess. More specifically, in question 1 the criterion—empathetic performance in a patient care situation—is a higher-order operationalization of empathetic performance on a computer simulation. In question 2, the criterion—confidence to incorporate skills learned during the program into future practice—is a higher-order operationalization of confidence self-reported on a confidence index immediately upon completion of the program. Knapp (1985, pp. 189–192) stresses that in an investigation of the criterion validity of a particular measure, the criterion against which the obtained scores are to be validated should be a higher status operationalization of the same construct that the measure is trying to tap, and not an operationalization of some other construct. He cautions that the distinction between criterion-related validity and a substantive research study regarding the relationship between the two variables is a fine one, but one that must be established. The reader is encouraged to read Knapp’s article, in which he offers many salient comments regarding the use and misuse of reliability and validity testing, citing examples from studies published in the nursing literature.

Similarly in both questions, it is evident that the investigator wants to know the extent to which performance on an important criterion (i.e., empathetic nursing practice and confidence in incorporating skills into practice) can be estimated using information from a less costly, more easily obtained measure (i.e., computer simulation to measure empathy in patient care and confidence index). If scores on a confidence index administered at the completion of an educational program are found by means of criterion-related validity studies to be a good predictor of participants’ future confidence to incorporate learnings into nursing practice, continuing use of the confidence index would be a cost-effective way for those delivering the program to assess incorporation at a time when they might intervene to improve the expected outcome. Similarly, a confidence index is far more economical to administer than a continuing longitudinal study of confidence to incorporate skills into practice using subjects who complete the learning experience. In the case of the measurement of empathetic nursing practice, it is far more convenient and economical to measure empathy using a computer simulation than to conduct an observational study of nursing performance in the clinical setting.

In regard to both questions, criterion-related validity is assessed by measuring the performance of the target population or a representative sample of that population on both the predictor and criterion variables, and then determining the linear correlation, that is, Pearson \( r \) or other appropriate correlational and/or regression analyses as a measure or measures of the quality of the predictor for estimating performance on that particular criterion in that target population. The important distinction between the two questions relates to the type of criterion-related validity study indicated by each. Question 1 is a question of concurrent validity; that is, it addresses the extent to which a computer simulation to measure empathy in nursing practice can be used to assess empathy in the delivery of patient care at the present time. Thus, to assess concurrent validity it requires that the predictor measure—the computer simulation—be administered to a representative group of nurses, that a criterion measure of empathetic nursing
practice with established reliability and validity be administered to the same group of nurses at the same time or a short time later, and that results on the two measures be compared using the appropriate correlation or regression procedure. The results of this comparison would then be employed to infer the predictor measure’s ability to predict present standing on the criterion.

In question 2, the concern is with predictive validity in that the criterion measurement occurs much later than the predictor measurement and the comparison of the two measures’ results are employed to predict the ability of the confidence index to predict future confidence to incorporate skills into nursing practice. Predictive validity studies most often employ longitudinal and/or cross-sectional designs and correlation and regression analyses to investigate the relationship between the predictor and criterion measures over time. It should be noted that the utility of most criterion-related validity coefficients is limited by the fact that salient characteristics in most populations are dynamic and changing.

Similarly, the value of the results of criterion-related validity studies is a function of the representativeness of the sample and the choice of a criterion measure. Criterion measures must be valid and, more important, must be reliable and meaningful. Many important nursing and health care variables are difficult to define and measure. Too often a criterion is determined by convenience. For example, when the criterion of interest is not readily available, it is tempting to use a substitute criterion rather than to wait until the desired criterion is available.

The results of criterion-related studies must be carefully evaluated in light of several factors. Factors to be considered in planning and interpreting criterion-related studies relate to (1) the target population, (2) the sample, (3) the criterion, (4) measurement reliability, and (5) the need for a cross-validation (Martuza, 1977). More specifically, it should be noted that;

1. Criterion-related validity coefficients obtained at one time must be interpreted in light of other events occurring within the target population at the same time and later, and in most cases, will have little or no value later. An assumption underlying criterion-related validity procedures is that the nature of the target population is relatively static and unchanging. In reality, however, the relationship between any two variables within a particular population is more apt to change than to remain static, rendering the value of most validity coefficients short-lived.

2. Validity coefficients obtained when procedures for sampling the target populations are inadequate will frequently underestimate the true validity of the predictor in question. The sampling procedure used in criterion-related validity studies must be such that it provides a sample representative of the target population in general and gives each potential subject an equal chance of being selected for inclusion in the sample. Similarly, during the conduct of the study, careful attention must be directed toward assessing the presence of attrition and its potential influence on study results. Selection bias and attrition when present may reduce score variability; that is, they may restrict the range of scores on the predictor and/or criterion variables, thus lowering the value of the resulting correlation coefficient and providing an inaccurate estimate of the true validity of the predictor in question.

3. A given criterion-related validity coefficient is interpretable only in terms of how the criterion is defined in that study. Important criteria are usually difficult to define and measure in a universally acceptable manner. Occasionally, this fact leads to compromise and results in the selection of a criterion variable that is expedient, convenient, or agreeable to those involved rather than a criterion that is appropriate and of sufficient quality. For example, in nursing, because of the long amount of time often required to collect information (e.g., assessing the incorporation of learning into practice may involve years of costly data collection), it is tempting to use a substitute criterion rather than wait until the desired criterion is available. However, the substitute criterion used may not typically bear the same relevance
to the predictors as the desired criterion. In criterion-related validity studies, this possibility must be given careful consideration and expediency alone should not rule the conduct of the study.

4. A spurious increase in the validity coefficient may result from criterion contamination. If criterion contamination is to be avoided, measures of the predictor and criterion variables must be independently obtained and free of bias. Whenever criterion-related studies employ a rating or judging procedure, the probability of criterion-related contamination is present; that is, if raters have knowledge of how members of the sample performed on the predictor, this knowledge may influence their rating on the criterion—high scorers on the predictor tend to be rated high on the criterion and vice versa. The result is an erroneous increase in the correlation between predictor and criterion, providing evidence that the predictor is more effective than it actually is.

5. A reduced validity coefficient may result when the predictor and/or criterion measures have not demonstrated sufficient reliability. Reliability is a necessary prerequisite for validity. Prior to employing predictor and criterion measures in criterion-related validity studies, each should have been examined for and demonstrate sufficient evidence for reliability. Although there is a formula that exists for estimating the attenuation of a correlation resulting from measurement error (Nunnally, 1967, pp. 217–220), its general use is not recommended. In most practical situations, it is preferable to employ the most reliable predictor and criterion measures one can and then live with the results obtained in that manner, rather than attempt to estimate what might be given in an error-free world, that is, to estimate the correlation that would be obtained if infallible measurement techniques were ever available.

6. Correlation coefficients resulting from criterion-related validity studies tend to overestimate the strength of the predictor-criterion relationship.

In criterion-related validity studies, the validity of a given predictor-criterion relationship in a specific population is simply the linear correlation between the predictor and the criterion in that specific population. As a result, the correlation coefficient tends to overestimate the true predictor-criterion relationship. To obtain a more realistic estimate of the relationship, a cross-validation procedure should be employed whenever possible. Ideally, two separate and independent samples from the sample population should be employed in a cross-validation procedure. In those instances in which it is not feasible to obtain two samples, it is better to randomly split the existing sample into two subsamples rather than opt not to cross-validate at all.

Given two samples, cross-validation proceeds in the following manner. First, a prediction equation is calculated using data from the first sample. The prediction equation obtained for the first sample is used to estimate the criterion performance for each of the individuals in the second sample ($C'$). Then, $r_{xy}$ is used to determine the linear correlation among the criterion scores predicted using the second sample ($C'$) and the actual criterion scores ($C$) obtained for the members of the second sample. This correlation $r_{xy}$ is then taken as a more precise estimate of the true correlation between the predictor and the criterion in the population of interest.

An example of criterion-related validity can be found in Bruyneel and colleagues (2009) who studied the predictive validity of the instrument employed in the International Hospital Outcomes Study (IHOS) for a European Union-funded project to study the effect of the nursing work environment and nursing staff deployment on nurse recruitment, retention, and productivity in 11 European countries. Additional examples of concurrent and predictive validity can be found in Gatti (2008) who studied maternal perceptions of insufficient milk supply in breast feeding, and Ellenbecker and colleagues (2008) who examined evidence for predictive validity in a study of predictors of home health care retention.

**Validity Generalization**

Validity generalization refers to the extent to which evidence for validity, usually predictive validity, obtained in one setting can be
generalized to other settings (Schmidt & Hunter, 1977). Meta-analysis (Cooper & Hedges, 1994; Glass, McGraw, & Smith, 1981; Hedges & Olkin, 1985; Isaac & Michael, 1995) is one approach that can be used to investigate validity generalization if a sufficient database of findings from specific validity studies is available to meet requirements for its use. Meta-analysis is a procedure used to summarize conclusions resulting from a large set of studies investigating a particular variable of interest. Findings from each study are converted to a common statistic, effect size. The mean of effect size is then calculated for all the studies reviewed to provide an estimate of average effect of the variable of interest. Issac and Michael (1995) note that a major disadvantage of the technique is that it does not distinguish between well-conducted and poorly conducted studies, but rather treats them equivalently as one body of information (p. 208). Therefore, caution must be exercised in selecting studies for inclusion in the meta-analysis. An example of meta-analysis of studies of nurse faculty job satisfaction can be found in the work of Gormley (2003, pp. 174–178). Additional examples of validity generalization activities, including meta-analysis, can be found in the works of Prevost et al. (2007), Pion and Cordray (2008), Peters and Mengersen (2008), Hafdahl and Williams (2009), and Forgues (2009).

Multitrait-Multimethod Approach

The multitrait-multimethod approach (Campbell & Fiske, 1959) is appropriately employed whenever it is feasible to:

- Measure two or more different constructs
- Use two or more different methodologies to measure each construct
- Administer all instruments to every subject at the same time
- Assume that performance on each instrument employed is independent, that is, not influenced by, biased by, or a function of performance on any other instrument

Whenever these conditions can be met, the multitrait-multimethod approach to instrument validation is preferred, because it produces more data with more efficiency than other available techniques.

Two basic premises underlying the multitrait-multimethod approach are (1) that different measures of the same construct should correlate highly with each other (the convergent validity principle), and (2) that measures of different constructs should have a low correlation with each other (the discriminant validity principle). An inherent aspect of the approach, and one that accounts for its popularity over other approaches, is the ability to separate trait from method variance. Trait variance is the variability in a set of scores resulting from individual differences in the trait being measured. Method variance is variance resulting from individual differences in a subject’s ability to respond appropriately to the type of measure used. The size of the correlation between any two measures is a function of both trait and method variance. Validity techniques that focus only on the size of the correlation between two measures are not able to account for the extent to which each of these types of variance is represented in their results. When validity is evident, the correlation between two measures of the same construct will be more a function of trait than method variance. In order to assess whether this is the case, it is necessary to focus not only on the size of the correlation but also on the patterns of the relationships between correlations of measures of the same and different constructs using common and different methods as well.

The multitrait-multimethod approach is best illustrated by example. In the simplest case, suppose a nurse had two instruments designed to measure the construct, maternal-infant bonding, and two instruments designed to measure the mother’s incorporation of prenatal learnings into her perinatal care (a second construct). Also, suppose that the format for one measure of each construct consists of a series of behaviors rated on a five-point scale. Each rating indicates the consistency with which a particular behavior is performed. The second measure of each construct is in the form of a performance checklist; that is, all of the behaviors on a standard list that describe the subject’s performance are checked.

Each of these four instruments, (1) maternal-infant bonding rating scale; (2) maternal-infant
bonding checklist; (3) perinatal care rating scale; and (4) perinatal care checklist, is administered to every member of the validation sample at the same time. The reliability of each instrument is then determined using an index of internal consistency (alphaKR 20/KR 21), and the correlation (rxy) between each pair of forms is computed. A multitrait-multimethod matrix is constructed and the correlations are entered in the following manner.

The reliability estimate for each form is entered as in Figure 6.6 to form what is referred to as the reliability diagonal. If these values are sufficiently high, the procedure continues; if not, the procedure terminates because reliability is a prerequisite for validity.

The values of the reliability estimates in Figure 6.6 range from 0.81 to 0.91, indicating sufficient evidence for reliability and thus the analysis may continue.

Convergent validity is examined by entering in the lower left block of the matrix in Figure 6.7 the correlation between the two measures of each construct assessed using different methods to form the validity diagonal. The values entered are 0.75 and 0.70, high enough to provide evidence for convergent validity.

The correlation between measures of different constructs employing a rating scale is entered in the upper block of Figure 6.8, and the correlation between measures of different constructs using a checklist is entered in the lower right block of the matrix. These coefficients indicate the relationship between measures of different constructs that use the same method of measurement and thus are a function of the

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**FIGURE 6.6** Reliability diagonal in constructing a multitrait-multimethod matrix.

<table>
<thead>
<tr>
<th>Method 1 (Rating Scale)</th>
<th>Method 2 (Checklist)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonding</td>
<td>Perinatal Care</td>
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<tr>
<td>Rating Scale</td>
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</tr>
<tr>
<td>Bonding</td>
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</tr>
<tr>
<td>Perinatal Care</td>
<td>0.88</td>
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<tr>
<td>Checklist</td>
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<tr>
<td>Bonding</td>
<td>0.75</td>
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<tr>
<td>Perinatal Care</td>
<td>0.81</td>
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**FIGURE 6.7** Validity diagonal in constructing a multitrait-multimethod matrix.

<table>
<thead>
<tr>
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<th>Method 2 (Checklist)</th>
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<tbody>
<tr>
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<td>Perinatal Care</td>
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<td>0.85</td>
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<td>Perinatal Care</td>
<td>0.88</td>
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<tr>
<td>Checklist</td>
<td></td>
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<tr>
<td>Bonding</td>
<td>0.75</td>
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<tr>
<td>Perinatal Care</td>
<td>0.70</td>
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**FIGURE 6.8** Heterotrait-monomethod in correlations in constructing a multitrait-multimethod matrix.

<table>
<thead>
<tr>
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<th>Method 2 (Checklist)</th>
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<tr>
<td>Bonding</td>
<td>Perinatal Care</td>
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<tr>
<td>Rating Scale</td>
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<tr>
<td>Bonding</td>
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<tr>
<td>Perinatal Care</td>
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<tr>
<td>Checklist</td>
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</tr>
<tr>
<td>Perinatal Care</td>
<td>0.70</td>
</tr>
</tbody>
</table>
relationship existing between the two constructs and the use of a common method. The size of these *heterotrait-monomethod* coefficients will be lower than the values on the validity diagonal if variability is more a function of trait than method variance. Since the values in Figure 6.8 follow this pattern, they provide evidence for construct validity.

The remaining correlations between measures of different constructs measured by different methods are entered in the lower block in the left of the matrix as shown in Figure 6.9. The values of these *heterotrait-heteromethod* coefficients should be lower than the values in the validity diagonal and the corresponding values of the *heterotrait-monomethod* coefficients. Since this pattern is apparent in Figure 6.9, evidence is present for discriminant validity.

In summary, if the information in Figure 6.9 resulted from an actual study, it would provide evidence for reliability, convergent validity, construct validity, and discriminant validity, that is, provide more data, more efficiently and economically than what is obtained using other approaches.

Figure 6.10 presents an extension of the example in which a multitrait-multimethod matrix is employed for the analysis of three constructs: bonding, perinatal care, and anxiety. Each construct is measured using two different methods: a rating scale and a checklist. As in the simplest case, both the size and patterns of the relationships are examined.

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### Table 6.9

<table>
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<td>Perinatal Care</td>
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<td>Perinatal Care</td>
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**FIGURE 6.9** Heterotrait-heteromethod in correlations in constructing a multitrait-multimethod matrix.

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### Table 6.10

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<td>Rating Scale</td>
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<tr>
<td>Perinatal Care</td>
<td>0.15</td>
</tr>
<tr>
<td>Anxiety</td>
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**FIGURE 6.10** Example of a multitrait-multimethod matrix employed for analysis of three constructs using two methods.
1. The reliability diagonal is examined first and correlations are found to range from 0.81 to 0.91, indicating sufficient reliability for the analysis to proceed.

2. The validity diagonals (in the lower left block of the matrix) indicate that the relationships between measures of the same construct using different methods range from 0.70 to 0.75, high enough to provide evidence for convergent validity.

3. Correlations among measures of different constructs employing a rating scale (upper left block, solid-line triangle) and the correlations among measures of different constructs using a checklist (lower block, solid-line triangle) are examined in light of the values in the validity diagonal. The values of the heterotrait-monomethod triangle are lower than those in the validity diagonal and hence provide evidence for construct validity.

4. The correlations among measures of different constructs measured by different methods (lower block, broken-line triangles) are examined in regard to the values in the validity diagonal and the heterotrait-monomethod triangles. Since the values in the heterotrait-heteromethod triangles are lower than those in the heterotrait-monomethod triangle, which in turn are lower than those on the validity diagonal, evidence for discriminant validity is present. Hence, from Figure 6.10 it can be seen that extension of the multitrait-multimethod approach from the simplest case to those employing more than two constructs is straightforward.

A word of caution is in order regarding the considerations to be made before employing the multitrait-multimethod approach. One disadvantage of this approach results from the demands it may place on subjects who must respond to multiple instruments at one time. Such a request not only has the potential for decreasing respondents’ willingness to participate, hence reducing the response rate, but also introduces the potential for more errors of measurement as a result of respondent fatigue. For this reason, it is important, especially in measuring clinical variables, to carefully consider the appropriateness of using the method in light of the setting as well as the respondents’ other needs. A second disadvantage may stem from the cost in time and money necessary to employ the method. One way to reduce the potential cost is to select or design individual measures that are economical and efficient themselves.

An example of use of the multitrait-multimethod validity assessment can be found in the work of Jones, Cason, and Mancini (2002) who employed the approach to evaluate the validity of a hospital-based nurse competency assessment within the context of a skills recredentialing program (pp. 22–28). Additional examples can be found in Cole, Ciesla, and Steiger (2007) and Aitken and colleagues (2008). Further discussion of multitrait-multimethod models for investigating validity is available in Eid, Lischetzke, Nussbeck, and Trierweiler (2003, pp. 38–60).

**Norm-Referenced Item-Analysis Procedures**

Item analysis is a procedure used to further assess the validity of a measure by separately evaluating each item to determine whether that item discriminates in the same manner in which the overall measure is intended to discriminate (Issac & Michael, 1995, p. 123). Item-analysis procedures of interest in the norm-referenced case include (1) item \( p \) level, (2) discrimination index, (3) item-response chart, and (4) differential item functioning.

**Item \( p \) Level**

The \( p \) level (also referred to as the difficulty level) of an item is the proportion of correct responses to that item. It is determined by counting the number of subjects selecting the correct or desired response to a particular item and then dividing this number by the total number of subjects. For example, a 10-item performance measure is employed to observe the behaviors of 20 nurses working in a pediatric ambulatory center. It is determined that 10 subjects performed correctly in response to item 1; the remaining subjects did not. Thus, the \( p \) level for this item is 10/20 or 0.50. The range of \( p \) levels may be from 0 to 1.00. The closer the value of \( p \) is to 1.00, the
easier the item; the closer \( p \) is to zero, the more difficult the item. When norm-referenced measures are employed, \( p \) levels between 0.30 and 0.70 are desirable, because extremely easy or extremely difficult items have very little power to discriminate or differentiate among subjects (Martuzza, 1977).

### Discrimination Index

The discrimination index (\( D \)) assesses an item’s ability to discriminate; that is, if performance on a given item is a good predictor of performance on the overall measure, the item is said to be a good discriminator. To determine the \( D \) value for a given item:

1. Rank all subjects’ performance on the measure by using total scores from high to low.
2. Identify those individuals who ranked in the upper 25%.
3. Identify those individuals who ranked in the lower 25%.
4. Place the remaining scores aside.
5. Determine the proportion of respondents in the top 25% who answered the item correctly (\( P_u \))
6. Determine the proportion of respondents in the lower 25% who answered the item correctly (\( P_l \))
7. Calculate \( D \) by subtracting \( P_l \) from \( P_u \) (i.e., \( D = P_u - P_l \))
8. Repeat steps 5 through 7 for each item on the measure.

\( D \) values range from −1.00 to +1.00. \( D \) values greater than +0.20 are desirable for a norm-referenced measure (Martuzza, 1977). A positive \( D \) value is desirable and indicates that the item is discriminating in the same manner as the total test; that is, those who score high on the test tend to respond correctly to the item, while those who score low do not. A negative \( D \) value suggests that the item is not discriminating in the same way as the total test; that is, respondents who obtain low scores on the total measure tend to get the item correct, while those who score high on the measure tend to respond incorrectly to the item. A negative \( D \) value usually indicates that an item is faulty and needs improvement. Possible explanations for a negative \( D \) value are that the item provides a clue to the lower-scoring subjects that enables them to guess the correct response or that the item is misinterpreted by the high scorers.

### Item-Response Chart

Like \( D \), the item-response chart assesses an item’s ability to discriminate. The respondents ranking in the upper and lower 25% are identified as in steps 1 through 4 for determining \( D \). A fourfold table like the one in Figure 6.11 is then constructed using the two categories, high/low scorers and correct/incorrect for a given item. The information in Figure 6.11 is entered into a computer program to determine if a significant difference exists between the two groups. The resulting chi square value of 12.7 is significant at 0.05. A significant chi square value, as in the example, indicates that a significant difference exists in the proportion of high and low scorers who have correct responses. Items that meet this criterion should be retained, while those that do not should be discarded or modified to improve their ability to discriminate.

<table>
<thead>
<tr>
<th>Score</th>
<th>Incorrect</th>
<th>Correct</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>(B) 1</td>
<td>(A) 10</td>
<td>(A+B) 11</td>
</tr>
<tr>
<td>Low</td>
<td>(D) 8</td>
<td>(C) 1</td>
<td>(C+D) 9</td>
</tr>
<tr>
<td>Totals</td>
<td>(B+D) 9</td>
<td>(A+C) 11</td>
<td>(N) 20</td>
</tr>
</tbody>
</table>

**FIGURE 6.11** Item-response chart for a true/false or multiple-choice measure (\( n = 20 \)).
Next, one inspects the total response patterns in the item-response chart to identify problems with distractors. Examination of the information in Figure 6.12 suggests that the item does not discriminate well.

The incorrect option was selected by only 10% of the subjects. It would therefore be prudent to examine the item to determine if these results are due to some item defect and to revise the item accordingly. Potential problems are that the correct option contains a clue that is used by many of the lower group in responding; or that the incorrect option is grammatically inconsistent with the stem, thus cluing subjects not to select it. If the item appears sound as constructed, it would be useful to analyze the content and procedures to which the item relates for the purpose of determining why the item's discriminating power is marginal. In addition to its utility in analyzing true/false or multiple-choice measures, the item-response chart is also useful in situations in which affective measures with more than two choices are employed in an attempt to distinguish between the attitudes, values, or preferences of two groups of subjects on a given measure.

For example, one would use an item-response chart like the one in Figure 6.13 in the following manner to assess an item's ability to distinguish between practitioners' and educators’ preferences for involvement in a particular type of nursing practice.

1. A group of educators and practitioners are asked to respond to the item:
   Item: I prefer working directly with patients to working with students in the clinical area.
   Options: __ A. agree (desired response by practitioners)
   __ D. disagree (desired response by educators)
   __ U. undecided

2. Data are divided into two groups: educators and practitioners
3. A $2 \times 3$ table is constructed as in Figure 6.13.
4. Using the data in the table, a computer program is employed to determine the difference between the means of the two groups using a chi square statistic.
5. The resulting chi square $= 4.98$, $df = 2$ does not meet or exceed the critical value and thus is not significant.

Therefore, it is concluded that there is not a statistically significant difference between the proportion of practitioners and educators who answered as expected, that is, it was expected that practitioners would agree with the statement

<table>
<thead>
<tr>
<th>Response</th>
<th>Incorrect</th>
<th>Correct</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>5</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>Low</td>
<td>5</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Totals</td>
<td>10</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

FIGURE 6.12 Example of an item-response chart indicating an item without discriminatory power resulting from a faulty distractor.

<table>
<thead>
<tr>
<th>Group</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practitioners</td>
<td>10</td>
<td>5</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Educators</td>
<td>20</td>
<td>5</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>10</td>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

FIGURE 6.13 Item-response chart for an affective measure with more than two responses.
“I prefer working directly with patients to working with students in the clinical area,” and that educators would disagree. If chi square had been significant, the item would be discriminating as expected and would be retained. The item as it stands, however, needs revision or should be eliminated and replaced by an item with more power to discriminate between practitioners’ preferences and educators’ preferences for involvement in nursing practice.

**Differential Item Function**

Differential item function (DIF) refers to “when examinees of the same ability but belonging to different groups have differing probabilities of success on an item” (Hattie, Jaeger, & Bond, 1999, p. 432). When DIF is present, it is an indicator of potential item bias, in that an unbiased item, by definition, is one for which the probability of success is the same for equally able respondents regardless of their group membership (e.g., ethnicity or gender). A relatively simple approach to detecting DIF is to compare item-discrimination indices (i.e., D, p level, and/or item-response charting) across different groups of respondents to determine if responses to the item(s) differ by group membership.

Several additional, more sophisticated, approaches to detecting DIF derived from classical measurement theory include (1) using hypothesis testing of the differences between two or more groups sampled from the same population who respond to the same measure employing analysis of variance (ANOVA) procedures to examine the interaction of groups by items, or the chi square statistic to examine the differences between an expected number of respondents in a particular ability category and the actual number observed to respond in that category; in both cases, rejection of the null hypothesis of no statistically significant differences is indicative of item bias (Issac & Michael, 1995); (2) performing a distractor response analysis where differences in response patterns of two or more groups to the incorrect alternative to an item by testing the null hypothesis of no statistically significant differences between group response frequencies in the discrete categories of question distractors; rejection of the null hypothesis suggests item bias is present (Issac & Michael, 1995); and (3) employing the Mantel-Haenszel procedure (Holland & Thayer, 1988; Silverlake, 1999) where two groups of respondents with similar scores on the same measure are matched, and the performance of each group is compared on each item; items demonstrating differences between groups are presumed to be biased.

Another approach to detecting DIF, based on item-response theory, compares item characteristic curves (ICC) for each group of respondents, assuming that ICC curves should be similar if items are unbiased (Embretson & Hershberger, 1999; Nunnally & Bernstein, 1994). An example of the use of ICC curves for investigating item score patterns can be found in Meijer (2003, pp. 72–87) and McArdle and colleagues (2009). Bauer and Hussong (2009) discuss differential item functioning within the context of integrative data analysis (IDA) or the simultaneous analysis of data obtained from two or more independent studies. Readers interested in a comprehensive discussion of item bias and approaches to detecting DIF are referred to Osterlind (1983).

**CRITERION-REFERENCED VALIDITY ASSESSMENT**

The validity of a criterion-referenced measure can be analyzed at the item and test levels to ascertain if the measure functions in a manner consistent with its purposes. As Berk (1980b, p. 47) so aptly pointed out, the focus of item validity for criterion-referenced measures is “how well each item measures its respective objective (item-objective congruence)” and helps classify persons or objects into their appropriate category (item discrimination). Test validity focuses on the representativeness of a cluster of items in relation to the specified content domain (content validity), the significance of test results in relation to the initial conceptualization of the measure (construct validity), the decisions that result from the scores on the measure (decision validity), the extent to which future performance on a measure can be predicted from performance on a prior measure (predictive validity), and the extent to which an individual’s performance on one measure can be
used to estimate an individual’s performance on a criterion measure (concurrent validity). Since criterion-referenced measures result in the classification of phenomena in relation to the domain of interest, the validity of standards or cut scores assumes special significance. In essence, validity in terms of criterion-referenced interpretations relates to the extent to which scores result in the accurate classification of objects in regard to their domain status. The measure also must be content valid; that is; its items or tasks must adequately represent the domain that is the focus of measurement. Since validity of the content of the measure is requisite to the validity of the total measure or test, attention is now given to a discussion of content validation of criterion-referenced measures.

**Validity Assessment by Content Specialists**

Content specialists selected for the evaluation of content in a criterion-referenced measure should be conversant with the domain treated in the measuring tool. The developer of a measure should keep in mind that the ratings of content specialists are only as good as their level of expertise in the area of content measured. One or more poor content specialists can greatly compromise the process of content validation. In most instances, two or more content specialists are employed; however, the number depends on the type of procedure.

Of the content validity procedures discussed, item-objective congruence focuses on content validity at the item level, while the other procedures primarily place emphasis on the content validity of the group of items within a measure. Remember that if more than one objective is used for a measure, the items that are measures of each objective usually are treated as separate tests when interpreting the results of validity assessments.

**Criterion-Referenced Content Validity**

Unless the items or tasks in a criterion-referenced measure assess the objective, any use of scores obtained will be questionable. For a measure to provide a clear description of domain status, the content domain must be consistent with its domain specifications or objective. Thus, content validity of a criterion-referenced measure is the first type of validity that should be established and is prerequisite for all other types of validity.

At the total test level, content validity for criterion-referenced measures relates to the representativeness of the total collection of test items or tasks as a measure of the content domain. In Chapter 4, a discussion of test specifications is provided. The major purpose of this approach to the construction of criterion-referenced measures is to facilitate the generation of content-valid test items that are homogeneous. The most frequently used posteriori content validity approach in criterion-referenced measurement uses content specialists to assess the quality and representativeness of the items within the test for measuring the content domain. Content specialists examine the format and content of each item and assess whether it is an appropriate measure of some part of the content domain of interest as determined by test specifications.

**Determination of Interrater Agreement**

Rating scales frequently are used to assess the validity of the group of items within a measure. Content specialists are provided with the conceptual definition of the variable(s) to be measured or the domain specifications (or the objectives) for the measure along with the set of items. The content specialists then independently rate the relevance of each item to the specified content domain as described previously in the norm-referenced case. The ratings of two content specialists are used to compute $P_o$ and $K$ as measures of interrater agreement as described in Chapter 5. Suppose the ratings obtained from the judges are as shown in Table 6.1. $P_o$ then is the proportion of items given a rating of not/somewhat relevant (1 or 2) and quite/very relevant (3 or 4) by both content specialists. Hence, in the case of content validity determination, $P_o$ is representative of the consistency of judges’ ratings of the relevance of the group of items within the test to the specified content domain. As noted previously, $K$ is $P_o$ corrected for chance agreements.
Once obtained, what do the values of $P_o$ and $K$ mean? An acceptable level of interrater agreement varies from situation to situation. However, safe guidelines for acceptable levels are $P_o$ values greater than or equal to 0.80, or $K$ greater than or equal to 0.25. If $P_o$ and $K$ or either of these values is too low, one or a combination of two problems could be operating. First, this could be an indication that the test items lack homogeneity and that the domain is ambiguous or is not well defined. Second, the problem could be due to the raters who might have interpreted the rating scale labels differently or used the rating scale differently (Martuza, 1977). Refinement of the domain specifications is required if the former is the case. If the latter is the problem, the raters are given more explicit directions and guidelines in the use of the scale to reduce the chance of differential use. The index of content validity (CVI), as discussed in the norm-referenced case, can be calculated from the content specialists’ ratings and is the proportion of items rated as quite/very relevant (3 or 4) by both judges. In the present case the CVI is $24/30 = 0.80$.

As indicated earlier, low values of $P_o$ and $K$ may be due to lack of homogeneity of items because of an inadequate domain definition. A clear and precise domain definition and domain specifications function to communicate what the results of measurements mean to those people who must interpret them, and what types of items and content should be included in the measure to those people who must construct the items. Content specialists’ ratings can be used to help check the descriptive clarity of the domain definition of a measure when indicated (Popham, 1978). Suppose that three content specialists are used to judge the congruence of the items in a measure of the specified domain, and that items were developed by 10 item writers who contributed three items each. The proportion of homogeneous items, as determined by each rater, will be useful in assessing the adequacy of the domain definition. For each judge the number of items rated as congruent divided by the total number of items in the measure yields the proportion of homogeneous items. For example, if a judge rated 20 of the items in a 30-item measure as congruent, the proportion of homogeneous items would be $20/30 = 0.67$.

Suppose the proportions of homogeneous items for the three content specialists are 0.67 (20 out of 30), 0.50 (15 out of 30), and 0.60 (18 out of 30). If, upon inspection of the item-by-item ratings of the judges, the majority of the item writers who contributed three items each. The proportion of homogeneous items, as determined by each rater, will be useful in assessing the adequacy of the domain definition. For each judge the number of items rated as congruent divided by the total number of items in the measure yields the proportion of homogeneous items. For example, if a judge rated 20 of the items in a 30-item measure as congruent, the proportion of homogeneous items would be $20/30 = 0.67$.

Assume that the proportions of homogeneous items for the three content specialists are 0.90 (27 out of 30), 0.93 (28 out of 30), and 0.93 (28 out of 30). After scrutinizing the items, it becomes apparent that each of the items judged to be unlike the rest had been prepared by one item writer. In this case the flaw is not likely to be

### Table 6.1 Hypothetical Content Specialists’ Ratings of the Relevance of 30 Items for Assessing Adjustment to Parenthood

<table>
<thead>
<tr>
<th>Judge</th>
<th>Not/Somewhat Relevant (1 or 2)</th>
<th>Quite/Very Relevant (3 or 4)</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A)</td>
<td>(B)</td>
<td>(A + B)</td>
</tr>
<tr>
<td>Judge 1</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Judge 2</td>
<td>1</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Totals</td>
<td>4</td>
<td>26</td>
<td>30</td>
</tr>
</tbody>
</table>
in the domain definition as specified, but in the interpretations of one item writer.

**Average Congruency Percentage**

The content validity of a test also can be estimated by an average congruency percentage (Popham, 1978). Suppose four content specialists are identified and asked to read the domain specifications for a measure and then judge the congruence of each item on a 20-item measure with the specifications. The proportion of items rated congruent by each judge is calculated and converted to a percentage. Then the mean percentage for all four judges is calculated to obtain the average congruency percentage. For example, if the percentages of congruent items for the judges are 95%, 90%, 100%, and 100%, the average congruency percentage would be 96.25%. An average congruency percentage of 90% or higher can be safely considered acceptable.

When using content specialists’ ratings, including a specified number of irrelevant or incongruent items in the item pool can check the accuracy of each content specialist. The number of such aberrant items detected can determine the effectiveness of content specialists. Ratings of any content specialist who does not meet a set minimum level of performance in detecting these bad items are discarded from the analysis.

**CRITERION-REFERENCED CONSTRUCT VALIDITY**

Measurements obtained through the use of criterion-referenced measures are used to describe and make decisions based on an object’s domain status. Even though content validation of a measure is an important initial step in validity assessment, content validity evidence alone does not ensure a measure’s construct validity. Hence, evidence of the content representativeness of a measure does not guarantee that the measure is useful for its intended purpose. Although “we may say that a test’s results are accurately descriptive of the domain of behaviors it is supposed to measure, it is quite another thing to say that the function to which you wish to put a descriptively valid test is appropriate” (Popham, 1978, p. 159). Thus, the major focus of construct validation for criterion-referenced measures is to establish support for the measure’s ability to accurately categorize phenomena in accordance with the purpose for which it is being used. Approaches used to assess construct validity for criterion-referenced measures are presented below.

**Experimental Methods and the Contrasted-Groups Approach**

Experimental manipulation and the contrasted-groups approach also can be used to generate support for the construct validity of criterion-referenced measures. The basic principles and procedures for these two approaches are the same for criterion-referenced measures as for norm-referenced measures. Since criterion-referenced measures yield nominal or ordinal data, nonparametric statistical procedures are likely to be required when comparative statistical analysis is conducted. Experimental methods or the contrasted-groups approach also may be used to assess the decision validity of a measure, an important type of validity for criterion-referenced instruments.

**Decision Validity**

The measurements obtained from criterion-referenced measures are often used to make decisions. “Criterion-referenced tests have emerged as instruments that provide data via which mastery decisions can be made, as opposed to providing the decision itself” (Hashway, 1998, p. 112). For example: (1) a student may be allowed to progress to the next unit of instruction if test results indicate that the preceding unit has been mastered; (2) a woman in early labor may be allowed to ambulate if the nurse assesses, on pelvic examination, that the fetal head is engaged (as opposed to unengaged) in the pelvis; or (3) a diabetic patient may be allowed to go home if the necessary skills for self-care have been mastered. These are just a few of the many examples of how criterion-referenced results can be used for decision making. The decision validity of criterion-referenced measures that are used for such decisions takes on special significance, because the consequences of a bad decision can have detrimental effects. The decision validity of
a measure is supported when the set standard(s) or criterion classifies subjects or objects with a high level of confidence.

In the most instances, two criterion groups are used to test the decision validity of a measure: one group known to be low in the attribute of interest and the other high. For example, suppose a measure is designed to test mastery of skills for application of aseptic technique. Also, suppose that students in a fundamentals of nursing course, who have no prior exposure to aseptic technique, are randomly assigned to one of two groups: one receiving instruction on aseptic technique and the other receiving no instruction in the area. If the test has decision validity, a much higher percentage of students in the group receiving instruction should be classified as masters after instruction than as nonmasters, and a higher percentage of those receiving no instruction should be classified as nonmasters by the test than as masters. The decision validity of the test would be calculated “by summing the percentage of instructed students who exceed the performance standard and the percentage of uninstructed students who did not” (Hambleton, 1980, p. 98). It is assumed that these are the groups that are correctly classified by the testing procedure. Thus, decision validity can range from 0 to 100%, with high percentages reflecting high decision validity.

Criterion groups for testing the decision validity of a measure also can be created if individuals can be classified prior to testing according to whether they are known by independent means to be low or high on the attribute tested. The congruence between the classifications resulting from the measure and the known classifications are used to calculate the decision validity of the measure. For example, assume that the validity of a nurse’s assessments of the position of the fetal presenting part on pelvic examination during labor are considered. Suppose the fetal positions are also determined via sonography. The congruence between the nurse’s assessments and the results from sonography is used to determine the decision validity of the nurse’s assessments.

Decision validity is influenced not only by the quality of the measure, but also by the appropriateness of the criterion groups, the characteristics of the subjects, and the level of performance or cut score required. Of course, decision validity is necessary only in instances in which scores or results are used to make decisions (Hambleton, 1980).

Maurer (2005) notes that when using criterion-referenced tests for making decisions for personnel selection that there are two types of distinct cut scores that may be applied, which are a “cutoff score” and a “critical score.” The “cutoff score” may not depend on a specific criterion because it may vary for employment purposes based on the number of available slots in relation to the number of applicants. Therefore, the “cutoff score” for personnel selection may not be considered a criterion-referenced cut score. The “critical score,” on the other hand, is a criterion-referenced cut score because it is the score above which candidates are considered successful and capable of performance of the specified job.

Criterion-Related Validity

The functional usefulness of criterion-referenced measures is supported by criterion-related validity evidence. Criterion-related validity, particularly predictive validity evidence, establishes support that a measure functions as it should. Criterion-related validity studies of criterion-referenced measures are conducted in the same manner as for norm-referenced measures. The reader is referred to previous sections on norm-referenced validity for a thorough discussion of criterion-related validity approaches.

CRITERION-REFERENCED ITEM-ANALYSIS PROCEDURES

Some empirical procedures used in the validation of norm-referenced items can be used in criterion-referenced test validation. However, the statistics must be used and interpreted correctly in the context of the criterion-referenced framework. Rovinelli and Hambleton (1977) suggested that empirical methods used for item-discrimination indices have limited usefulness, because they can be used only to identify aberrant items without any intention of eliminating items from the item pool. It is not appropriate to rely on item statistics to select the items for
criterion-referenced measures, because theoretically this would alter the content domain and thereby weaken the representativeness of items and, thus, the interpretability of the domain score (Berk, 1980a; Hambleton, Swaminathan, Algina, & Coulson, 1978; Millman, 1974; Popham, 1978). Item-content validity is the extent to which each item is a measure of the content domain. Obtaining content specialists’ ratings holds the most merit for assessing item validities for determining which items should be retained or discarded; empirical item-discrimination indices should be used primarily to detect aberrant items in need of revision or correction (Hambleton, 1980).

**Item-Objective or Item-Subscale Congruence**

The item-objective congruence procedure, which may also be referred to as the item-subscale congruence procedure when used with questionnaires, provides an index of the validity of an item based on the ratings of two or more content specialists (Rovinelli & Hambleton, 1977). In this method content specialists are directed to assign a value of +1, 0, or –1 for each item, depending upon the item’s congruence with the measure’s objective or subscale. Whenever an item is judged to be a definite measure of the objective or subscale, a value of +1 is assigned. A rating of 0 indicates that the judge is undecided about whether the item is a measure of the objective or subscale. The assignment of a –1 rating reflects a definite judgment that the item is not a measure of the objective or subscale. Hence, the task of the content specialists is to make a judgment about whether an item falls within the content domain as specified by the measure’s objective or subscale. The data that result from the judges’ ratings are then used to compute the index of item-objective congruence or item-subscale congruence.

The index of item-objective congruence provides useful information about the agreement between content specialists’ ratings as to whether each item in a test or questionnaire measures the intended objective (or subscale). In this procedure an item is assessed to determine which of several objectives or subscales in a measure it represents. The limits of the index range from –1.00 to +1.00. An index of +1.00 will occur when perfect positive item-objective or subscale congruence exists, that is, when all content specialists assign a +1 to the item for its related objective or subscale and a –1 to the item for all other objectives or subscales that are measured by the tool. An index of –1.00 represents the worst possible value of the index and occurs when all content specialists assign a –1 to the item for what was expected to be its related objective or subscale and a +1 to the item for all other objectives or subscales. An advantage of the index of item-objective congruence (or item-subscale congruence) is that it does not depend on the number of content specialists used or on the number of objectives measured by the test or questionnaire. However, the tool must include more than one objective or subscale in order for this procedure to be used.

The index of item-objective (or item-subscale) congruence is provided by the following formula:

**Formula 6.1:** Calculating index of item-objective congruence (Martuza, 1977)

\[
I_{ik} = \frac{(M - 1) S_k - S'_k}{2N} \frac{1}{(M - 1)}
\]

where \( I_{ik} \) = the index of the item-objective congruence for item i and objective k

\( M \) = the number of objectives

\( N \) = the number of content specialists

\( S_k \) = the sum of the ratings assigned to objective k

\( S'_k \) = the sum of the ratings assigned to all objectives, except objective k

Based on the information provided in Table 6.2, the index of item-objective congruence can be calculated in the following manner. It should be noted that in this case:

\[
I_{ik} = I_{11}
\]

\( M = 4 \)

\( N = 3 \)

\( S_k = 2 \)

\( S'_k = (-3) + (-2) + (-3) = -8 \)

Hence \( I_{11} = (4 - 1) \frac{1}{(4 - 1)} + 2 - (-8)/2(3) \frac{1}{(4 - 1)} \)

\[= 6 + 8/18 \]

\[= 14/18 \]

\[= 0.78 \]
When the index is used to determine which items should be revised or retained during the measure's development process, an index cut-off score to separate valid from nonvalid items within the test should be set. The setting of this index cut-off score is usually derived by the test developer. Hambleton (1980) suggests that this should be done by creating the poorest set of content specialists’ ratings that the test developer is willing to accept as evidence that an item is within the content domain of interest. After computing the index for this set of minimally acceptable ratings, the resulting index serves as the index cutoff score for judging the validity of the items. It serves as the criterion against which each item within the measure is judged, based on its index of item-objective congruence, which resulted from content specialists’ ratings. If, for instance, the index cut-off score is 0.75, then all items with an index of item-objective congruence below 0.75 are deemed nonvalid, while those with an index of 0.75 or above are considered valid. Those with an index below 0.75 are discarded from the measure or analyzed and revised to improve their validity.

**Empirical Item-Analysis Procedures**

Criterion-referenced item-analysis procedures determine the effectiveness of a specific test item to discriminate subjects who have acquired the target behavior and those who have not. It is important that the content of the measure be kept as representative of the specified content domain as possible. Therefore, caution should be exercised before items are discarded from a criterion-referenced measure based on empirical item-analysis procedures. The nature of the subjects and the treatment or intervention may result in an item-discrimination index that may imply that the item does not function well when it is actually content valid. However, if there is sufficient evidence that an item is not functioning as it should and also is not content valid, it is recommended that it be discarded from the measure or revised.

In criterion-referenced item-analysis procedures, empirical data are obtained from respondents in order to evaluate the effectiveness of the items of the measuring tool. The most commonly used item-analysis procedures employ either pretest-posttest measurements with one group or two independent measurements with two different groups. The selection of the groups depends upon the purpose of the measure. Groups chosen for item analysis of criterion-referenced measures are often referred to as criterion groups. Two approaches are used for identifying criterion groups: (1) the criterion-groups technique, which also may be referred to as the uninstructed-instructed groups approach, when the focus of measurement is knowledge; and (2) pretreatment-posttreatment measures approach, which in appropriate instances may be called the preinstruction-postinstruction measurements approach.

The criterion-groups technique involves the testing of two separate groups at the same time—one group that is known by independent means to possess more of the specified trait or attribute, and a second group known to possess less. For example, if the purpose of a criterion-referenced measure is to identify parents who have and who have not adjusted to parenthood after the birth of a first child, two groups of parents would be of interest—those who have adjusted to parenthood and those who have not had a previous opportunity to adjust to parenthood. A group of parents who have previously experienced parenthood might then be contrasted with a group of inexperienced parents who have just had their first
Chapter 6  Validity of Measures  193

child. The subjects chosen for each of the groups should be as similar as possible on relevant characteristics, for example, social class, cultures, and ages. In addition, the proportional distribution of relevant characteristics between groups should be equivalent. The only real difference between the groups should be in terms of exposure to the specified treatment or experience.

The criterion-groups technique has a major advantage in that it is highly practical. Item analysis can be conducted at one time if a group that is known to possess more of the specified trait or attribute is available at the same time as a group that is low or lacking in the trait or attribute of interest. However, one disadvantage is the difficulty of defining criteria for identifying groups. Another is the requirement of equivalence of groups. It is often difficult to randomly assign persons to groups, such as when using instructed and uninstructed groups. Differences in group performance might be attributable to such characteristics as socioeconomic background, age, sex, or levels of ability if groups are not proportionately balanced on relevant characteristics.

The pretreatment-posttreatment measurements approach involves testing one group of subjects twice—once before exposure to some specific treatment (pretreatment), and again after exposure to the treatment (posttreatment). Subjects are usually tested with the same set of items on both occasions, or a parallel or equivalent set of items can be administered on the second testing. In the case in which instruction is the treatment, testing would occur before instruction (preinstruction) and after instruction (postinstruction).

This approach has the advantage of allowing analysis of individual as well as group gains. However, a major limitation is the impracticality of administering the posttest. Item analysis cannot be done until after the treatment or instruction has been completed. A second limitation is the amount of time that may be required between the pretest and posttest. When the period between testing is short, there is a potential problem for testing effect, which could influence performance on the posttest. The use of parallel or equivalent items helps to reduce testing effect. If this is not possible because of practical constraints or the nature of the content domain, the period between administrations might be extended to reduce the carryover effect of memory from the initial testing. The period between the pretest and posttest should not extend beyond 2 months to reduce the chances of a history or maturation effect. Intervening events or simply growing older can influence individual performance or results on the posttest. Improvement in performance due to history or maturation or both can become inextricably mixed with the treatment or effects of instruction. Item analysis is designed to focus only on the change in responses to items because of treatment or instruction (Berk, 1980a).

### Item Difficulty

Because of the purpose of criterion-referenced measures, it is appropriate to examine the difficulty level of items and compare them between criterion groups. Separate item \( p \) levels should be calculated for each item in the measure for each of the criterion groups. The approaches to calculating item \( p \) levels and their interpretation was discussed previously in this chapter in relation to norm-referenced item-analysis procedures. The item \( p \) levels for each item are compared between groups to help determine if respondents would have performed similarly on an item, regardless of which group they are in. The item \( p \) level should be higher for the group that is known to possess more of the specified trait or attribute than for the group known to possess less. Hence, the item \( p \) level should be substantially higher on a measure of parental adjustment for a group of experienced parents, who have had an opportunity to adjust to parenthood previously, than for a group of inexperienced parents. If this were the case, this would be positive evidence of item validity. Likewise, the item \( p \) levels of a group should be higher on a posttest after a relevant treatment has been provided than on the pretest.

### Item Discrimination

The focus of item-discrimination indices for criterion-referenced measures is on the measurement of performance changes (e.g., pretest-posttest) or differences (e.g., experienced parents-inexperienced parents) between
Three item-discrimination indices that can be employed when the pretreatment-posttreatment measurements approach is used are (1) pretest-posttest difference, (2) individual gain, and (3) net gain. The pretest-posttest difference index (PPDI) is the proportion of respondents who answered the item correctly on the posttest minus the proportion who responded to the item correctly on the pretest.

**Formula 6.3:** Calculating the pretest/posttest difference index (PPDI)

\[
PPDI = \frac{\text{the item } p \text{ level on the posttest} - \text{the item } p \text{ level on the pretest}}{\text{the item } p \text{ level on the posttest}}
\]

The individual gain index (IGI) is the proportion of respondents who answered the item incorrectly on the pretest and correctly on the posttest. For example, in Table 6.3, which shows the response data on an item by 50 respondents, IGI would be the value in cell C divided by the total number of respondents as given below in Formula 6.4.

**Formula 6.4:** Calculating the individual gain index (IGI)

\[
IGI = \frac{C}{A + B + C + D} = \frac{35}{50} = 0.70
\]

The net gain index (NGI) is the proportion of respondents who answered the item incorrectly on both occasions subtracted from the IGI. Thus, NGI is an extension of IGI that considers the performance of all respondents who answered the item incorrectly on the pretest. Given the
The range of values for each of the indices discussed above is $-1.00$ to $+1.00$, except for IGI, which has a range of $0$ to $+1.00$. A high positive index for each of these item-discrimination indices is desirable, since this would reflect the item’s ability to discriminate between criterion groups.

The nature of the content domain and the measure’s objective, along with the method used to compute discrimination, would influence the level at which the item-discrimination index should be positive. A summary of criterion-referenced item-discrimination indices discussed above is presented in Table 6.4.

A useful adjunct item-discrimination index is provided through the use of $P$, or $K$ to measure the effectiveness of an item in relation to the total test in classifying subjects into categories (Martin, 1977). For example, groups of masters and

### TABLE 6.4 Summary of Selected Criterion-Referenced Item-Discrimination Indices

<table>
<thead>
<tr>
<th>Index</th>
<th>Range of Values</th>
<th>Definition</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion groups difference index (CGDI)</td>
<td>$-1.00$ to $+1.00$</td>
<td>The proportion of respondents in the group known to possess more of the attribute of interest who answered the item correctly minus the proportion of respondents in the group known to possess less of the attribute who answered it correctly.</td>
<td>Commonly referred to as the uninstructed-instructed group difference index when used in instructional context. Index is only sensitive to group differences. Does not focus on individual performance differences.</td>
</tr>
<tr>
<td>Pretest-posttest difference index (PPDI)</td>
<td>$-1.00$ to $+1.00$</td>
<td>The proportion of respondents who answered the item correctly on the posttest minus the proportion who responded to the item correctly on the pretest.</td>
<td>Index is only sensitive to group changes in performance and not to individual performance gain or loss.</td>
</tr>
<tr>
<td>Individual gain index (IGI)</td>
<td>$0$ to $+1.00$</td>
<td>The proportion of respondents who answered the item incorrectly on the pretest and correctly on the posttest.</td>
<td>Reflects change in performance in group based on performance changes by the individuals within the group who shifted from incorrect to correct response from pretest to posttest.</td>
</tr>
<tr>
<td>Net gain index (NGI)</td>
<td>$-1.00$ to $+1.00$</td>
<td>The proportion of respondents who answered item incorrectly on both the pretest and posttest subtracted from IGI.</td>
<td>Considers performance of all respondents who answered item incorrectly on the pretest. Yields values that are more conservative than preceding indices.</td>
</tr>
</tbody>
</table>

considered in terms of the value of $K_{\text{max}}$, there is evidence that the item discriminates between masters and nonmasters, since $K/K_{\text{max}}$ is 0.55.

When item $p$ levels and discrimination indices do not support the validity of the item, the problem could be explained in terms of the item itself, the objective, or the nature of the treatment. When an item $p$ level is much higher than expected on the pretest or in a group with less of the specified attribute, it is possible that there has been previous exposure to the content domain. If the $p$ level is much lower than expected on a posttest, the objective may be too difficult or the treatment may have been ineffective. A much lower than expected item-discrimination index could be due to one or a combination of problems cited above (Berk, 1980a).

When the item itself is suspected of being faulty, then it must be carefully scrutinized. Usually a negative discrimination index is due to a faulty item. Examination of the structure of the item and each response alternative is in order. Ambiguity, ineffective distractors, and more than one correct answer on a multiple-choice

nonmasters by the test are checked against the proportion of masters and nonmasters on the item. If, for example, the data (expressed as proportions) in Table 6.5 reflect classifications by a specific item and the test for a group of subjects, agreement between these two classifications could be considered an index of item discrimination. Thus, in this case there is 38% agreement between the item and the test as determined by the value of $K$.

\[
P_o = 0.70 + 0.10 = 0.80 \\
P_c = (0.75) (0.85) + (0.25) (0.15) = 0.68 \\
K = P_o - P_c / 1 - P_c \\
= 0.80 - 0.68/1 - 0.68 \\
= 0.12/0.32 \\
= 0.38
\]

At this point, the value of $K_{\text{max}}$ can be calculated to determine the maximum possible agreements consistent with the observed marginal proportions in Table 6.5. The tabular adjustments required are presented in Table 6.6. The value of $K_{\text{max}}$ in this instance is 0.69. When $K$ is considered in terms of the value of $K_{\text{max}}$, there is evidence that the item discriminates between masters and nonmasters, since $K/K_{\text{max}}$ is 0.55.

When item $p$ levels and discrimination indices do not support the validity of the item, the problem could be explained in terms of the item itself, the objective, or the nature of the treatment. When an item $p$ level is much higher than expected on the pretest or in a group with less of the specified attribute, it is possible that there has been previous exposure to the content domain. If the $p$ level is much lower than expected on a posttest, the objective may be too difficult or the treatment may have been ineffective. A much lower than expected item-discrimination index could be due to one or a combination of problems cited above (Berk, 1980a).

When the item itself is suspected of being faulty, then it must be carefully scrutinized. Usually a negative discrimination index is due to a faulty item. Examination of the structure of the item and each response alternative is in order. Ambiguity, ineffective distractors, and more than one correct answer on a multiple-choice

<table>
<thead>
<tr>
<th>Item Classifications</th>
<th>Test Classifications</th>
<th>Master</th>
<th>Nonmaster</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>(A)</td>
<td>0.70</td>
<td>0.05</td>
<td>0.75</td>
</tr>
<tr>
<td>Nonmaster</td>
<td>(C)</td>
<td>0.15</td>
<td>0.10</td>
<td>0.25</td>
</tr>
<tr>
<td>Totals</td>
<td>(A + C)</td>
<td>0.85</td>
<td>0.15</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item Classifications</th>
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<th>Master</th>
<th>Nonmaster</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>(A)</td>
<td>0.75</td>
<td>0.00</td>
<td>0.75</td>
</tr>
<tr>
<td>Nonmaster</td>
<td>(C)</td>
<td>0.10</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>Totals</td>
<td>(A + C)</td>
<td>0.85</td>
<td>0.15</td>
<td>1.00</td>
</tr>
</tbody>
</table>

TABLE 6.5 Joint Mastery Classifications of Examinees by One Item and the Total Test Score Expressed as Proportions

TABLE 6.6 Tabular Adjustments Required in Table 6.5 for Computation
test should be considered. It is a good idea to get item reviews from respondents at the time the tool is administered, when the purpose of the administration is to obtain data for item analysis. Respondents can be asked to identify confusing items, items with no correct answer or more than one correct answer, and other problems encountered while progressing through the test. Such information can be used when identifying and revising poor items.

**SUMMARY**

Every measurement involves some error that cannot be eliminated but can be reduced by use of sound approaches to measurement. Systematic errors of measurement decrease validity. Validity is a unitary concept. It is the degree to which all of the accumulated evidence supports the intended interpretation of test scores for the intended purpose (AERA, APA, & NCME, 1999, p. 11). Validity must be assessed every time a given measure is employed. For any given tool or method, validity will be investigated in multiple ways depending upon the purpose for measurement and evidence for validity accrued with repeated use of the measure. When investigating the validity of a measure, consideration should be given to evidence based on (1) content, (2) response processes, (3) internal structure, (4) relations to other variables, and (5) consequences of testing. Norm-referenced validity procedures usually include content validity (CVI and alpha coefficient); construct validity (contrasted groups, hypothesis testing, factor analysis, and/or multitrait-multimethod); criterion-related validity (criterion-related validity studies, assessment of validity generalization, meta-analysis). Item-response procedures contribute to validity by separately evaluating each item on a measure to determine whether that item performs in the same manner as the overall measure is intended to perform. Item-analysis procedures employed in the norm-referenced case usually include item \( p \) level, the discrimination index, item-response charts, and differential item function (DIF) that is an indicator of item bias. Several approaches are available for detecting DIF based on classical measurement theory and item-response theory.

The concern of criterion-referenced validity is not only with whether a measure assesses what it is purported to measure, but also whether it functions in accordance with the purpose for which it is designed and used. Content validity and the assessment of construct validity and criterion-related and decision validity are important for criterion-referenced measures. As with norm-referenced measures, the validity of criterion-referenced tools may be assessed at the test or item levels. Item validity is a prerequisite to test validity and may be estimated by the determination of item-objective congruence with the use of content specialists or estimated via empirical means. Item validity estimates provide important information that can be used to revise and improve criterion-referenced measures, thereby improving test validity. However, the validity of standards or cut scores takes on special significance and has a direct impact on the validity of the measure, because criterion standards or cut scores are used to classify phenomena in relation to a specified content domain.

**REFERENCES**


Gagné, P., & Hancock, G. R. (2006). Measurement model quality, sample size, and


Schmidt, F. L., & Hunter, J. E. (1977). Development of a general solution to the problem of
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Standardization, a key process related to measurement, encompasses both uniformity of procedures for administering and scoring tests and norms as a basis for interpreting scores. The standardization process is carried out in a consistent and controlled manner with an extensive variety of situations and subjects (Nunnally & Bernstein, 1994). The goals of attaining consistency and control are central to both nursing practice and research, and the use of data to establish norms is in widespread use in all areas of health care, particularly with the current emphasis on expanding the scientific basis for evidence-based practice and personalized health care (e.g., Initiative on Personalized Health Care, 2007, 2008; President’s Council of Advisors on Science and Technology, 2008). Therefore, standardized approaches to measurement are methodologies that are highly appropriate for answering many nursing and health care questions and for studying phenomena regarding patients, health, and nursing care.

Standardized approaches to the development, use, and interpretation of measures are relevant in nursing practice: for example, in developing and using consistent approaches to designing interventions; administering and recording prescribed treatment; assessing patients’ symptoms, health status, and outcomes; and in evaluating the quality, safety, effectiveness, and impact of clinical practice and educational programs (e.g., Cozby, 2009; Electronic Benchmarking Inc. [EBI], 2009; Kazley & Ozcan, 2008; The National Quality Forum [NQF], 2003, 2004, 2005, 2007; North American Nursing Diagnosis Association, International, 2009; Stewart & Ware, 1992; Ware & Sherbourne, 1992). They are central to the design and conduct of clinical trials (Chow & Liu, 2004; Portney & Watkins, 2009) and other experimental studies of the effects of interventions. Standardized approaches to measurement can also be used in combination with qualitative methods in studies that employ methodological triangulation, described in Chapter 26.

Standardized measurement techniques have long been used in clinical and research laboratory settings to minimize error and assure consistent interpretation of results (see Chapters 20 and 21) (Bowling, 2001, 2002; Portney & Watkins, 2009). Nursing (Ryan & Doyle, 2009; Strickland & Dilorio, 2003; Waltz & Jenkins, 2001) and the behavioral sciences (e.g., Allison & Baskin, 2009; Butcher, 2009; Leavitt, 2008; Murphy & Davidshofer, 2001) use standardized measures—often used in combination with less highly structured approaches—to eliminate bias and reduce error in the research process. In this chapter standardization is defined, and the use and development of standardized measures are detailed.

**DEFINITION**

Broadly defined, a standardized measure, first proposed by Kelley (1914), is one that is constructed, administered, scored, and interpreted in a prescribed, precise, and consistent manner in order to reduce external influences that compromise reliability (Nunnally & Bernstein, 1994). The defining characteristics of a standardized measure refer to the properties of the measure itself and the way it was developed, rather than to the nature of the entity being measured (Nunnally & Bernstein, 1994). In order to be considered standardized, a measure must be carefully
developed, rigorously tested before general use, consistently administered and scored, and interpreted on the basis of established norms. Standardized measures are considered norm-referenced measures, because an individual’s score is interpreted by comparing it with scores obtained by other subjects in a well-defined comparison group. They are distinguished by the explicit and conscious exercise of control in all aspects of their development, use, and interpretation (Nunnally & Bernstein, 1994; Urbina, 2004). The term “standardized” has been most often applied to paper-and-pencil measures, but the essential characteristics and principles apply equally to other types of measures as well.

As used in this text, the term “standardized” is applied to measures that have four essential characteristics:

1. A fixed set of items or operations designed to measure a clearly defined concept, attribute, or behavior;
2. Explicit rules and procedures for administration and scoring;
3. Provision of norms to assist in interpreting scores;
4. An ongoing development process that involves careful testing, analysis, and revision in order to assure high technical quality.

In light of these criteria a variety of instruments and procedures may be considered standardized measures. Examples include published paper-and-pencil tests designed to measure scholastic aptitude and complex cognitive abilities (see Educational Testing Service, 2009), including critical thinking (see Insight Assessment, 2009); tests to measure personality traits (Butcher, 2009), mood states (e.g., Locke & Putnam, 2009; Radloff, 1977), emotional adjustment (e.g., Derogatis & Rutigliano, 1998; Kamphaus, DiStefano, & Lease, 2003); and measures of health status, quality of life, functional status, and satisfaction with care (e.g., Medical Outcomes Trust, 2009; RAND Health, 2009); tests to assess the developmental level of infants and children (Center for Early Education and Development, 2000); observational scales used in client assessment (e.g., Allison & Baskin, 2009; Bowling, 2001; Stromberg & Olsen, 2004); and measures used in educational program evaluation (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999) and clinical quality control (NQF, 2003, 2004, 2005). Hence, a standardized approach is ideal for measuring a wide range of attributes and behaviors of interest in nursing.

**STANDARDIZED VERSUS NONSTANDARDIZED MEASURES**

Clearly not all measures used in nursing research are standardized, but may have incorporated one or more of the four essential characteristics required of standardized measures. Such measures will be referred to as “nonstandardized” measures. In this sense, standardization may be considered a matter of degree and one can compare nonstandardized measures with respect to their approximation of the model for standardized measures described below and detailed in Table 7.1.

**Comparative Advantages**

The comparative advantages and disadvantages of standardized and nonstandardized measures are summarized in Table 7.1. Standardized measures are more desirable for some purposes than for others; so a standardized measure is not necessarily superior to a nonstandardized measure. For example, if a nurse researcher wished to assess the developmental level of an abused child in relation to national norms, a standardized measure of child development would be appropriate. On the other hand, if the purpose were to assess coping strategies of abused children, a standardized measure would be of little value because national norms do not exist.

Because standardized and nonstandardized measures can provide different types of information for use in decision making, evaluating or understanding a particular phenomenon, the two types of measures are often used simultaneously. For example, schools of nursing often use both nonstandardized teacher-made tests and standardized tests developed by organizations (e.g., National League of Nursing) or proprietary...
companies (e.g., HESI, ATI, EBI) to measure student achievement in a given subfield of nursing. For instance, as a basis for admission decisions, schools may require both standardized aptitude tests (such as Scholastic Aptitude Test [SAT]) and locally developed nonstandardized aptitude tests related to specific abilities deemed relevant to their particular curriculum. A clinician or researcher wanting to measure preoperative anxiety might combine a standardized laboratory

### TABLE 7.1 Comparative Advantages and Disadvantages of Standardized and Nonstandardized Measures

<table>
<thead>
<tr>
<th>Standardized Measures</th>
<th>Nonstandardized Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
</tr>
<tr>
<td>Advantages: Involves input of experts; method of construction is designed to enhance technical quality, reliability, and validity; procedure used in construction and testing is usually described.</td>
<td>Advantages: May be carried out in situations in which time and resources are limited; short span of time is required between planning and use of the measure.</td>
</tr>
<tr>
<td>Disadvantages: Costly, time-consuming; requires adequate resources.</td>
<td>Disadvantages: Construction procedure is variable and does not necessarily assure high quality; procedure generally is not described in detail; amount of expert input is variable and may be unknown.</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td></td>
</tr>
<tr>
<td>Advantages: Measures attributes or behaviors that are common to a variety of settings and situations; is applicable to many settings; reflects widespread consensus rather than localized emphasis; is applicable across time and locale; is well defined and fixed, allowing consistent comparison; parameters are usually specified.</td>
<td>Advantages: Well-adapted to specialized needs and emphasis; flexibility allows adaptation to changes in materials or procedures; allows inclusion of controversal or timely information.</td>
</tr>
<tr>
<td>Disadvantages: Inflexible; cannot be adapted to local or specialized situations; may reflect consensus views that are incongruent with specialized needs and purposes; precludes innovative, controversal, or time-bound material.</td>
<td>Disadvantages: May reflect unique views or biases that are not deemed relevant by recognized authorities. Time- and situation-specificity precludes widespread use.</td>
</tr>
<tr>
<td><strong>Psychometrics</strong></td>
<td></td>
</tr>
<tr>
<td>Advantages: Reliability (internal consistency and test-retest) is high, yielding stable results; procedures to establish reliability and validity are reported, so are known to the user; items and operations have high discriminating power.</td>
<td>Advantages: Technical properties to be optimized are determined based on purposes of the measure (e.g., qualitative studies).</td>
</tr>
<tr>
<td>Disadvantages: Stability of scores results in insensitivity to minor fluctuations that may be desirable to measure.</td>
<td>Disadvantages: Technical properties frequently are unknown and may be highly variable, dependent on the construction procedures used.</td>
</tr>
<tr>
<td><strong>Administration and Scoring</strong></td>
<td></td>
</tr>
<tr>
<td>Advantages: Established procedures provide consistency, giving comparable results; effects of different testing conditions and environments are minimized; centralized or automated scoring is cost-efficient for large-scale efforts.</td>
<td>Advantages: Procedures can be developed based on specific needs and resources; flexible procedures permit last-minute alterations; local and/or hand scoring is cost-efficient for small samples; time lag between administration and scoring is determined by the user.</td>
</tr>
<tr>
<td>Disadvantages: Inflexibility precludes altering to fit individual circumstances and resources; may be costly and time-consuming; scheduling of administration and return of scored results may be controlled externally.</td>
<td>Disadvantages: Consistency between different administrations of the same measure is variable; different rules may be applied in scoring, thus yielding incomparable results.</td>
</tr>
</tbody>
</table>
### TABLE 7.1  Comparative Advantages and Disadvantages of Standardized and Nonstandardized Measures (Continued)

<table>
<thead>
<tr>
<th>Standardized Measures</th>
<th>Nonstandardized Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interpretation of Scores</strong></td>
<td><strong>Advantages:</strong> Comparisons and interpretations can be geared to specific needs and unique circumstances; amenable to situations for which comparison to a defined group is not an appropriate way to assign meaning to a score.</td>
</tr>
<tr>
<td><strong>Advantages:</strong> Scores can be uniformly compared</td>
<td><strong>Disadvantages:</strong> National norms may be inappropriate for unique purposes; utility for decision making in specific settings is variable; inappropriate for purposes that do not require comparison with the status quo.</td>
</tr>
<tr>
<td>with norm groups, often at the national level;</td>
<td></td>
</tr>
<tr>
<td>interpretation is likely to be consistent across applications; explicit instructions may be provided to facilitate interpretation.</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages:</strong> National norms may be inappropriate for unique purposes; utility for decision making in specific settings is variable; inappropriate for purposes that do not require comparison with the status quo.</td>
<td></td>
</tr>
</tbody>
</table>

Procedure (e.g., measurement of catecholamines in the urine), a standardized measure of anxiety (e.g., the State-Trait Anxiety Inventory [Spielberger, 2003; Spielberger, Gorsuch, & Lushene, 1970]), and a nonstandardized verbal self-rating of anxiety. Decisions about the use of standardized or nonstandardized measures must be based on the purposes for which the information will be used and the types of questions that must be answered, and of course depend on whether a standardized measure exists.

### Construction

Standardized measures are constructed by following a number of sequential steps. Although there is some variation, the following procedure is generally used (Johnston & Pennypacker, 2008; Nunnally & Bernstein, 1994):

1. Objectives, specifications, and a blueprint are developed.
2. Items are written and operations identified.
3. The items are pretested and analyzed using item statistics.
4. Acceptable items are assembled into a preliminary form (or preliminary equivalent forms) of the measure.
5. The preliminary form of the measure is experimentally administered to criterion groups of examinees to determine or verify the adequacy of item limits and instructions, difficulty level, discriminating power, reliability, and validity.
6. Revisions are made to eliminate items or operations that are unnecessary, problematic, or do not contribute to the measure’s reliability and validity.
7. A final form of the measure is assembled.
8. Uniform mechanisms for administration and explicit instructions for scoring are established.
9. The final form of the measure is administered to carefully selected referent groups in order to develop norms.
10. The final version of the measure, a manual, and supplementary materials are made available for use.

This process is time-consuming and complex, often taking several years. Because of the effort and time involved, standardized measures are usually developed for widespread use. Ideally their development incorporates the collaboration of content and measurement experts throughout, in order to produce an instrument or device that is of high technical quality and can be used and interpreted consistently in various settings.

Some measures that are have been in widespread use over many years were not developed originally with standardization in mind; however, their repeated use in a variety of contexts has allowed sufficient accumulation of data to provide national or even international norms for interpretation (Portney & Watkins, 2009). Examples of instruments that have essentially met the criteria for standardization are the Brief Symptom Inventory (BSI)-18 (Derogatis, 1993; 2000) and
the SF-36 (RAND Health, 2009; Stewart & Ware, 1992; Ware & Sherbourne, 1992). These self-report tools are available online (http://www.pearsonassessments.com; http://www.sf-36.com; http://www.rand.org/health/surveys_tools/mos/mos_core_scoring.pdf) and are administered to numerous individuals by many investigators in the United States and abroad. The data are being supplied to tool developers, who are continually reevaluating the psychometric properties of the tool and setting up norms.

DEVELOPING, ADMINISTERING, AND SCORING STANDARDIZED MEASURES CONTENT

Because they are designed for widespread and consistent use, standardized tests are characterized by content that is (1) sufficiently generic for applicability in a variety of settings, (2) not time-bound or rapidly outmoded, and (3) fixed or predefined (Portney & Watkins, 2009). In contrast, the content of nonstandardized measures is typically more specific for use in a particular setting and has more flexibility. Content may be updated frequently and adapted to accommodate minor changes.

Selection of content for any standardized measure is based on a statement of purpose and a blueprint that specifies the elements or dimensions of the domain of behavior or cognition that is to be sampled and the relative emphasis that is to be given to each element (Nunnally & Bernstein, 1994). The purpose of a standardized measure is generally stated in nonsituation-specific terms so the measure is acceptable to a variety of potential users. Similarly, the blueprint reflects a definition of the domain that is potentially acceptable across settings and defensible on the basis of published research or expert opinion. Such a blueprint would eliminate content that is relevant only in a particular setting or situation or that is specific to a particular theory.

Consider, for example, the difference between the content of a nonstandardized test that is administered in one school of nursing to measure critical thinking specific to a given course and a standardized measure designed for administration across the nation to all undergraduate nursing students. The former might reflect content that is defined as important by an individual faculty member or small group, and could make reference to situations unique to that setting. The standardized test, however, would need to reflect content and scenarios that would be possible for students in schools nationally to understand. Standardized measures require screening content to avoid time-bound, conflicting, or controversial ideas and new information that has not yet gained widespread acceptance. This activity is best carried out by experts who have not been involved in the development of the content.

Because standardized measures are very time-consuming to develop, they are generally used for several years without modification. Cognitive or affective items that assume or test knowledge of current events or very recent advances in the field are more appropriately included in nonstandardized than in standardized measures.

By definition, the content of a standardized measure is preestablished and preferably guided by theory. Items or operations are carefully selected and tested. They cannot be changed or deleted by the user of the measure without modifying its known psychometric properties (reliability and validity). To make changes would be to negate the essence of standardization. Nonstandardized measures are not content-constrained and can be changed; however, when a nonstandardized measure that has been tested and used previously is modified for subsequent use, it in effect is transformed into a different measure, and former estimates of reliability and validity no longer apply (Nunnally & Bernstein, 1994).

Administration

In order to assure consistency, standardized measures are characterized by prescribed administration and scoring procedures. The method for administering the measure is determined in advance by the developer and is then pretested (Nunnally & Bernstein, 1994). Once the instrument has been finalized, it is administered to a representative referent group for establishing norms. This is termed a norming administration.
In actuality, for most standardized measures a series of administrations to subsamples is required in order to encompass the entire referent sample, which may be geographically dispersed. In each instance the measure is administered according to the same specifications and under conditions identical to those that will be used in subsequent administrations (Portney & Watkins, 2009). For example, if the measure is designed for administration to patients in a home environment and within a specific time limit, these conditions must prevail during each referent subsample administration in order to assure comparability of results. At the time of the norming administration, supplementary data about characteristics of the referent sample members are also collected. These data are later used to prepare differentiated norms specific to particular subunits of the referent group. More detail about norms and the norming administration is provided in a later section of this chapter.

Rigid control over the conditions of administration to assure uniformity is critical to the concept of standardization (Kaplan & Saccuzzo, 2009; McIntyre & Miller, 2007). Once it is final, explicit instructions are provided for users in a test manual. Specific administration procedures include such elements as time limits, scripted directions that are to be given the individual being tested and, especially for laboratory devices, the way in which the instrument is to be used. Detailed instructions for administration and instructions for the subjects must be in final form before the measure is released for more widespread administration and must be followed precisely. The rapid evolution of computerized administration of measures has helped considerably to increase control over instrument administration while adding expectations about the availability of appropriate equipment and assistance and technological support for respondents.

The requirement for standard administration procedures and conditions places responsibility on the measure’s developer to provide explicit instructions that leave little latitude for error. In the case of complex administration procedures, special training and certification may be required to assure consistency. This requirement also places considerable responsibility on the user to become thoroughly familiar with the procedures in advance and then to implement them. This entails trying to anticipate and eliminate potential threats to consistency. Assembling all necessary materials in advance and selecting a quiet location for administering the measure are examples of steps that might be taken to prevent delays and distractions during administration.

Any unanticipated alteration of the prescribed protocol should be noted carefully so that it can be taken into account in interpreting results. Such alterations might include (1) distractions that would affect an entire group of subjects (e.g., fire alarm or loss of power), (2) systematic errors in executing the procedure itself (e.g., inaccurate time keeping, incorrectly calibrated device), and (3) influences unique to an individual score (e.g., a subject being called away from the administration momentarily or receiving supplemental instructions). In addition, it may be important to note special circumstances external to the test administration that might affect the performance of an individual or group. For example, if a nurse researcher were measuring staff nurses’ job satisfaction, an event such as recent layoffs in the institution would be likely to influence results and should be noted. Although not all distractions or idiosyncratic circumstances can be eliminated, the user of the standardized measure must (1) try to prevent altering the established procedures to the greatest extent possible, (2) record any unanticipated alterations that do occur, and (3) evaluate the potential impact of any alterations in order to determine whether the results are usable. Many manuals for standardized measures now include instructions about how to handle unexpected problems that may occur during administration. If they are sufficiently disruptive, problems that occur during administration may seriously compromise the validity of the results of that particular administration, requiring that they be nullified and the measure readministered.

Even for automated laboratory tests, there is the potential for considerable variability in the way samples are obtained and prepared. To avoid threats to the reliability and validity of the results, it is essential to assure adequate training of personnel who will be using the instruments and to adhere strictly to procedural recommendations.
Rules for scoring a standardized measure are explicit, and in many instances very detailed. For example, user manuals with explicit scoring procedures have been developed for using the Medical Outcomes Study (MOS) core survey and associated instruments to measure health and quality of life outcomes. Several of the measures have been developed by selecting items from the core survey and then validating their reliability and validity with multiple populations (see RAND Health, 2009).

For paper-and-pencil tests, scoring keys are generally provided if the instrument is to be hand-scored. Instruments may be printed on special forms that can be electronically scanned and then computer scored, thereby eliminating transcription errors. In some instances completed instruments, such as health risk appraisals or aptitude and achievement tests, are sent to a central scoring facility for computer-assisted scoring. Standardized measures that involve observation include detailed rules for scoring and often special training to assure that any given behavior will be assigned the same numerical value by different raters and that identical behaviors will receive the same score (Portney & Watkins, 2009).

Technological advances permit highly automated scoring procedures for many physiological laboratory measures; in effect, scoring rules are incorporated in the design of the instrument and are applied automatically in processing the entity to be measured. Computer technology has also simplified scoring procedures in which multiple elements are weighted differently, so it is possible to integrate self-report and normed physiological data to determine a single score (Portney & Watkins, 2009).
and scoring within a given use of the instrument (e.g., throughout the course of a clinical trial) and exercising caution in redefining a procedure that was previously established for use as an informal measure. If the administration and scoring procedures differ from one application to another or from the procedure originally designed by the developer, the results are not truly comparable.

**NORMS**

As used in reference to standardized measures, norms refer to statistical information that describes the scores earned by members of a defined population or reference group (or generated from a defined set of observations) with which the score earned by a particular individual (or generated from a given observation) can be compared (Nunnally & Bernstein, 1994). Frequently the norms are based on a reference group that is composed of individuals from widespread geographic areas, so that an individual's score is interpreted by comparing it with a national or international distribution. Discussion of norms and standards frequently causes confusion about the correct terminology. A standard is an ideal—an object or state defined by an authority or consensus as the basis for comparison. It represents what ought to be, whereas a norm represents what is. For many aspects of physical and chemical measurement (e.g., weight, length, temperature), standards have been established and serve as the basis for scoring a given result. For example, in the measurement of weight, the National Bureau of Standards provides a standard available online at (http://www.nist.gov/) that serves as the basis for constructing measurement devices (e.g., scales, balances), determining their accuracy and scoring results.

Norms or distributions of scores describing the weights of representative samples of objects (including people) have been generated to depict weight distribution in the general population. In addition, values have been generated from actuarial studies to represent ideal weights (standards) for men and women of specific heights and infants of specific heights and ages. An additional example is that accumulated data have been used to determine screening criteria for labeling specific health conditions, such as hypertension, hyperlipidemia, and diabetes mellitus. Although they have been criticized as being somewhat arbitrary and insufficiently age-specific, such standards are used to answer the question “How does this score compare with the ideal score?” Of note is that such standards defining “ideals” and cut-points for categorization can and do change over time. Norms are used to answer the question “How does this score compare with those generated from a representative sample of units measured in the same way with the same instrument?” Just as populations change in the distribution of particular attributes (e.g., weight) over time, so the norms have to be recalculated periodically.

**Types of Norms**

Norms can be classified on the basis of the scope of the population from which they were generated or the units in which they are expressed. National norms are those describing scores earned by a national sample of subjects. They have been established for many of the standardized tests used in nursing and are useful for comparison with individuals from a wide variety of locales and backgrounds (e.g., National Council of State Boards of Nursing, 2009a, 2009b). Increasingly, the scope of samples used to establish norms for standardized measures used in nursing education and research is international. Both international and national samples are characterized by their heterogeneity; that is, they contain individuals who vary in sociodemographic characteristics such as age, gender, race, urban-rural residence, social status, and educational background. As a result, national or international norms may be too general to permit specific interpretation and action. In order to supply information that will be useful, national norms may be provided in terms that display the distribution of the sample as a whole (total group norms) as well as the distributions of subgroups selected according to relevant characteristics (differentiated norms). Examples of differentiated norms are gender-specific norms, age-specific norms, and occupation-specific norms. National norms may be based on a representative sample of the nation’s population or...
Chapter 7  Standardized Approaches to Measurement  211

on a nationwide sample of select, but relevant, groups of individuals. Norms for the National League for Nursing (NLN) achievement tests are not based on a sample of the U.S. population but on a sample of students from nursing education programs across the country.

Regional and local norms are those established with more geographically circumscribed samples. Although the developer of a nationally standardized measure may supply norms specific to given multistate regions of the country, local norms generally are established by users themselves: teachers, counselors, administrators, and practitioners. Local norms are established on the basis of samples of subjects in a given school, agency, or district. Because these samples are generally more homogeneous than regional or national samples, local norms are valuable as a basis for decision making in specific settings. For example, schools of nursing may find local norms for standardized aptitude tests derived from a sample of current students more useful than national norms in admission decisions.

Statistical units for presenting norms may also be used to classify them. Examples are percentile norms and standard score norms such as \( t \) scores (Nunnally & Bernstein, 1994). The strengths and weaknesses associated with expressing norms in terms of these units were addressed in Chapter 4.

Establishing Norms

The careful multistep process used to establish norms, described above, is carried out after the final version of the instrument has been produced (Nunnally & Bernstein, 1994):

1. A sample group (or groups) of individuals who are representative of those for whom the measure is designed is (are) selected.
2. The final form of the measure is administered to these individuals according to the set procedure or protocol that has been developed and under conditions that are identical to those recommended for administration.
3. Raw scores of the sample individuals are plotted in a frequency distribution and descriptive statistics are computed.
4. A decision is made regarding the statistical units that will be used to express the norms and these statistics are computed (e.g., \( t \) scores, \( Z \)-scores). Tables or graphs displaying the norms are prepared.

Selecting the Standardization Sample

The scores of individuals selected for the standardization group or referent group serve as the basis for comparing all subsequent scores on the measures; thus, it is mandatory that these individuals accurately represent the larger population of individuals for whom the measure was designed (McIntyre & Miller, 2007). Using the purposes of the measure and the blueprint, the population of intended subjects must be clearly specified. Because most measures are designed for a specific purpose and are not universally applicable across all ages, cultures, educational levels, and situations, the relevant population is limited to some extent by the test purposes and blueprint (Portney & Watkins, 2009). Many cognitive measures, for example, are designed to be age-specific, applicable only to persons from the general population who fall within specific age ranges. Other measures are designed only for persons in specific settings or circumstances or who have had certain experiences. For example, some measures of functional health are disease-specific, designed only for patients with a specific diagnosis, such as rheumatoid arthritis, while others are more generically applicable.

The relevant population is also determined by the scope of the norms to be developed. Examples of populations appropriate for establishing national norms would be all students enrolled in baccalaureate nursing programs, all patients who have undergone coronary artery bypass graft (CABG) surgery in the past 3 years, or all 3-week-old infants with no known birth defects. Populations for local norms might include, for example, all students enrolled in a given school of nursing, all patients who had CABG surgery in a particular health system, or all infants born in a particular hospital during the past 5 years. The important point is that the relevant population must be specified to include all individuals to whom the measure can appropriately be applied.

As noted above, when current evidence reveals potential for scores to be correlated with
which the process of selecting an individual for the sample is prescribed, such that each individual in the population has a known probability of being selected into the sample. Probability samples are selected at random; that is, the basis for the selection of a given individual is by chance rather than by conscious choice. It is possible to assume that by drawing a random sample any differences between the sample and the population will be randomly (and/or normally) distributed. The primary advantages of using probability sampling for selecting a referent group to establish norms are that bias is minimized and sampling error can be estimated. Several types of probability samples that can be used for selecting referent groups are described in Table 7.2 (also see Levy & Lemeshow, 1980, 1999).

Those probability sampling procedures that require enumerating each individual in the population (simple random sampling, systematic sampling, or stratified random sampling) are usually impractical for selecting most referent groups because large numbers of individuals must be included and comprehensive lists of all potential subjects are rarely available. Cluster samples, which involve identifying groups or clusters of individuals as the primary sampling units, are more efficient when the population is large. Such groups or clusters might include political or legal jurisdictions, such as cities or census tracts, or organizations, such as schools or hospitals, or the classrooms and patient units that comprise them.

Once the clusters in the population are listed, a random sample of clusters is drawn and the individuals within the randomly selected clusters make up the referent group. In establishing national and regional norms that involve a very large population, multistage cluster sampling is usually employed. This is a procedure that involves dividing the initially selected clusters into subunits or secondary sampling units, which are, in turn, randomly selected. The procedure can be continued through several stages involving successively smaller clusters until individuals can be enumerated and randomly sampled. When some characteristics of the population related to the measure are known, it is possible to stratify within each cluster for any stage of the sampling process. This procedure, called

Selecting the Norming Sample(s)

Once the relevant population for the measure is identified, it is necessary to select a sample that is representative of the population to make up the referent group. Selecting a referent group that is truly representative of the individuals for whom the measure is intended is the most important and most difficult task in the standardization process. The norms for the measure are established on the basis of scores from this sample (referent group) and serve as the basis for comparing scores from subsequent administration of the measure. Thus, if a referent sample is atypical of the population that will ultimately be measured, interpretation of scores will potentially be flawed. If there is bias in the norms (i.e., if they do not represent the true distribution of the scores in the population), this bias will be transmitted systematically in all subsequent interpretations of scores.

Some sampling procedures are more likely than others to yield a referent group that is representative of the test population. Probability sampling refers to a class of sampling procedures in which the process of selecting an individual for the sample is prescribed, such that each individual in the population has a known probability of being selected into the sample. Probability samples are selected at random; that is, the basis for the selection of a given individual is by chance rather than by conscious choice. It is possible to assume that by drawing a random sample any differences between the sample and the population will be randomly (and/or normally) distributed. The primary advantages of using probability sampling for selecting a referent group to establish norms are that bias is minimized and sampling error can be estimated. Several types of probability samples that can be used for selecting referent groups are described in Table 7.2 (also see Levy & Lemeshow, 1980, 1999).

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TABLE 7.2  Probability Samples Used to Select Referent Groups

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Procedure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Random</td>
<td>1. List and number the individuals in the population.</td>
<td>1. Complete listing is often difficult to construct.</td>
</tr>
<tr>
<td></td>
<td>2. Randomly select the sample using a random number table or other device.</td>
<td>2. The procedure is costly and time-consuming.</td>
</tr>
<tr>
<td>Stratified Random</td>
<td>1. Subdivide the population into two or more groups (strata) that are homogenous with respect to a given characteristic.</td>
<td>1. Some characteristics of the population must be known in advance.</td>
</tr>
<tr>
<td></td>
<td>2. From each group (stratum), randomly select a sample.</td>
<td>2. Can be used to assure representativeness on the selected characteristic(s) used for stratification.</td>
</tr>
<tr>
<td></td>
<td>3. Numbers of subjects may be selected in proportion to the size of each stratum in the population (proportionate stratified random sample), or sampling fractions may differ from stratum to stratum (disproportionate stratified random sample).</td>
<td>3. Can be used to assure inclusion of sufficient numbers of subjects within selected subgroups.</td>
</tr>
<tr>
<td></td>
<td>4. The procedure is costly and time-consuming.</td>
<td></td>
</tr>
<tr>
<td>Systematic</td>
<td>1. List all individuals in the population.</td>
<td>1. Can be applied to stratified or unstratified listings.</td>
</tr>
<tr>
<td></td>
<td>2. Determine the width of the selection interval (K) to be used by dividing the total number of sample cases desired.</td>
<td>2. Generally is more efficient and convenient than simple random sampling.</td>
</tr>
<tr>
<td></td>
<td>3. Select a starting point at random (termed the random start) within the first selection interval using a random number table.</td>
<td>3. Is subject to bias if there is periodic or rhythmic tendency inherent in the list (e.g., if every Kth element has more or less of a given characteristic than the others).</td>
</tr>
<tr>
<td></td>
<td>4. After the random start, select every Kth case.</td>
<td>4. Is subject to bias if there is a linear trend in the list.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Effects of periodically and linearity can be minimized by shifting random starts partway through the list.</td>
</tr>
<tr>
<td>Cluster</td>
<td>1. List the largest (most inclusive) unit in which population elements are found (termed the primary sampling units).</td>
<td>1. In all but the final stage, clusters or groups are sampled rather than individuals.</td>
</tr>
<tr>
<td></td>
<td>2. Randomly select a sample of these units.</td>
<td>2. Stratification can be used for any part of the multistage process.</td>
</tr>
<tr>
<td></td>
<td>3. Subdivide the sampled units into smaller units (secondary sampling units).</td>
<td>3. Is cost- and time-efficient, particularly for large, dispersed populations.</td>
</tr>
<tr>
<td></td>
<td>4. Randomly select a sample of these units.</td>
<td>4. Sampling errors are greater with cluster samples than with other samples of the same size.</td>
</tr>
<tr>
<td></td>
<td>5. Repeat the procedure in steps 3–4 as many times as necessary until the final stage is reached.</td>
<td>5. Special statistical procedures should be employed for data analysis (i.e., hierarchical cluster analysis [SPSS, 2009]).</td>
</tr>
</tbody>
</table>
multistage stratified cluster sampling, involves dividing the sampling units into homogenous strata or subunits on the basis of one or more characteristics related to the measure (i.e., the score), then sampling at random within strata.

An example of a multistage cluster sampling procedure is included in Figure 7.1. Cluster samples are more convenient and efficient than those that require enumerating the entire population; however, considerably larger sample sizes are required to achieve the same reliability of norms as would be achieved by simple random sampling (Levy & Lemeshow, 1999).

In the example shown in Figure 7.1, let us assume that the size of the hospital in which a nurse works is a variable believed to be related to job satisfaction. In order to introduce more precision into the sampling procedures and to assure that the referent group includes nurses from large and small hospitals, stratification can be employed at stage 2. Once all hospitals are listed, two strata can be formed, provided bed capacity is known. Stratum 1 would consist of all hospitals within the selected state that have 500 or more beds, and stratum 2 would consist of all hospitals with fewer than 500 beds. Hospitals would be randomly selected from within each stratum. The primary advantage of stratified sampling is that it increases the precision of the norms generated. However, this holds only if the variables selected as the basis for stratification are related to the measure for which norms are being developed. Stratification is frequently impossible because the characteristics of the population are not sufficiently well known to permit subdivision into homogenous groupings.

In the above example, if the intent is to represent as closely as possible in the sample the proportions of large and small hospitals in the state, it is desirable to use a procedure that involves sampling from each stratum at a rate proportionate to its distribution in the population. Using proportional allocation procedures (PAP) (Levy & Lemeshow, 1999), we would select into the sample the number of hospitals in each stratum that corresponds to its percentage of the total number of hospitals in the state. Assuming that small hospitals make up 25% of the 160 hospitals in the state and that a 10% sample of hospitals is to be drawn, then 4 small and 12 large hospitals would be chosen.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Step</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>List all states and randomly select a sample.</td>
<td>Primary Sampling Unit: State</td>
</tr>
<tr>
<td>Stage 2</td>
<td>List all acute hospitals within each state and randomly select a sample.</td>
<td>Secondary Sampling Unit: Hospital</td>
</tr>
<tr>
<td>Stage 3</td>
<td>List all patient care units within each hospital and randomly select a sample.</td>
<td>Tertiary Sampling Unit: Patient care unit</td>
</tr>
<tr>
<td>Stage 4</td>
<td>List all RNs employed in each unit and randomly select a sample.</td>
<td>Basic Sampling Unit or Element: Individual nurse</td>
</tr>
</tbody>
</table>

FIGURE 7.1 Steps in selecting a cluster sample.
Disproportionate sampling is used when strata are sampled at rates that are not proportionate to their distribution in the population (e.g., if equal numbers of large and small hospitals had been selected irrespective of their proportions in the population). This approach may be employed to assure sufficient variety in the referent group or to assure inclusion of members of a stratum that may contain only a small number of individuals (or units) who may be theoretically very important (Levy & Lemeshow, 1999). For detailed information about probability sampling procedures, the reader is referred to Levy and Lemeshow (1980, 1999).

Probability sampling is critical to increasing the likelihood that the referent group will be representative of the population for which the measure is intended. Because it is time-consuming and involves the development of a detailed sampling frame, test developers may employ other sampling methods that are easier but that allow the introduction of bias and will not permit an accurate estimation of error. Examples include:

1. Convenience samples, selected on the basis of availability.
2. Samples in which respondents can volunteer or select themselves.
3. Purposeful samples, selected because they are thought to be typical.
4. Samples that experts say represent an appropriate target population.
5. Samples that are drawn from listings that may incorporate an inherent bias (e.g., telephone directories, voluntary organization rosters, listings of individuals who have contacted a given health agency).

Such procedures are likely to result in nonrepresentative referent groups. Also problematic because of potential bias are probability samples derived from outdated or incomplete population lists and samples that include a high percentage of nonresponse or nonparticipation (Aday & Llewellyn, 2006; Di Iorio 2005).

**Sample Size**

In addition to the sampling method used to select the referent group, it is necessary to consider the size of the sample to be used. As a general principle, all else being equal, the larger the sample, the more likely it is to be representative of the population. The size of the sample needed is based on mathematical calculation of sampling error that would result from using a given sample size and a given sampling procedure. In addition, consideration must be given to the degree of precision required in the norms, in light of the purposes for which they will be used and the decisions that will be made. The greater the precision required (i.e., the smaller the sample error that can be tolerated), the larger the sample size must be. Sample size is, in part, determined by practical considerations such as time and cost.

**Norming Administration and Scoring**

The term “norming administration” refers to the administration of the measure to the representative referent group in order to generate a frequency distribution that will serve as the basis for comparing and interpreting scores on the measure. Usually multiple norming administrations are required to include the entire referent sample. Each administration is carried out using identical procedures and the scores added to the cumulative database.

Raw scores earned by the entire referent sample are represented in a frequency distribution, as described in Chapter 3. If the measure has several component parts (subscales), a separate frequency distribution is developed for each. If it is possible that personal characteristics are related to the score on the measure, it is desirable to categorize the referent sample on the basis of one or more of these characteristics and develop separate frequency distributions for each category. Subgroups based on gender, age, race and ethnicity, occupation, educational level, field of study, residence, and clinical diagnosis are frequently identified, because they are likely to represent distinct subpopulations that differ with respect to the scores earned. There is no set number of variables that should be used to identify subgroups. The choice is based on existing knowledge about the attribute being measured. It is important that data are available for as many subpopulations as necessary for comparison.
purposes and that the characteristics selected are those that are shown to influence the score.

For each frequency distribution summary statistics are calculated as described in Chapter 3. In addition to measures of central tendency (mean, mode, median), statistics that describe the spread of scores (range, variance, standard deviation) and the shape of the distribution (skewness and kurtosis) are computed. The latter statistics allow evaluation of how closely the obtained distribution of scores approximates the theoretical normal curve. The measures of central tendency and dispersion calculated for the referent group (and subgroups) serve as the basis for assigning meaning to any given raw score.

Developers of standardized tests must decide how best to communicate to others the nature of the data derived from the standardization administration. The objective is to describe the data in a manner that is clear and definite and has direct meaning. As noted in Chapter 4, raw scores lack meaning and must be converted into some type of derived score in order to be interpreted.

The types of derived scores most often used to convey information about referent groups of standardized measures used in health research and practice are percentile scores and standard scores. These scores describe the standing of a given score in relation to the distribution of scores obtained from the referent group. The computation of percentile and standard scores was described in Chapter 4. Percentile scores indicate the percentage of scores that fall below the given score; their advantage is that they are easy to interpret. However, one limitation is that percentile units are not equal at all points on the scale of raw scores, because a large number of individuals obtain scores near the middle of the distribution. Thus, a percentile difference of 8 points near the middle of the scale (e.g., 48th vs. 56th percentile) represents a much smaller difference between raw scores than does a percentage difference of equal magnitude at either end of the distribution (e.g., 5th vs. 13th percentile).

Standard scores express the raw score in terms of standard deviation units above or below the mean. Using standard deviation units has the advantage of providing equal units, such that a given difference between two standard scores represents the same difference between raw scores anywhere along the distribution. This assumption is generally appropriate for referent samples because numbers of subjects are sufficiently large. However, standard scores are not advantageous when a nonnormal distribution of scores in the referent groups reflects the actual characteristics of the attribute’s distribution in the population of interest.

Several types of standard scores can be used as the basis for describing norms. The Z score, described in Chapter 4 (Using Formula 4.1), ranges between –4.0 (a score 4 standard deviation units below the mean) and +4.0 (a score 4 standard deviation units above the mean). Because of the potential risk of error when minus signs are used, Z scores are frequently transformed to another standard score that uses only positive numbers. Examples of standard scores that use positive numbers are t scores and stanines. The t score is obtained by multiplying the Z score by 10, then adding the product to 50, which is the mean of the t score distribution (see Formula 4.2). Stanines present norms on a 9-point scale of equal units, each the width of one-half of a standard deviation unit. Stanine scores have a mean of 5 and a standard deviation of 2.

The advantage of standard scores is that, regardless of the value of the mean and standard deviation of a distribution, the interpretation of a given score is consistent (Nunnally & Bernstein, 1994). This feature facilitates comparison across several measures. Standard scores can also be interpreted in terms of percentile rank, assuming a normal distribution. As described in Chapter 4, each standard deviation unit in a normal distribution contains a fixed percentage of cases. Thus, a raw score one standard deviation above the mean can be expressed as a Z score of +1.0, a t score of 60, a stanine score of 7, or a percentile score of 84.

For some measures of early cognitive and physical development, the performance of a referent group may be expressed in terms of age-equivalents. These norms are based on the average scores obtained by individuals of different ages. For example, if children in the referent group who are 2 years and 3 months of age have an average score of 30 on the measure, the
score 30 is assigned an age equivalent of 2–3. Age equivalents are expressed in terms of two sets of numbers, the first representing the year and the second the month of age. They represent average or typical performance for a given age group. Because patterns of growth vary at different ages, age equivalents do not have uniform meaning across all age groups and are easily misinterpreted. As a result they are being replaced by age-specific norms (i.e., norms differentiated on the basis of age), which are calculated using the frequency distributions for specific age groups and are presented as percentile or standard scores.

### Communicating the Norms

Tables and graphs are prepared to portray the referent group data in a manner that facilitates interpretation by users. The tables must be accurate and clear, in order to encourage reliability and validity in score interpretation. Specific instructions for the use of the table or graph should be provided, and each should be sufficiently well labeled to stand alone, that is, to be interpreted by the consumer without reference to a complex narrative. Current statistical computer software has built-in capacity to generate graphic and tabular displays for most analyses (e.g., Norusis, 2009; Statistical Package for the Social Sciences [SPSS], 2009).

### Updating Norms

Establishing norms for a standardized measure is an ongoing activity, even though it is a time-consuming and costly process. Norms become outdated due to cultural and lifestyle changes and technological advances. Changes in nutrition, sanitation, workplace technologies, and health care, for example, have made decade-old physiological and weight norms obsolete. Increases in the average level of schooling and changes in educational curricula and in the media tend to affect the scores earned on tests of general mental ability, thus rendering norms established even 5 years ago inaccurate as a basis for current comparison. Such changes necessitate repeating periodically the norm development procedure described above. The frequency with which the norming procedure must be repeated and new norms established depends on the likelihood that the attribute or behavior being measured has been influenced by recent changes. In addition to monitoring the occurrence of external or societal events or patterns that might be correlated to the measure, systematic and ongoing comparisons are made between distributions of current scores and those of the referent group. Such comparisons are easily made when a measure is centrally scored and all data from subsequent administrations of the measure are available to the test developer and publisher. Current published research using the instrument also provides comparative information.

### Adequacy of Norms

The process for establishing norms has been described in detail because it provides the basis for judging the adequacy of any set of norms generated. The adequacy of norms is, in turn, a prime consideration when selecting a standardized measure for use and when interpreting results. Criteria for determining the adequacy of norms include the following (Kaplan & Saccuzzo, 2009; Nunnally & Bernstein, 1994):

1. The norms were established on the basis of a representative sample from a clearly specified population.
2. The norms were established using a referent group with known (accurately described) characteristics.
3. The norms were established under conditions of uniform administration and scoring.
4. The date of the norming administration is known.
5. The statistical procedures used in deriving the norms were appropriate and accurately described.
6. The norms are clearly presented, with instructions for interpretation provided.
7. Differentiated norms are available to reflect relevant differences among subgroups with specific characteristics.
8. The norms are up to date.

Ideally, the developer of a standardized instrument provides information about the method
of sampling, the size and characteristics of the norm sample, the conditions of administration, and the date of testing, along with the norm values and table in an accompanying manual (in print or on compact disk). Increasingly, such information is available to users online. If the publisher, manufacturer, or developer does not automatically supply such information, it is advisable to request it directly and to review published literature related to the measure.

**INTERPRETATION OF SCORES**

In order to discuss the interpretation of scores on standardized measures, it is necessary to differentiate the meaning of a given piece of information (in this case, the score itself) from the use of that information. Ultimately, interpretation takes into account both the generic meaning of the score as it derives from the process of standardization itself and the purposes and context within which the information ultimately will be used. Given the way in which any standardized measure is developed, the meaning of a given score is determined with reference to established norms. The meaning derives from comparison of an individual score with the scores earned by others (the defined referent group) on the same measure. Importantly, the comparison is with performance that is typical of the referent group and should not be construed as comparison with an ideal or standard to be achieved. The generic meaning of any score on a standardized measure, therefore, is always normative, that is, defined in terms of comparison with the typical performance of a referent group (Nunnally & Bernstein, 1994).

The scores on standardized measures are most frequently used for the purposes of making interindividual or intergroup comparisons. Examples of interindividual comparisons would include ranking a group of applicants prior to selecting the one most qualified for a position or evaluating the anxiety level of a given patient as high or low in comparison with that of the typical adult. An intergroup comparison would be exemplified by the determination that the average satisfaction ratings of students and faculty in doctoral program A are higher than those in program B or are higher than the inter- and intradisciplinary averages. As noted above, scores on a standardized measure may be used to make intraindividual (also termed ipsative) comparisons, such as comparing scores earned on a number of separate measures or on subscales measuring different dimensions of behavior or cognition in order to develop a profile (Kerlinger & Lee, 2000).

A standardized measure score may be used to compare an individual's performance with a standard that has been established on the basis of previously gathered data regarding the relationship between typical performance on the measure and other salient variables. Examples abound in psychology (e.g., use of the CES-D ([Radloff, 1977]) to identify individuals whose depressive symptoms indicate risk). Similar procedures comparing individual results on a standardized measure with preestablished standards are used in businesses to select candidates for leadership positions, using data from standardized personality measures, or to select applicants for admission to a graduate program using Graduate Record Examination scores.

The generic meaning assigned to a score on a standardized measure involves a complex set of considerations related to the procedures used to develop the measure and to establish the norms, the nature of comparison (referent) group, the type of norms established, and the meaning of the statistics used. A score compared with national norms that have been differentiated on the basis of age and converted to percentile ranks would have a different meaning from one that is compared with local norms expressed as age equivalents. Developers and publishers or manufacturers of standardized instruments generally supply aids to help assign meaning to raw scores. These include tables, guidelines, examples, and in some instances, even computerized printed explanations that provide the appropriate meaning for a given. However, it is ultimately the responsibility of the user to make an informed judgment about the meaning of the score. The following guidelines should be kept in mind:
1. The conceptual meaning of whatever derived score is used should be clear to the user.

2. The score has meaning only in relation to the specific measure from which it was derived; thus, the meaning that can be inferred is limited by the purpose, scope, and content of the measure itself.

3. The score has meaning only in relation to the referent group used to establish norms; thus, the characteristics of the referent group must be studied carefully.

4. Measurement error must be taken into account; that is, the subject’s true score is recognized to fall not exactly on the point of the obtained score but within a range of scores, the limits of which are one standard error of measurement above and below the obtained score.

5. To the extent that they are provided and address relevant characteristics of the subject(s), differentiated norms should be used as the basis for comparison because they allow for more precise meaning to be inferred.

6. Relevant characteristics of the subject(s) should be taken into account. These include not only demographic characteristics, which help to identify subgroups for whom a given measure or set of norms may be inappropriate, but also abnormal circumstances that may have influenced performance on the measure.

It was noted above that standardized measures are sometimes used to make intraindividual or ipsative comparisons, that is, comparisons involving two or more scores earned by a single individual. Such comparisons are often used to identify an individual’s strengths and weaknesses. In order to assist with interpreting intraindividual comparisons, a profile chart is often developed. A profile chart represents the individual’s scores on various measures (or subscales of a more inclusive measure), which are plotted on comparable score scales. The median scores (scores that fall at the 50th percentile) of a group on several measures may also be plotted on a profile. Scores can be displayed either as bands that extend one standard error of measure above and below the obtained score or as specific points on the scale. The former style is preferable, because it allows the interpreter to take into account the inaccuracy of the scores on different measures.

In order to construct a profile based on comparable score scales, the norms must be comparable across all measures; that is, they must be converted to the same system of numbers (derived scores) and must have the same shape distribution. Ideally, all measures included in the profile should be normed on the same referent sample and should be independent of one another as well as with those of the referent group (Nunnally & Bernstein, 1994).

An individual’s profile is sometimes compared with the profile of a particular group, with the group profile defined as the median (50th percentile) score for the group on each measure. While this procedure allows evaluation of whether the individual’s scores are different from the central tendency of the group (as defined by the median), it does not permit an accurate assessment of the difference, since the entire array of referent group scores is not represented. Profile charts may be used to depict the comparison of one individual’s or group’s scores with those of another or to compare one individual’s score at different times. They are useful because of their flexibility, and because they provide a visual display, which helps in interpretation.

The ultimate interpretation of any score on a standardized measure requires taking into account the purposes for which the information will be used. For example, given the generic meaning of a score (say, that a staff nurse scores in the 90th percentile, and hence, ranks very high on a standardized measure of quantitative aptitude), that score would be interpreted differently depending upon the context for its intended use, for example, in selecting applicants for advanced training in statistics or in determining the degree of improvement in medication accuracy following a special training program for nurses with low quantitative ability.

Because the information derived from a standardized measure is used alone or in conjunction with other measures for making important decisions, it is a good practice to develop a model defining and setting priorities for the values to be maximized and the information to be provided...
by the measure. Such a model also serves as a guide to interpreting scores in the light of the decision to be made. A model developed to set priorities for values and informational needs for admission decisions would provide guidelines, for example, to determine whether subscale scores on a measure should be interpreted individually or whether the total (overall) score should be interpreted. The model would also provide the basis for deciding whether the subscale scores should be given equal weight in the decision or differently weighted in terms of their importance. The model would also specify the ways in which information from multiple standardized measure scores are subject to an indeterminate degree of error because of unmet assumptions and uncontrolled conditions. The best way to avoid making erroneous decisions is to base them on multiple indicators rather than on a single score. Thus, the final interpretation of a given score should be made only after assessing the extent to which it is congruent with other available information.

SELECTING STANDARDIZED MEASURES

In many instances nurses and other health professionals engaged in clinical practice, education, administration, and research lack the resources (time, money, expertise) to develop standardized measures themselves, yet desire the technical quality, consistent information, and precise comparative interpretation that a standardized measure can provide. Procedures and considerations for selecting and using standardized measures are discussed in this section.

Selecting the Measure

Selection of any measure must be based on careful consideration of the nature of the concept, attribute, or behavior about which the information is being sought and the purposes to be achieved by acquiring the information. The initial step in selecting a measure is to define clearly the kind of information required. While seemingly self-evident, this is in itself a time-consuming procedure, which often involves the combined efforts of a variety of people. However, its importance cannot be overemphasized.

Each standardized measure is unique in its assumptions and specific content and in the aspects of behavior, cognition, affect, or skill that it measures. Similarly, potential users have unique and contextually based needs for particular kinds of information. Only those who require information for particular purposes are in a position to define the exact nature of the information needed. The defined needs provide the primary criterion for selecting measures to meet them.

Many health decisions made on the basis of information gained from measurement have considerable impact on the decision makers and others. Examples are educational admissions decisions; promotion decisions in the military, educational, and clinical settings; decisions about curricular and program change; and clinical decisions to apply a particular diagnostic label or to use particular interventions. Given the potential impact of such decisions, the process of defining the need for information must be carried out thoughtfully, with attention given to goals to be achieved and the consequences of the decisions. During this process both local requirements and conditions and the values that underlie the specification of goals must be identified. Desired outcomes (goals) necessarily reflect values, whether or not they are recognized and acknowledged. Decision makers who identify and rank the values that they wish to maximize are able to set priorities for their information needs accordingly. Measures can be selected and their relative importance determined on this basis, heightening the probability that they will yield the information needed for a sound decision (Portney & Watkins, 2009).

The process of acknowledging and setting priorities for values and determining information needs may be complex, involving prolonged discussion in order to achieve agreement. Individuals who are in a position to evaluate the potential consequences of the decisions that are made are vital participants. For example, faculty members with intimate knowledge of a given nursing curriculum, its objectives, and the capabilities required of students to complete it successfully are in an optimal position to determine
the values that are to underlie admissions decisions and the relative importance of those values. Their priorities supply the model for identifying the specific attributes that are to be measured and the importance that each is to be assigned. Let us assume that a faculty decision-making group determines that the value to be given highest priority is academic potential, but decides that creativity is relatively unimportant. The implication is that information will be sought about applicants’ academic potential via measures such as aptitude tests and previous grade-point average, whereas information about applicants’ creativity will not be solicited or will be measured less extensively.

Once the information needs are defined and priorities set, decisions are made about use of standardized versus (or in addition to) non-standardized measures. Refer to Table 7.1 for a review of characteristics to consider. Having determined the specific needs to be met by standardized measures, the next step is to identify those measures that have potential to provide the information desired. A number of resources are available to aid in the search. Particularly helpful are the well-known publications *Tests in Print VII* (Murphy, Spies, & Plake, 2006) and *15th Mental Measurements Yearbook* (Geisinger, Spies, Carlson, & Plake, 2007). The former includes a description of most standardized tests including title, author, publisher, age levels covered, publication dates, special comments, number and type of scores provided, and references to test reviews and publications using the test. The latter includes evaluative information about the tests as well as additional descriptive information. Other sources of information are compendia of instruments and books that describe standardized instruments, test publishers’ and instrument manufacturers’ catalogs, and articles in professional journals.

**Using the Measure**

Sample sets of those measures deemed potentially useful and accompanying test manuals can be ordered for review and evaluation. They should be examined carefully for evidence of high technical quality and characteristics that are desirable for the particular use intended. Test materials must be reviewed critically and with some skepticism, disregarding evaluative statements unless they are supported by detailed descriptions and statistical evidence. Table 7.3 provides a list of considerations to guide the evaluation of standardized measures.

In addition to the general considerations listed in Table 7.1, criteria specific to the particular situation for which the measure is to be used should be identified in order to facilitate the selection process. For example, a faculty group planning an applicant selection process for the graduate program in a school of nursing may determine in advance that it wishes to consider only those standardized aptitude measures that are administered abroad as well as in the United States. A nurse researcher contemplating a health risk assessment of large numbers of adults may decide to consider only measures that are machine-scored by a centralized facility, whereas a group of clinicians might prefer a standardized measure that can be hand-scored within a matter of minutes. The final selection is based on comparative evaluation within the context of priorities established by the user.

**SUMMARY**

Standardized measures are norm-referenced measures that are constructed, administered, and scored in a prescribed and consistent manner and interpreted with reference to established norms. Because they are carefully constructed, are of high technical quality, and are designed for widespread use, they have potential utility for measuring many types of nursing phenomena. They are useful for situations in which scores are best interpreted by means of comparison to a defined population and in which the attributes or behaviors being measured are relatively stable and are common across many situations and settings. They are not meant to be specific to a particular setting, nor can they be altered to meet local needs.

One of the major advantages of a standardized measure is that norms are provided to aid in interpreting results. Norms are statistics that describe the scores earned by a defined referent group with known characteristics, which is
TABLE 7.3 Questions to Guide Evaluation of Standardized Measures

1. **Purpose:** Are the stated purpose and recommended uses for the measure congruent with the purpose for which it will be employed? Will the measure yield the desired information?

2. **Conceptual basis:** Is the theoretical model that guided the development of the measure identical to (or, at the very least, compatible with) the model being employed? What are the assumptions and potential biases underlying the measure? Are the values inherent in the development of the measure congruent with those that are to be maximized in the current situation?

3. **Content:** Is the content of the measure appropriate without modification for the use intended? Is it up to date? Is the content appropriate for the ages, reading abilities, and frames of reference of potential subjects?

4. **Technical quality:** What types of reliability and validity have been established? What is the nature of evidence supporting the reliability and validity of the measure? How was the measure developed and tested? What were the qualifications of the individuals involved?

5. **Norms:** How were norms established? How was the referent group selected and what are its characteristics? Are the norms appropriate and sufficiently detailed for use as a basis of comparison? Are the norms clear and easily interpretable? Are they up to date?

6. **Administration:** Are clear and explicit instructions provided for administration? What resources are required for administration? How easy, costly, and time-consuming is the administration? Is training required? What about subject burden?

7. **Scoring:** Is the measure hand- or machine-scored? What costs or special equipment are required? How likely are errors to occur in scoring? What is the time required for scoring?

8. **Interpretation:** Can scores be easily and consistently interpreted? Are materials provided to aid in interpretation?

9. **Cost:** What is the cost for employing the measure, including purchase, administration, and scoring costs? What is the cost (if any) to subjects? Are the costs proportional to the relative importance of the information that will be obtained?

10. **Critical reviews:** What are the evaluations provided by others who have used the measure? What problems, strengths, and weaknesses have been identified?

The selection of a standardized measure for use in nursing and health research is based on the defined needs for information; the stated purpose, assumptions, and content domain of the measure; its technical quality; the adequacy of the norms; and the costs and procedures required for administration and scoring. Administration and scoring of the selected measures must be carried out with consistent adherence to prescribed procedures. Interpretation of the results is guided by the established norms but also takes into account the characteristics of the referent group and examinee(s) and technical features of the measure. Particularly when older instruments are being used, the results ideally are interpreted in the light of information from other sources about the measure and others measuring the same phenomena.

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Measurement Issues in Qualitative Research

Judith E. Hupcey

Qualitative inquiry is an approach to research that focuses on the description and understanding of phenomenon (or concepts) within the social world from the perspective of individuals who are experiencing that world. Qualitative approaches are most appropriate for nursing because they aid in our understanding of phenomena such as the processes associated with health and illness (e.g., grounded theory), how culture influences people’s lives and responses to illness (e.g., ethnography), and the essence of a health/illness experience for an individual (e.g., phenomenology). The knowledge and theories developed from this understanding can help advance nursing science with the goal of improving health outcomes by assisting others through similar situations.

There are many issues that affect quantitative inquiry that had been ignored or skirted by qualitative researchers. Over the last 30 years as qualitative methods have become an accepted means of studying phenomenon of interest to nursing, stricter criteria have been imposed on the qualitative researcher. This has occurred for a number of reasons. The most important reason relates to the advancement of nursing science. Moving nursing science forward requires more than filling our journals with interesting, yet merely descriptive studies. Researchers need to take their work to the next level, which is theory development. This perspective may be pushing qualitative research, as a whole, toward the positivistic end of the qualitative research continuum. However, in order for nursing research to be funded and postfunding be useful to nursing science, issues such as validity, reliability, and generalizability of qualitative research need to be addressed (Morse, 1999a). Although there are excellent nurse researchers who have opposing paradigmatic views on this (such as an autoethnographer, postmodern or feminist researchers), major funding sources (see the National Institute of Mental Health [2001] guidelines for qualitative research proposals) require for the researcher to address these issues in the same manner as in a quantitative proposal. This chapter will present the more traditional approach to these issues while still describing some of the other terms that may be used by the qualitative researcher (e.g., instead of validity—trustworthiness) and discuss threats to validity, reliability, generalizability and ways to minimize these threats.

OVERVIEW OF QUALITATIVE RESEARCH

Qualitative research is undertaken for a number of reasons. First, when little is known about a concept or phenomenon as a result of limited previous research, because it is a new area of interest, or is an area that has evolved and prior research and/or theory no longer fit the phenomenon, a qualitative approach would be appropriate. The research could be done simply to explore/describe a phenomenon or could be done with the purpose of theory development or refinement. A second reason for using a qualitative approach is based on the phenomenon/concept under investigation. Many phenomena and
concepts are just not suitable for quantitative measurement.

There are numerous characteristics of qualitative research that distinguish it from a traditional quantitative research. The following is a list of some of the hallmarks of a qualitative approach. Qualitative research is:

- Inductive: the researcher begins with data and builds concepts, categories, hypotheses, models, and theory from these data;
- Concerned with process and meaning from an emic (participants’) view: purpose is not to show causality or outcomes, but how individuals make sense of their world (thus there are multiple realities);
- Undertaken in the field or naturalistic setting: no controls are placed on extraneous variables or the setting, these variations are intertwined with the phenomenon under investigation, so are important in the understanding of process and meaning; and
- Uses the researcher as a tool for data collection and analysis: requires that the researcher continually differentiate between his or her own reality and that of the participants and still be close enough to the participants’ world to understand and describe it (Creswell, 1998; Morse & Field, 1995; Polit & Beck, 2004).

Although there are numerous qualitative approaches that are used by nurses, several will be used as examples in this chapter and briefly described. These include phenomenology, grounded theory, ethnography, focus group, case study, and narrative/storytelling.

**Phenomenology**

Phenomenology is a qualitative method that is based in philosophy. Its aim is to understand and then describe in detail the essence of the experience as it is lived by the person (Munhall, 1994; Van Manen, 1990). The goal is to accurately describe the phenomenon under study and to transform the lived experience into a textual expression of its essence (this can be done with text, pictures, music, etc.). The phenomenon is described as it is experienced by the person (e.g., the experience of waiting by the wife of a critically ill patient), without the use of theories and, to the extent possible, without researcher preconceptions and presuppositions. Data are collected through multiple in-depth conversations with the participant(s), so that the researcher is the primary data collection tool.

**Grounded Theory**

The methods of grounded theory come from a sociological perspective. They were initially developed by Glaser and Strauss (1967) and subsequently refined by Glaser (1978) and Strauss and Corbin (1998). The primary goal of a grounded theory is to generate explanatory models of human behavior that are grounded in the data. Preexisting theory is not used so the researcher remains open-minded about what concepts will emerge and how they will be organized. A grounded theory documents processes (e.g., the development of trust in health care providers) and change over time to link categories and to develop models. According to Glaser (1978, 1992), the resultant theory must fit the data, work, have relevance, and be modifiable.

Data are collected using interviews, observations, and field notes. A constant comparative process is used for data collection and analysis. Here data are collected and analyzed simultaneously. Thus the researcher is observing, collecting data, organizing and analyzing the data, and forming theory from the data all at the same time. Hypotheses are compared and tested with incoming data (every piece of information is compared to every other). Within this process the researcher also uses theoretical sampling, where the researcher decides what data to collect next and where to find them, based on the needs of the developing theory.

**Ethnography**

Ethnography is a branch of anthropology that focuses on the study of cultural groups. The purpose of ethnography is to tell the story of participants’ lives from the perspective of the culture of which they are a part (Fetterman, 1989). This investigation involves an in-depth study of the members of the culture through participant
observation, interviews, and field notes. The researcher needs to spend time (or may live) with the group and become part of the cultural setting in order to collect data and understand the cultural group under investigation.

A focused ethnography is a variation of the traditional ethnography and is an approach that may be more appropriate to nursing. Here the participants are linked by location (e.g., a hospital unit) not a place of residence or culture in the anthropological sense, but share behavioral norms and a common language (Morse & Field, 1995). In a focused ethnography the topic is selected prior to data collection, while in a traditional ethnography it emerges from the data. Data collection, including interviews and observations, is limited to particular events and topics related to the event. The product is an understanding of essential culture schemas.

### Focus Groups

A focus group is a technique for data collection that uses group interactions to obtain an understanding of participants' experiences and beliefs. A focus group can be used solely as a technique to collect data (e.g., within an ethnographic study or grounded theory) or as a stand-alone method. Since in-depth data cannot be obtained from each participant, focus groups typically are used for problem identification, program planning, and program evaluation. The group is researcher-controlled in that the topic chosen and questions asked are those of the researcher. However, the discussion and group diversity and consensus come from the group and its discussion (Morgan, 1997).

### Case Study

Case studies are an exploration of a “bounded system” or a case (or multiple cases) over time through detailed, in-depth data collection involving multiple sources of information such as interviews, observations documents, archival records, artifacts, audiovisual materials (Yin, 1994), that are rich in context (Creswell, 1998). The case can be an individual, an event, program, or organization. The product of a case study is a detailed description of the case, including chronology, naturalistic generalizations, and lessons learned from the case (Creswell, 1998).

### Narrative/Storytelling

A narrative is a method that is used “to give a voice to the silenced” (Frank, 1995) and as a way to study humans’ experiences within the social world. Within narrative inquiry, information is gathered for the purpose of storytelling. It is an art of both listening to the narrative and then telling the story (or writing a narrative of the experience) (Riessman, 1993). Data are collected through in-depth interview, field notes, journals, letters, and stories told by the participant. The researcher then writes the narrative of the participant (this may be a collaborative effort between the researcher and participant).

### Validity, Reliability, and Generalizability of Qualitative Findings

As suggested earlier, in order for qualitative inquiry to advance nursing science, methodological and analytic issues such as validity, reliability, and generalizability need to be addressed when a study is designed. Threats to these issues can occur when the study is initially designed (e.g., picking the wrong method for the research question, or not adequately planning the sample), during data collection, and during data analysis. In this section these issues will be defined. This will be followed by a discussion of the threats to validity and reliability during sampling, data collection, and data analysis and how these threats can be minimized.

### Validity

In qualitative research, validity can be defined as the “truth value,” or trustworthiness of the data and resultant analysis and interpretation,
or the extent to which the findings represent reality (Morse & Field, 1995). Others have broken validity down further. Miles and Huberman (1994) discuss internal validity and external validity; while Maxwell (1992) describes it even further as he believes that internal and external validity reflect positivistic assumptions. He posits five types of understanding and validity: descriptive validity, interpretive validity, theoretical validity, generalizability (this will be discussed separately), and evaluative validity. Each of these types of validity will be discussed below.

**Internal Validity**
Internal validity asks the question of whether the researchers are measuring or observing what they think they are measuring or observing (LeCompte & Goetz, 1982). In qualitative terms, Miles and Huberman (1994) also refer to internal validity as credibility or authenticity, where the findings need to make sense and be credible to both the participants and readers. Internal validity is enhanced during both data collection and analysis when the researcher uses multiple sources of data, links data to the emerging categories and theory, confirms findings with additional data, and looks for negative evidence (tries to find data that may not support the analysis/hypotheses being developed).

**External Validity**
External validity asks the question of whether the findings and conclusions of the study can be transferred to other contexts, thus generalizable beyond the present study (applicable across groups) (LeCompte & Goetz, 1982; Miles & Huberman, 1994). Other terms used for external validity are “transferability” and “fittingness” (Miles & Huberman, 1994). External validity is enhanced by having an adequate sample, including sample size, sample diversity, and appropriate purposive/theoretical sampling. The findings should be abstract enough to apply to other contexts and contain enough rich description for the reader (or other researchers) to evaluate the findings. For some types of qualitative research (e.g., phenomenology) there are no claims that findings are generalizable beyond the subjects in that particular sample.

**Descriptive Validity**
Descriptive validity is related to the “truth value,” or credibility/authenticity (or valid description) of the data and what was reported from the data (Maxwell, 1992). Here, the researcher needs to carefully collect and corroborate data (this can be done by obtaining feedback about the accuracy of the data and analysis from the original participants or by using secondary participants to confirm the emerging analysis), and present an accurate account of these data.

**Interpretive Validity**
Interpretive validity relates to meaning or the interpretation of the data (Maxwell, 1992). Does the researcher accurately understand and portray the participant’s (emic) view or meaning?

**Theoretical Validity**
Theoretical validity moves beyond the descriptive and interpretive types of validity to analysis of the validity of a theory (Maxwell, 1992). Thus, does the derived model fit with the data and is it abstract enough to extend theory beyond description?

**Evaluative Validity**
Evaluative validity applies an evaluative framework to the objects of the study, not the study design itself (Maxwell, 1992). Here a judgment is made about the correctness or worth of the meanings or actions. Therefore, how the researcher describes, interprets, or constructs the story or theory is important.

**Reliability**
Reliability in qualitative research is concerned with consistency over time and across researchers and settings and objectivity and confirmability (Miles & Huberman, 1994). There is a distinction made between internal and external reliability. Internal reliability is defined by LeCompte and Goetz (1982) as “the degree to which other researchers, given a set of previously generated
constructs, would match them with the data in the same way as did the original researcher” (p. 32). Other terms for internal reliability are “dependability” and “auditability.” Miles and Huberman refer to this as “quality control.” They ask questions such as: Is the research question clear and does it match the method used? Does the research design specify the role of the researcher? How will data be collected to maximize the phenomenon of interest and to answer the research question (with specific protocols if multiples data collectors are utilized)? When and how will coding checks, data quality checks, and peer reviews take place? And, do the findings match across sources of data and the developing theory?

External reliability is defined as “whether independent researchers would discover the same phenomena or generate the same constructs in the same or similar setting” (LeCompte & Goetz, 1982, p. 32). Miles and Huberman (1994) consider this issue as one of “relative neutrality and reasonable freedom from unacknowledged researcher biases” (p. 278). They ask questions that relate to the ability to replicate a study. Are the methods and procedures well described, including the sequence for data collection and analysis and the development of conclusions (thus, is there an audit trial)? Are researcher biases addressed? Has the researcher linked conclusions to the data and shown potential hypothesis that were refuted and why? And, are the data available for others to analyze?

Generalizability

Generalizability is often referred to as external validity or transferability. Maxwell (1992) defines generalizability as “the extent to which one can extend the account of a particular situation or population to other persons, times, or settings than those directly studied” (p. 293). Generalizability is applicable with the development of theory from qualitative work and the utility of the theory to other persons in similar situations.

Generalizability has typically been a concern of quantitative researchers while many qualitative researchers and texts ignore this issue. There are instances when generalizability is not a concern for the qualitative researcher. Some qualitative methods are not intended to produce generalizable findings but still generate valuable pieces of work (such as with some phenomenologies, individual case studies, and narrative/storytelling). However, Morse (1999b) points out that for qualitative research to be useable and to advance nursing science, generalizability needs to be addressed. This is particularly true if one of the goals of the qualitative study is to develop theory. Although the means for how qualitatively derived theory is developed is different from quantitatively derived theory, the qualitatively derived theory should still meet strict evaluative criteria (Morse, 1997), and thus, will be applicable beyond the immediate group studied.

Adequacy of the Sample

The adequacy of the sample, including both selection and sample size, will influence the credibility (thus validity, reliability, and generalizability) of qualitative results. There is a general misconception that in qualitative research the sample size is small and homogenous and many times not an important issue to address when developing a qualitative research proposal. On the other extreme, some researchers overcompensate and plan a study with a huge number of participants to be comparable to a quantitative study. A sample that is too large and diverse may become cumbersome and will not allow for the in-depth analysis that is one of the hallmarks of qualitative research (Sandelowski, 1995). There is no hidden formula that helps the researcher determine sample size, but Morse (1998) has suggested two principles that need to be considered: first, the more data obtained from each participant, the fewer the number of participants needed, and second, the broader the research topic, the larger the sample will need to be in order to reach saturation or redundancy. Here we will consider those and other factors that should be combined to assist the researcher in determining an adequate sample. The factors that will be addressed are the overall purpose of the study, the research question/topic of interest, type of purposive sampling to be employed,
the sampling unit (e.g., number of participants vs. number of interviews or incidents), and the research approach (or method) that undergirds the study.

**Purpose of the Research**

The purpose of qualitative research studies ranges from a study that aims at pure description (such as in case study, storytelling, narrative, focus group) to the development of theory (such as in phenomenology, grounded theory, ethnography). Thus, sample size would be influenced by the overall purpose of a study. If the purpose of a study is to describe, for example, a person's life or a specific event/phenomenon, few participants may be needed (for a case study even a sample of one may be adequate). In this situation, the quality and quantity of information obtained from each individual needs to be significant, so multiple in-depth interviews alone or along with other sources of data, such as journal entries, need to be collected. The purpose of focus group research also is descriptive in nature, however, the sample size may be larger than with other qualitative methods. This follows Morse's (1998) principle above that states that a larger sample is needed when fewer data are obtained from each participant. In focus groups when there are 8–10 participants, limited or superficial information can be obtained from each participant (Morgan, 1998). Thus, the number of participants needed to adequately address a topic is at least 25–30, depending on the topic and homogeneity of the groups. If the purpose of a research project is to develop theory, then the size and diversity of the sample in terms of numbers of participants, number of sampling units (interviews/observations), and data sources needs to be significant.

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2 For a comprehensive discussion of levels of qualitatively derived theory, see Morse (1997).

3 See Morgan (1998) for greater detail on numbers of groups and sample size.

4 Notice here I say “project” and not “study,” because although an individual study may begin the process of theory development, numerous studies are needed, thus the word “project,” to build solid high-level theory (Hupcey & Penrod, 2003).

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**Research Question/Topic**

The research question or topic of interest will also have a major influence on sample selection and the sample size. One of the tenets of qualitative research is to maximize the phenomenon. The researcher needs to pick the sample that will best answer the research question or examine the topic of interest. The sample is selected based on the data that can be obtained from the participant. Sampling in this manner is biased in that the researcher is looking for participants who are most knowledgeable, thus have the greatest experience related to the research topic (Morse, 1998). Demographic delimiters such as gender, ethnicity, socioeconomic factors, and so forth, that may be used in quantitative research may hold no analytic value in sample selection strategies for qualitative studies. However, keeping this in mind, within an individual study, some of these demographic factors may actually turn out to influence the participants’ experiences. If this does occur, then data for these individual groups need to be collected, and if possible within the constraints of an individual study, sufficient data need to be collected from each group to reach saturation.

A second consideration in terms of demographics, particularly age, gender, and ethnicity, is that federal funding guidelines presently mandate the inclusion of adults and children, males and females, and all ethnic groups in research studies. There may be ways to justify the exclusion of certain groups, such as children; however, studies may not be funded when ethnic groups are excluded. If the qualitative researcher truly believes that ethnicity is of analytic importance, then the study needs to be designed to address these different groups.

Sample size is also influenced by the research question/topic. A very specific research question would require a smaller sample than a broader topic. For example, investigating the experiences of wives of critically ill patients (i.e., only adult patients) would require a smaller sample than a

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5 Many small studies do not have the time or resources to collect enough data on each group when this occurs; in these situations, the researcher must acknowledge this as a limitation of the study and present this as a future avenue for research.
study that explored families’ experiences (which would include both adult and pediatric patients). In the wife study, although the researcher may want to include women with a variety of experiences (e.g., women of different ages whose husbands were critical as a result of different acute, chronic, or traumatic conditions with varying prognoses), the participant group is still fairly discrete. If the study included all family members, the sample would need to be larger to include some of the same variations as in the wife study, but also husbands, children, parents, siblings, and so forth. Some of these subgroups may not be dissimilar so would not need to be saturated separately, however, until enough data are obtained from these groups, this would not be known.

Type of Sampling

The type of sampling is another factor to consider when designing a study. Purposive sampling is the mainstay of qualitative research and is defined as the selection of data sources to meet the needs of the study. These data sources may be individuals who have knowledge of or experience with the research topic of interest or other types of data that would enhance the researcher’s ability to comprehensively understand the topic of interest. According to Sandelowski (1995), there are three variations within purposive sampling, demographic, phenomenal, and theoretical. Demographic variation is based on the belief that a demographic factor is analytically important to the study. Participants are selected based on both their experience with the topic of interest and the demographic factor, such as gender. Phenomenal variation incorporates dimensions or characteristics associated with the phenomenon of interest. For example, as described above in the study of wives of critically ill patients, some variations would be the prognosis and cause of the critical illness. Participants would be purposively selected to include these variations. Both demographic and phenomenal sampling decisions are made prior to beginning the study. The third variation is theoretical sampling. Here, sampling decisions are made based on the analytic needs of the study. The researcher may begin by using some demographic or phenomenal variations, but as the study progresses, subsequent sampling is driven by the developing theory or model. So data sources are chosen that have specific characteristics that will expand, validate, or refute the emerging model.

Sampling Units

“Sampling unit” is a more useful term to consider when designing a qualitative research study. This gives a clearer idea of the sample than simply estimating in a proposal or documenting in the final report the number of study participants. A sampling unit can be an interview, a day of observation, or a single unit of observation (when the incident of interest occurs), or some other data source, such as an entry in a hospital record or a newspaper clipping. Often reviewers are leery when they read that the sample included “only” 10 participants. What is missing in this type of documentation is the fact that each participant was interviewed three times, wrote daily journals entries, or was observed for 8 hours during interactions with multiple family members (so many incidents of interest were observed). When completing a human subjects protection application, an estimate of the number of participants is needed, but for research funding proposals, the addition of the sampling units would strengthen the proposal. So instead of writing, “It is estimated that 15 participants will be needed to reach saturation,” the researcher could say, “It is estimated that 30 interviews will be needed” (so this could mean 15 participants interviewed twice, 10 participants interviewed three times, or 10 participants interviewed once, and 10 others interviewed twice).7 These sampling units need to be carefully thought out to ensure that the number of units proposed will be adequate to reach data saturation, yet not so many that the

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6 Sample size in qualitative research is always estimated, for the researcher does not know a priori the number of sampling units or participants that will be needed to reach analytic saturation. However, the researcher must have a theoretically based justification for this estimate.

7 When participants are interviewed a varying number of times, the reason why this is anticipated (or occurred) needs to be explained, and at times, justified.
data are oversaturated and extensive analysis becomes difficult.

**Sample Size Based on Qualitative Approach**

There is no set rule that determines sample size in qualitative research; however, there are some methodological guidelines that may assist the researcher. It must be remembered that sample size alone is not as important as the number of sampling units. For example, in phenomenology, a small sample of less than 10 participants is used; however, multiple interactions (i.e., interviews/conversations, writing samples, journals, other artistic units—poetry, art, music) with the participants are needed. A grounded theory approach would require somewhere between 30 and 50 participants and include both interviews and observation (Morse, 1994). An ethnographic approach would also require 30 to 50 participants, along with multiple other data sources (Morse, 1994). The number of participants in focus group research depends on the research question and the diversity of the participants. However, the general rule is that five groups of 6 to 10 participants are needed (Morgan, 1998). Case study research can be undertaken with one participant (i.e., individual, family, or organization), but requires numerous sampling units (so multiple interviews or other data sources). Case studies can also be done with an event or other type of incident (this becomes the case). Here the number of participants and other sources of data will depend on the event chosen and the amount of data needed to fully understand the case (Creswell, 1998). Narrative/storytelling usually uses long detailed descriptions from one or two individuals. These narratives are a result of multiple in-depth interviews or discussions with the participant(s).

**DATA COLLECTION**

Throughout data collection there are numerous places where threats to validity, reliability, and generalizability can occur. Sources include the research participant, the researcher as the data collector (specifically during interviewing and observations), and the specific techniques used for data collection.

**The Research Participant**

The quality of the collected data depends on the participant. In order for a participant to provide useful data during an interview, the participant must have had the experience that is being investigated, have processed and remember the experience, and be willing and able to articulate that experience. Not all individuals who agree to participate in a research study will fit those criteria. Some people are unable to relay their experiences. There are many possible reasons for this, including:

- They do not want to tell the story;
- They have not processed the experience yet, or they are still in the midst of the experience (here observation may be a more appropriate approach);
- They do not remember the event (e.g., due to the trauma of the experience or the severity of an illness);
- The experience was too personal;
- They fear that relating the experience will get them or someone else in trouble; and/or
- The interview is not being conducted in a private place.

Others threats to the validity of the collected data are the participants: telling the researcher what they think the researcher wants to hear, listening to clues during an interview and repeating back what they hear (e.g., the researcher uses the word “coping” and participant picks up on it and uses it), and acting differently than usual or acting the way they think they should act when being observed.

There are a number of ways to minimize these threats to validity and reliability. These include increasing the sample size, performing multiple interviews (this may allow the participant time to process the experience, become comfortable with the interview process and the researcher, and allow time for clarification

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8According to Morse (1994), approximately six participants are needed to understand the essence of an experience.
The researcher (or person collecting the data) has a major influence on the data collected and the quality and accuracy of that data (in other words, validity and reliability). As in all research, prior to beginning the study, everyone involved in data collection needs to understand the study and be trained in the techniques of interviewing and/or observation. During the initial set of interviews and periodically throughout the research study, the interviews are observed or recorded and critiqued for style (e.g., if the interview is unstructured, does it flow as an unstructured interview should), leading questions, advice giving, interruptions, and researcher biases.

Threats to validity and reliability are inherent in the process of interviewing a research participant, as interviews are not neutral tools for data collection. The interview itself is influenced by both the interviewer and interviewee. The interviewer creates the situation under which an interview takes place, that is, questions are asked and answers are given (Fontana & Frey, 2000). Within this situation personal characteristics of the interviewer such as age, race, gender, profession will influence how well the interviewer and interviewee connect, and thus, the data obtained during the interview. How questions are asked and what words are used by the interviewer also will influence the participants' responses.

Using a translator during the interview process may be necessary in some cases but poses problems with data validity (Esposito, 2001). Some of the general threats relate to the interpretation of the question by the translator, including whether the question was understood as it was supposed to be, whether it was translated as it was meant to be, and whether the question was even asked. Other concerns are a result of cultural and language issues (Twinn, 1997). Can the question even be translated or are there words or cultural aspects that do not translate? The same concerns apply to the responses given by the participant. In order to enhance validity, the translator should be trained as an interviewer and be an active part of the research project. He or she needs to understand the purpose of the study, why certain questions are asked, and what probes are needed to adequately address the research topic. If at all possible, the translator should understand not only the language, but also the culture, so that questions can be pre-evaluated for their relevance to that particular cultural group. Interview questions also need to be pretested through this translation process to ensure that valid data can be obtained.

Interviewing is an art and researchers need to critique their own interview style. Within this process, threats to validity and reliability can be addressed. Some important things to consider are the amount of talking by the interviewer versus the interviewee. A “good” interview will have enormous blocks of interviewee text with minimal talking by the interviewer. Other things to critique that are a concern within the interview are the following:

- Multiple questions being asked at once
- Interrupting the participant before he or she has completed the answer
- Summarizing or verifying what the participant said
- Teaching, preaching, or counseling the participant during a research-related interview (the interviewer is there as a researcher, not as a nurse, and can refer the participant to the appropriate source for information once the interview is finished)
- Changing directions before the participant has told his or her whole story
Part II  Understanding Measurement Design

- Using labels or technical terms
- Asking closed-ended questions (at times, some closed-ended questions are warranted, but for the most part, these should be avoided)

There also are technical problems that need to be preaddressed prior to beginning the process of interviewing. All interviewers need to know how to use the tape-recording equipment (e.g., Does it have auto-reverse or do you have to flip over the tape? Does it make noise when the tape is complete or does it just quietly turn off without you knowing it?), have spare batteries and tapes, and a proper microphone so voice quality will not be compromised if the setting for data collection is less than adequate (always try to do the interview in a quiet setting without distractions). Another problem is loss of data; either the interviewer did not record or it was lost (e.g., erased by accident, lost during transport to the transcriber). Again, knowing how to properly work the equipment should prevent an interview from not being recorded. Making a copy of the interview on a blank tape would provide a backup.

The Researcher as Observer
(Participant Observation)

The collection of observational data is more than just a documentation of visual information, but includes observations using all of the researcher’s senses. This technique is used when the information needed to address the research question cannot be obtained by interviews alone and/or when this type of data would augment other type of data (Jorgensen, 1989). Most qualitative observation is done by the researcher (or research assistant) in person, but there are instances when videotaping may be an option (issues related to videotaping will be discussed later). One of the fundamental aspects of participant observation (and one that enhances data validity) is that data collection takes place in the natural context in which it occurs and among those individuals who would naturally be part of that context.

There is a range of participation by the researcher who is collecting observational data, from complete observer to a complete participant. Each level has implications for the quality of the data collected. A complete observer (which is similar to videotaping) does not interact with the individuals or the setting being observed. This has been described as being “a fly on the wall” (Morse & Field, 1995, p. 109). The disadvantage of being a complete observer is that the researcher’s ability to interview or clarify why a behavior has occurred is not possible. As the researcher becomes more of a participant (either participant-as-observer where the researcher is part of the setting and acts as a researcher [observer] only part of the time, or observer-as-participant where the researcher is primarily in the setting to observe, but helps out once in a while [Morse & Field, 1995]), other potential threats to validity and reliability can occur. The more a researcher becomes part of a setting, the less objective (or biased) the observations become as the researcher may begin to see events through the eyes of the participants. On the other hand, active participation in a setting may facilitate the acquisition of insider knowledge, so it will help the researcher to determine when the event(s) of interest will occur and potentially what and where to observe.

There are numerous threats to both validity and reliability when using participant observation as a technique for data collection. A threat to validity is possible behavioral changes on the part of those being observed when the researcher is present. These changes decrease over time, so increasing the length of time in the setting should enhance the “truth value” of what is being observed. It is also important to be allowed to conduct observations at any time that the researcher deems appropriate so that the individuals being observed do not prepare for the visit (Morse & Field, 1995).

Other threats to validity and reliability include not knowing what is important to observe, thus observing and documenting the wrong information; missing significant events (because the researcher is observing something else); prematurely determining what is important to observe, so missing the phenomenon of interest; incomplete or incorrect documentation of the phenomenon in terms of field notes.12

12For a complete description of field notes, see Morse and Field (1995, pp. 111–115).
Participant observation rarely consists of solely observational data. Thus, many of the concerns previously raised can be addressed by using multiple techniques for data collection such as interviews and documents. Proper documentation of the phenomenon being observed in a field note (done at regular intervals so information is not forgotten or missed) will also strengthen both the validity and reliability of the data collected. Although the observation itself cannot be critiqued, the field notes from the observatory periods can be evaluated. During this evaluation, questions can be raised as to what has been observed and why, and the comprehensiveness of the field note. This process is extremely important since these field notes are the data that will be used for analysis purposes.

Videotaping has been suggested as a way to address some of the limitations of participant observation. According to Bottorff (1994), three reasons for using videotaping are “when behaviors of interest are of very short duration, the distinctive character of events change moment by moment, or more detailed and precise descriptions of behaviors and/or processes than possible with ordinary participant observation are required” (p. 244). The two advantages of videotape recording are density and permanence (Bottorff, 1994). Density refers to the amount of information that can be simultaneously recorded. Density is significantly higher with videotaping versus participant observation; however, as Bottorff (1994) points out, there are also limitations to this technique. The camera is still only picking up certain events, depending on where it is aimed (so may pick up what’s going on in the room, but miss closer facial expressions), microphones may pick up extraneous noises and not the vocalizations of importance, and as with participant observation, behaviors may change because of the camera. Permanence refers to the ability to have the event on tape, allowing the researcher to review the event as often as needed and the analysis can be demonstrated to others. Having a videotape of an event definitely increases data validity and reliability; however, the inability to have data beyond the tape (similar to complete observer) is always present. So as different hypotheses are developed, unless data collection is ongoing, testing will not be possible. Thus, other forms of data collection used along with videotaping are encouraged.

**Techniques for Data Collection**

One of the most common mistakes made by researchers is not using the appropriate techniques for data collection to adequately investigate the research topic of interest. In order to have valid data that truly reflects reality, multiple sources of data are usually required. Simply interviewing participants may only give a partial picture, since they may not be able to relay the whole story (there are many things that are done unconsciously, so cannot be easily verbalized). Thus, in many instances, participant observation and other sources of data, such as medical records, are also needed. There are, however, other times when the researcher is interested solely in past experiences and participant observation is not needed and would provide useless data. Another common error is the use of group interviews or focus groups, when in-depth individual interviews are needed to sufficiently explore the topic. And, finally, the use of wrong interview structure can pose a serious threat to validity and reliability. Using semistructured or structured interviews too early in a research study when little information is known about the phenomenon of interest can result in the true phenomenon not emerging. Many times, the researcher develops a list of structured interview questions that presuppose which concepts are of importance to the participant, thus not allowing these to emerge from the data. On the other hand, if the research is at the point of hypothesis testing and beginning theory development, unstructured interviews will not provide the data needed for this to occur.

**DATA ANALYSIS**

During the process of data analysis, there also are numerous places where threats to validity and reliability can occur. But before data analysis is discussed, data quality needs to be addressed.
Of number one importance to data quality is the accuracy of the transcribed interviews and field notes. Accuracy of the data set is the responsibility of the researcher. Each transcribed piece of data needs to be checked for accuracy, since simple things like inaccurate punctuation or a mistyped word can change the entire meaning of a sentence (Easton, McComish, & Greenberg, 2000). In addition, the researcher needs to fill in gaps in the transcription (spots where the typist could not understand or hear the tape). The researcher who actually performed the interview is the best person to do this since he or she may be able to reconstruct what was said.

There are areas that researchers should consider when having interviews transcribed. These include which features of the interview are important and need to be part of the transcript versus what can be ignored (Sandelowski, 1994). For example, how will emotional expression be described? Are pauses important and how will you and the typist determine how to document them? And, does every “uh huh” need to be included? Each of these decisions should be made based on the overall purpose of the research and the method chosen for the study.

The validity and reliability of a study is integrally tied to the process of data analysis. The findings and conclusions of a study need to be cohesively linked to the data. There are key areas that should be addressed during the planning stage of a research project, so that validity and reliability will not be compromised once analysis begins. First, the choice of type of analysis needs to match the overall purpose of the study, the methods chosen, and the type of data collected. Thus, a constant comparative analysis will not work for a focus group study, but is the technique of choice for a grounded theory. Content analysis is appropriate if every participant is asked and responds to the same question. However, if unstructured open-ended interviews are done, counting the amount of times a word or phrase is used would not work. Second, preplanning how model verification, coding checks, and audit trails will occur will make the process proceed smoothly. Finally, assembling a team to assist with the analysis will help address researcher bias (especially if the team is not all nurses or at least not all nurses from the same specialty area).

Problems that frequently come up during analysis include premature closure of analysis and development of categories/models. Here, either researcher bias comes into play or the researcher observes a pattern of some type early in the analysis process and decides “This is it.” When this occurs, data are inaccurately placed into categories (here the researcher begins to work deductively instead of inductively); thus, when the real pattern or categories appear, they are missed. For a beginning researcher, working with an experienced qualitative researcher and/or a research team should prevent this from occurring. The research team needs to independently code the data and then compare codes and developing categories. Areas of incongruence need to be discussed using specific examples from the data set. If incongruencies continue, further data collection may be needed to examine each area. The experienced researcher should be able to question the research team to ensure that the categories or conclusions are grounded in the data and ask the “what about” questions. The team needs to have rich description from the data to support developing categories to answer questions, such as “You say that this works for situation x, what about in situation y?” (e.g., Once trust is established, wives of critically ill patients are able to relinquish care to the nursing staff, but does the same hold true for parents?). This back and forth and potential verification with the original participants or secondary informants will help to strengthen the analysis.

**SUMMARY**

Validity and reliability are important issues to consider when doing a qualitative study. These issues are intertwined and a threat to one will result in threats to the other. In order for a qualitative study to be useable and to help advance nursing science, qualitative researchers can no longer avoid these issues. Validity and reliability need to be addressed during the initial project planning, sampling procedures, data collection, and data analysis.
REFERENCES


Part III
Measurement via the Digital World
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Researchers across disciplines are increasingly relying on existing data sources to examine health issues. The expanding computerization of health information, decreasing costs of storage, increasing analytical tools and techniques, and the constraints on collecting primary data have propelled the use of such data. Existing data sources include both administrative data—data collected for reasons other than research—and data developed for another study or for surveillance. Utilizing existing data is particularly desirable because they are relatively cheap (compared to primary data collection), cover large samples, are often longitudinal, and are not intrusive to subjects.

Despite these advantages, technical and methodological barriers make using these data particularly challenging. The fundamental issues relate to the fact that the data were not developed and collected to answer the researcher’s question. Traditionally, researchers conceptualize their research study and develop methodology that is consistent with the conceptualization. The research design, the sample, the measures, and the proposed analyses are intimately linked to the research aims. Using existing data places constraints on all aspects of research. The designs are most often correlational. Study subjects must be selected from the data by inclusion and exclusion criteria that are defined with existing data. Researchers may have to rely on measures developed for reasons that may not be consistent with their conceptualization or study sample. Analyses are constrained by the level of the existing data and the potential bias in some data elements. The burden is on users to know their data, conduct iterative preliminary analyses to explore and document reliability and validity issues, and to summarize findings acknowledging the potential limitations.

This chapter provides an overview of common sources of existing data, including the types of information that are included and the limitations to that information when used for research. Issues in working with these data are discussed, with particular emphasis on reliability and validity and what can be done to address these concerns.

**EXISTING HEALTH DATA**

Existing health data can be broadly divided into two categories: secondary data and administrative data. While the use of any data not collected specifically for a research study (e.g., primary data) might be referred as secondary data, a distinction is made here between data that was collected for surveillance or another research study (secondary data) and data not collected for research purposes (administrative data).

Secondary data allow analyses of hypothesis and relationships that may not have been examined in the original study. This approach is efficient since planning for and collection of data is eliminated, but it is also challenges the researcher to understand the original researcher’s conceptualizations and methodological choices.
Students and novice researchers often conduct secondary analysis of established researchers’ data to explore unexamined relationships or study other outcomes.

Another example of secondary analysis is the use of the national surveys from the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC) (CDC, 2009). These datasets, developed for surveillance and research, provide important information to guide actions and policies related to the health of people in the United States. The National Health Interview Survey (NHIS), for example, is used to monitor access to care and progress toward several of the Healthy People, 2020 goals. The National Nursing Home Survey collects data on nursing homes, their residents, and their staff.

The need to measure varied aspects of health, to be representative of target populations, and to cover diverse types of health conditions and health services imposes strong methodological rigor on the data collection and documentation. Much of these data are readily available for download and input statements for different statistical programs are provided.

A second broad category of existing data is administrative data, most often resulting from the administration of services and programs. This may include organizational level data (e.g., statewide nursing home characteristic databases) as well as the person-level data (e.g., claims or encounter data collected by providers, insurers, or regulators). The latter data has been more recently referred to simply as the “reuse” of health data by the American Medical Informatics Association (AMIA) (Bloomrosen & Detmer, 2008).

In addition to supporting clinical care, electronic patient data “reuse” has expanded to support surveillance, performance measurement, and regulatory monitoring. While limitations are acknowledged (Iezzoni, 2003), utilization of these data is likely to continue to increase. Researchers are also expected to expand their use of these data since the advantages extend beyond the researcher’s efficiency and include the ability to cover entire systems of care or populations rather than segments (e.g., by payer, organization, etc). Large datasets allow an examination of infrequent outcomes and may have adequate power to detect differences. Much administrative data also have additional advantages such as the ability to examine changes over time and to link to other datasets representing other explanatory variables (e.g., organizational and geographic attributes). This is particularly important in studying outcomes where a systems approach is desirable. However, administrative data are, by definition, collected for reasons other than research. The purposes and procedures for collecting that data may have inherent sources of bias. Therefore, there is a greater onus on the researcher to understand what the data represent—and what they do not represent.

**COMMON DATA ELEMENTS**

Data elements in existing data can be summarized under four categories: demographics, clinical diagnosis and treatment, organizational characteristics, and geographic characteristics. While there is increasing standardization of definitions and coding, variation still remains. The Public Health Data Standards Consortium, a nonprofit membership-based group that seeks to establish health standards to improve health care, is a good source of information about broader standardization issues (Public Health Data Standards Consortium, 2009).

A major advancement in the standardization of much health data has been the development of standardized code sets for health care transactions, part of the administrative simplification components of the Health Insurance Portability and Accountability Act of 1996 (HIPAA; P.L. 104-91). This has resulted in the same definitions and coding of data elements across care delivery sites. Organizations and states can no longer rely on home-grown or local coding. Even though the intent of these changes was to achieve the administrative cost savings with Electronic Data Interchange (EDI), researchers will benefit.

**Demographics**

Demographic elements have been measured in various ways in existing data. This includes both the definition of the measure and the coding when the variable is nominal. Age, gender, and
marital status are collected in most person-level data. Age and gender coding is generally consistent, however, the number of categories for marital status may differ by data source. The coding of race and ethnicity also varies and has been inconsistent and controversial, primarily because they have been developed to monitor access in housing, education, and employment rather than as a scientifically derived category. The most commonly seen coding requires two parts: first a response to ethnicity (Hispanic/Latino or not), and second the selection of all races that apply (American Indian/Alaskan native, Asian, Black/African American, Native Hawaiian/Pacific Islander, and White). For any measure where subjectivity is possible, it is important to consider how the data are collected. Self-reported versus observer-reported race may result in different categorization.

Continuous demographic variables may be collapsed to categories that may not be consistent across datasets. Income, for example, may be collected as actual income but collapsed to ordinal categories for data release. These income categories can vary widely and researchers may need to further collapse them based on the distribution of the data, the research design, or the comparisons that are to be made. Reporting ordinal or categorical data is likely to become more common with increased concerns for patient confidentiality. Age, for example, is not a protected element but using age in combination with other elements in the file (e.g., location of care, procedures, diagnoses, etc.) may allow identification of an individual in a dataset. Thus, age is released only in aggregate categories in some databases.

Other demographic data may be represented by codes. The most common way to classify worker occupation type has been the Standard Occupational Classification (SOC) codes. The SOC system is maintained by the Bureau of Labor Statistics and classifies occupations on the basis of work performed, required skills, education, training, and credentials (Bureau of Labor Statistics, n.d.). The codes have recently been revised to provide more detail for several health care–related occupations, including advanced practice nurses. Table 9.1 illustrates the codes that represent registered nurses.

### TABLE 9.1 Standard Occupational Classification (SOC) Codes Representing Registered Nurses

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>29-0000</td>
<td>Healthcare Practitioners and Technical Occupations</td>
</tr>
<tr>
<td>29-1000</td>
<td>Health Diagnosing and Treating Practitioners</td>
</tr>
<tr>
<td>29-1140</td>
<td>Registered Nurses</td>
</tr>
<tr>
<td>29-1150</td>
<td>Nurse Anesthetists</td>
</tr>
<tr>
<td>29-1160</td>
<td>Nurse Midwives</td>
</tr>
<tr>
<td>29-1170</td>
<td>Nurse Practitioners</td>
</tr>
</tbody>
</table>

### Clinical Data

Much of the clinical data in surveys and administrative data are represented by diagnoses, procedures, and services provided. Table 9.2 illustrates common coding systems seen in administrative data.

The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) is used for coding diagnoses in most databases. Three-, four-, and five-digit codes, organized by body system, reflect increasing specificity. For example, Table 9.3 illustrates the ICD-9-CM diagnosis code for diabetes. The 4th digit represents the manifestations (e.g., ketoacidosis, coma, and circulatory disorders), and the 5th digit represents the type of diabetes (Type 1, Type 2).

ICD-9-CM Procedure Codes are used for coding of inpatient procedures and are 4-digit codes organized by body system. Table 9.4 illustrates the ICD-9-CM procedure codes for breast excisions. Note that the codes reflect an increasing extent of breast removal, but there may be differences in how a surgeon classifies a lumpectomy from a quadrant resection.

Coders are instructed to code to the highest specificity possible, but it is possible to code a nine in the fourth position, indicating a less specific category. For procedures billed by physicians and other health professionals, Current Procedural Terminology (CPT) codes are used rather than ICD-9-CM. The CPT codes are republished and updated annually by the American Medical Association (AMA).

Regardless of the coding system used, to code clinical diagnoses, procedures, drugs, and other
### TABLE 9.2 Some Coding Systems Represented in Existing Health Data

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnoses</strong></td>
<td></td>
</tr>
<tr>
<td>International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)</td>
<td>Diagnoses, supplementary classifications representing factors influencing health status (V-codes) and environmental events that may have contributed to adverse events (E-codes).</td>
</tr>
<tr>
<td><strong>Procedures/Services</strong></td>
<td></td>
</tr>
<tr>
<td>Healthcare Common Procedure Coding System (HCPCS)</td>
<td>Items, supplies, and nonphysician services not covered by CPT codes.</td>
</tr>
<tr>
<td>Pharmacy</td>
<td></td>
</tr>
<tr>
<td>National Drug Codes (NDC)</td>
<td>Universal product identifier for human drugs.</td>
</tr>
</tbody>
</table>

### TABLE 9.3 Diabetic Diagnoses Coding in ICD-9-CM

<table>
<thead>
<tr>
<th>ICD-9-CM Code</th>
<th>ICD-9-CM Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>250.0</td>
<td>Diabetes mellitus without mention of complications</td>
</tr>
<tr>
<td>250.1</td>
<td>Diabetes with ketoacidosis</td>
</tr>
<tr>
<td>250.2</td>
<td>Diabetes with hyperosmolarity</td>
</tr>
<tr>
<td>250.3</td>
<td>Diabetes with other coma</td>
</tr>
<tr>
<td>250.4</td>
<td>Diabetes with renal manifestations</td>
</tr>
<tr>
<td>250.5</td>
<td>Diabetes with ophthalmic manifestations</td>
</tr>
<tr>
<td>250.6</td>
<td>Diabetes with neurological manifestations</td>
</tr>
<tr>
<td>250.7</td>
<td>Diabetes with peripheral circulatory disorders</td>
</tr>
<tr>
<td>250.8</td>
<td>Diabetes with other specified manifestations</td>
</tr>
<tr>
<td>250.9</td>
<td>Diabetes with unspecified complication</td>
</tr>
</tbody>
</table>

**Note:** 5th digit represents type of diabetes.

Despite the increasing sophistication and consistency in using coding systems, coding error remains a major concern. Iezzoni’s book *Risk Adjustment for Measuring Health Care Outcomes* (2003) provides multiple examples to illustrate the practical difficulties. A fundamental difficulty may be a lack of clarity of what the correct diagnosis code should be. A patient presenting to the emergency room with decompensation of chronic lung disease could legitimately be coded as chronic obstructive lung disease (491.2), chronic bronchitis (491.9), emphysema (492.8), acute bronchitis (466.0), or respiratory failure (492.8). A second difficulty may be related to how diagnoses are selected, recorded, and ordered. It is likely that physicians become knowledgeable of the common codes used in their practice and fit patient conditions to the known codes. Even how the patient relates his or her history can influence coding as the patient is likely to report “old” diagnoses. The ordering of diagnoses is also crucial in settings where it affects payment. Yet, it is not always clear what the principal diagnosis should be, particularly when patients have multiple chronic illnesses. For example, a patient admitted for postobstructive pneumonia related...
Chapter 9 Using Existing Administrative and National Databases

that are commonly used to assess risk or other outcomes: source of admission (e.g., emergency room, home, physician’s office, etc.), type of admission (e.g., emergent, urgent, elective), and disposition (e.g., routine, to home care, died, etc.). Researchers must be familiar with the organization and limitations of the codes used in their research study. For example, hospitals may not routinely code to the specificity that is possible. In addition, some codes influence reimbursement and may be an inherent source of bias.

With thousands of ICD-9-CM diagnoses codes, established algorithms that can be applied to the diagnoses and procedure codes may be useful. For inpatient claims, for example, discharge data are “grouped” using the diagnosis related groups (DRG) algorithm as part of the hospital prospective payment system. Researchers can use this aggregated grouping to include or exclude patients from their sample, to examine variation in costs, and to measure case mix. However, selecting cases by diagnoses or procedure codes may be more appropriate since DRGs were developed for reimbursement purposes. The Agency for Healthcare Research and Quality (AHRQ) has developed other algorithms to create more clinically meaningful categories (Clinical Classifications Software), to identify chronic conditions (Chronic Condition Indicator), and to identify comorbid conditions (Comorbidity Software). All are available for download from AHRQ (AHRQ, 2009).

Organizational Characteristics or Identifiers

It is often desirable to examine organizational characteristics to examine factors influencing outcomes. Both public and private data are available for these purposes. For example, many states now publish information about hospitals and nursing home characteristics as part of the “report care” movement. Electronic forms of these data can be obtained but they often must be linked using a common identifier. “Crosswalks” linking organization names or identifiers to other databases may need to be developed. Even in these situations, linkages may be challenging

<table>
<thead>
<tr>
<th>ICD-9-CM Code</th>
<th>ICD-9-CM Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.0</td>
<td>Mastectomy</td>
</tr>
<tr>
<td>85.11</td>
<td>Closed breast biopsy</td>
</tr>
<tr>
<td>85.12</td>
<td>Open breast biopsy</td>
</tr>
<tr>
<td>85.19</td>
<td>Breast diagnostic procedure not elsewhere classified</td>
</tr>
<tr>
<td>85.20</td>
<td>Breast tissue destruction not otherwise specified</td>
</tr>
<tr>
<td>85.21</td>
<td>Local excision of breast lesion</td>
</tr>
<tr>
<td>85.22</td>
<td>Quadrant resection of the breast</td>
</tr>
<tr>
<td>85.23</td>
<td>Subtotal mastectomy</td>
</tr>
<tr>
<td>85.24</td>
<td>Excision of ectopic breast tissue</td>
</tr>
<tr>
<td>85.25</td>
<td>Excision of nipple</td>
</tr>
<tr>
<td>85.41</td>
<td>Unilateral simple mastectomy</td>
</tr>
<tr>
<td>85.42</td>
<td>Bilateral simple mastectomy</td>
</tr>
<tr>
<td>85.43</td>
<td>Unilateral extended simple mastectomy</td>
</tr>
<tr>
<td>85.44</td>
<td>Bilateral extended simple mastectomy</td>
</tr>
<tr>
<td>85.45</td>
<td>Unilateral radical mastectomy</td>
</tr>
<tr>
<td>85.46</td>
<td>Bilateral radical mastectomy</td>
</tr>
<tr>
<td>85.47</td>
<td>Unilateral extended radical mastectomy</td>
</tr>
<tr>
<td>85.48</td>
<td>Bilateral extended radical mastectomy</td>
</tr>
</tbody>
</table>

to lung cancer may be assigned a pneumonia code or a lung cancer code. Researchers using these data should consult with clinicians if there are questions about coding practices.

Specifically related to hospital claims, the Centers for Medicare and Medicaid Services (CMS) now requires that hospitals submit present on admission (PoA) information on all primary and secondary diagnoses on their Medicare claims (CMS, 2003). Researchers have already used PoA to adjust hospital performance measures from administrative data (Averill, Vertrees, McCullough, Hughes, & Goldfield, 2006; Bahl, Thompson, Kau, Hu, & Campbell, 2008; Naessens & Huschka, 2004). In general, hospital rates of these complications were lower, reflecting the limitations of using discharge abstract ICD-9-CM diagnoses.

In addition to ICD-9-CM codes, other data elements may be used to reflect patient condition. Hospital discharge data have several variables
since organizations change names, ownership, and even location.

The HIPAA Administrative Simplification Standard also facilitated the merging of information with the establishment of a unique provider identifier. The National Provider Identifier (NPI) is a unique identification number for covered health care providers. This includes organizations (hospitals, nursing homes, ambulatory care facilities, durable medical equipment suppliers, clinical laboratories, pharmacies, and many other “institutional” type providers); clinicians (physicians, dentists, psychologists, pharmacists, nurses, chiropractors); and groups (health maintenance organizations). Establishing a single identifier has made linkages easier. The NPI is a 10-position, intelligence-free numeric identifier (10-digit number). This means that the numbers do not carry other information about health care providers, such as the state in which they live or their medical specialty.

**Geography**

For many research aims, geographic characteristics are important to analyze. For example, hospital zip codes can be used to define market areas and patient zip code information can be used to examine referral patterns, access to services, and community needs. Zip code or geographic area files that include data reflecting characteristics of that zip code can be purchased. For example, the median income of zip code and population density may be used to construct proxies of socioeconomic status. However, zip codes are considered personal health information; therefore, requests for this element must be clearly justified.

Another commonly used geographical designation is the metropolitan statistical area (MSA). The general concept of coding is to classify all areas based on their population and linkages to adjacent communities having a high degree of economic and social integration with that core. Other geographical designations are state and county. The Federal Information Processing Standards (FIPS) codes uniquely identify various jurisdictions such as county and state and can be used to link to geographic descriptors.

FIPS county codes can be linked to the Area Resource File (ARF), a database containing more than 6,000 variables for each county in the United States, including economic indicators, health professions supply, health facility numbers and types, population characteristics, and environment (Health Resources Services Administration [HRSA], 2009).

**ACCESS TO DATA**

Access to large existing health care data has both technical and privacy barriers. Many of the datasets from the National Center for Health Statistics can be downloaded. Data may be supplied in a particular software format (e.g., SAS) or may be in text form with input statements for different software programs. Likewise, the Inter-university Consortium for Political and Social Research (ICPSR), a not-for-profit organization that serves member colleges and universities, maintains datasets and provides access to archives of social science data (ICPSR, 2009).

Most of the health data that falls under the “reuse” terminology reflects person-level clinical data and claims. These data are more difficult to obtain, depending on the type and extent of data that are requested. If all patient identifiers have been removed or sufficiently encrypted, the data may be available for purchase by signing a simple confidentiality agreement. On the other hand, if identifiers are needed to link persons across care settings and time, a proposal and justification are reviewed by the data supplier. Many of the federal agencies use a third entity to deal with data requests. For example, CMS requires that researchers work with the Research Data Assistance Center (ResDAC) to prepare a request (ResDAC, 2009). Data requests may involve legal and ethical reviews. The fundamental approach is that researchers should request and receive only the smallest reasonable amount of data that will allow the research aims to be achieved. Furthermore, data should be de-identified as quickly as possible and securely stored with limited access.

While the increasing accessibility makes data management easier, research teams must include individuals with experience manipulating these
data. Just as important are individuals who are knowledgeable of the technical aspects of data preparation such as imputation, formats, and sampling. Documentation provided with data can vary in breadth and quality. Documentation and technical reports, formerly requiring several notebooks, are now stored in electronic, hyperlinked files. Users must read the documentation thoroughly to make sure that they are conducting appropriate analyses and not misrepresenting findings. This is perhaps the greatest difference in using data where researchers have control over the definitions and measures that are used. With administrative data, users must constantly consider how their conceptualization might differ from what the documentation details.

**STUDY DESIGN**

Some of the earliest users of existing data were health service researchers studying hospital costs and markets. Even as research broadened to other risk factors and outcomes, most of the designs are observational. Case control or cohort designs may also be used, particularly when there is longitudinal data as in the national health surveys. Even with stronger designs and improved design and statistical control, researchers should have a healthy skepticism about making definitive conclusions. Causal inferences are difficult since timing of events is often hard to pinpoint and extraneous factors influencing outcomes are numerous and difficult to assess.

**Measurement**

A fundamental problem with using existing data is that the data elements were defined and collected by others and using them as measures may be inconsistent with the study conceptualization. Moreover, there may be unknown sources of measurement error. For example, even with highly developed coding systems like ICD-9-CM, there are multiple opportunities for error. More often, the rules under which the data were defined, collected, and categorized are not known or fully understood.

**RELIABILITY**

Reliability of administrative data generally reflects the reproducibility of the data—collected by different methods, different persons, and at different sites. Some of the elements in administrative data represent observed events that can be clearly classified with nearly universal understanding (e.g., died). When these events are important for reimbursement or outcome evaluations, the likelihood that they are classified...
correctly is even greater. It is possible to examine other variables in the same dataset to check the reliability (e.g., consistency of death with cardiac arrest diagnosis, intensive care use, etc.). However, there are other variables that are less easy to categorize such as those that are based on a subjective assessment. The reason for a health visit, for example, may be recorded based on a receptionist’s note, the patient’s words, or the physician’s judgment. Finding another variable in the dataset to check reliability is not likely. If there are multiwaves of data collection, it is possible to assess reliability, although it may be confounded with true change.

From the time of designing the data collection protocols to the actual entry of data into the computer, there are many potential areas for error. For example, new procedures and technologies are often performed before they are added to the diagnoses and procedure coding systems. Alternative legal codes are used but may not represent the exact procedure that was done. In this instance, the classification rules are flawed, resulting in inaccurate information. Another major source of error in health claims data is inadequate documentation. The physician may not clearly describe the procedure, the coder may not be able to read or understand what the physician wrote, and the code that is closest to the existing code may be used. Other problems with the ICD-9-CM codes themselves have been described and include the inability to distinguish clinical dissimilar diagnoses because of inherently imprecise codes, the lack of definitions for codes, the availability of nonspecific codes as alternatives to more precise codes (Iezzoni, 2003).

Whenever possible, the results found with analyses of existing data should be compared to other sources of the same information. Results obtained may be compared with measures from other time periods, or data from other sources. This “benchmark” data may not represent the exact population studied but should be close. For example, rates of procedures may be benchmarked with another data source or report. If possible, comparisons to medical records may provide evidence of reliability. Reliability should also be assessed at different levels of analysis, depending on what is known about the potential sources of error. For example, percentage agreements may be reported by hospital, by physician, or by patient subgroups. Unfortunately, reabstraction studies are expensive and often only a sample of records can be examined.

Data elements that represent labels may also be sources of error. For example, social security numbers and telephone numbers are labels with no inherent definitions for categories or mathematical properties. Yet, these variables are also subject to error from multiple sources. They may be recorded wrong initially, be recorded with extra or missing digits, or they may simply result from a keystroke error. Data screening procedures can identify extra or missing digits through algorithms that search for codes that do not meet defined specifications. However, when data are collected wrong in the first place or there are data entry coding problems, identifying these errors is difficult and most often, they go undetected.

Validity in administrative data reflects how closely the data correspond to the researcher’s conceptualization and needs of the study. For many data elements in existing data, the definitions and coding rules have already placed constraints on what is really desirable for study purposes. For example, reported family income may be used to compute measures of socioeconomic status. Yet, the measure itself may not be defined to take into account the number of people in the household. Moreover, the actual reported amount may have been coded into ordinal categories to protect privacy. Thus, the ability of income to truly represent socioeconomic status is further compromised.

Identifying criterion measures for variables in administrative data is particularly difficult. The medical record, while the gold standard, may be missing the important information. The old adage in health care, “If it is not documented, it did not happen,” reflects this problem. A good example is the measurement of complications with ICD-9-CM data. While there are codes that represent complications (primarily the 990–999 ICD-9-CM diagnosis codes), and rules
for how these are to used, physicians may not use them out of fear of malpractice or of being identified as providing poor quality of care. In addition, incorrect diagnoses may be entered on a medical record or provisional diagnoses may be disproved but left on the record.

An obvious—but costly—approach to dealing with validity problems is to use different measures and different methods to assess the same attribute. This might be achieved in claims data by linking to other datasets. For example, pharmacy data may be linked to outpatient claims to assess accuracy of a diabetes diagnosis. In the national health surveys, questions asked in different ways within the same survey can be cross-tabulated. Electronic edits and corroborating measures may also be used to assess validity. For example, if cardiogenic shock were an assigned diagnosis, a one-day length of stay would only seem likely if the patient died.

**ANALYSES**

In light of the multiple sources of bias, it is apparent researchers using existing data must conduct adequate analyses to be assured that the findings are accurate and the conclusions are not overstated. Extensive data screening procedures are essential. This iterative process seeks to identify outliers, wild codes, and other data irregularities. Data quality assessments seek to identify sources and extent of missing data. But, more specific to existing data, potential sources of bias must be uncovered. Once the preliminary assessments are done, then decisions must be made about how to deal with these issues. Data elements may be dropped, recoded, or transformed. Missing data may be imputed. Research questions may need to be modified. All of this is done before beginning the principal analyses.

Most of the national health surveys use a complex sampling design, necessitating additional analytic procedures. The degree of sampling complexity can vary but may include multiple stages, disproportionate sampling, and clustering. While appropriate weights are included in the data, researchers must understand which weights to use. Moreover, standard statistical software packages (e.g., SPSS, SAS) assume a simple random sample with independent and identically distributed observations. Therefore, other software or customized procedures may be necessary to account for the sample weights and for the variance estimation weights (Kneipp & Yarandi, 2002).

Another analytical challenge particularly relevant to studying outcomes using claims data is the inherent nested nature of the data (e.g., patients cared for by nurse practitioners, in particular clinics). This situation violates the assumptions of independent observations and necessitates multilevel analyses to account for these clustered observations (Lake, 2006). Statistical software programs are advancing and most are able to deal with these analytical challenges.

**SUMMARY**

Researchers have access to massive amounts of data. Data quality is improving. Techniques to analyze data have expanded. Yet, there are many challenges that must be met when using existing data. Making sure that the data are appropriate for the question is fundamental. Becoming knowledgeable about the data and the potential problems must be done in the early stages of a study. A detailed review of the documentation and technical documentation is time-consuming but will help shape the study design. Researchers must utilize their fundamental knowledge of research methodology to design the best study possible—despite the potential sources of bias. Finally, when discussing findings, language should be specific, limitations must be acknowledged, and findings should not be overstated.

**REFERENCES**


Computers have touched nearly every area of life and measurement is not an exception. Innovative strategies, rapid and highly complex computational capability, ever-increasing capacity for storage of information, and undreamed of economy and accessibility are among characteristics that impact aspects of the measurement process.

Two areas of computerized testing are addressed in this chapter: (1) computer simulation, and (2) computer-based testing encompassing discussion of computerized fixed testing as well as a focus on computer adaptive testing (CAT). The NCLEX-RN Examination and the work being carried out as part of the Patient-Reported Outcomes Measurement Information System (PROMIS) initiative, a part of the NIH Roadmap, are discussed as examples of contemporary applications of CAT.

**COMPUTER SIMULATION**

Early uses of computer simulation involved using the computer to carry out a series of statistical trials using the Monte Carlo method (Nunnally & Bernstein, 1994). Today advanced graphical and acoustical simulation are realities so there is a variety of ways in which computer simulation can be used, including interventions in research studies and providing options for teaching and learning experiences that may also include evaluation of learner outcomes.

In some cases, a simulation is designed for a single purpose while in others, purposes are combined. DxR Clinician (DxR Development, 2008) is an example of patient simulation software offering case learning experiences with virtual patients as well as evaluation capability. Advanced practice nursing graduate students and medical students use these simulations to develop competence in working through specified virtual patient cases. Faculty can use these simulations to evaluate student clinical decision-making and care-management skills. The clinical competency exam information is controlled through CCX Software (DxR Development, 2008) that is made up of four utilities. In the first, faculty members have the option of creating or editing an existing case as well as setting the grading criteria. Next, students gather data from their patient that can involve interviewing and examining the patient as well as ordering laboratory tests for which results are available and need to be interpreted. Students then make a differential diagnosis and develop a plan of care for managing the patient. The third utility allows the faculty to evaluate the record of the student interactions with the virtual patient in assessment and patient care planning. The fourth utility handles results from an individual student over multiple cases or groups of students, or performance on a single or group of cases.

Strengths of computer simulations such as this include (1) the consistency of case or simulation presentation being assured, which strengthens the evaluation process; (2) the opportunity for the faculty to create or edit scenarios as well as determine the criteria for grading; (3) students having the opportunity to compare their answers with the evaluation criteria as well as to be informed of cost aspects of the laboratory work they have ordered; and (4) capture of student performance records in workable formats for comparison across virtual
patient cases and students. Costs of the simulation software and computer equipment needed are the major limitations.

In addition, computer simulations may be used in other aspects of the measurement process. Discussions of fixed and adaptive computer-based testing follow.

**COMPUTER-BASED TESTING**

“Computer-based testing” is a very broad term and can encompass a variety of types of tests with the only common factor being that a computer is used in administration of the test/measure. Aside from use in administration of tests, computers are frequently used in various phases of the measurement process from test development, formatting, scoring and reporting, and test/item evaluation. Various software products are available for use in test preparation as well as administration, scoring, estimating reliability and validity, and allowing for different types of item analysis. Additionally, some allow for computerized test administration that is done as/or paper and pencil, computer, and/or allow for online administration such as Questionmark (n.d.). These software products range from relatively simple to complex in purpose, capability, and cost. Basic functions allow for item writing. In some packages, this activity can extend to test development/authoring and formatting. Additionally, some allow for computerized test administration that is done as paper and pencil, computer, and/or allow for online administration. Other software products have capability for building and maintaining item banks that can be used for fixed testing.

An example of relatively simple software is a test construction kit providing various types of item shells (e.g., multiple choice, matching, true/false, and cloze sentences) and formatting available via shareware at http://www.shareup.net/Home-Education/Teaching-Tools/Test-Construction-Kit-review-6354.html (JCG Software, n.d.) at a very nominal cost. Some products are designed to perform a particular function such as scoring or creating gradebooks. Examples of more sophisticated products for various aspects of testing such as item banking and item analysis are offered by companies such as Assessment Systems Corporation (n.d.). More comprehensive packages provide complete testing systems, some of which are appropriate for online testing. As complexity and capability increase, cost also rises and can be considerable.

In selecting software for use in computerized testing—whether test construction, administration, or scoring—the type of testing for which it is appropriate, fixed or adaptive, is an important consideration. Particular care must be exercised in selecting software for aspects of the measurement process, such as scoring and item analysis.

**Fixed Computer Testing**

The original form of computerized testing, as well as the most frequently used form today, is the fixed-form. The term “fixed” reflects the static nature of presentation of measures in test administration. In the earliest forms of fixed computer testing, and often in early stages of using an instrument, existing paper-and-pencil measures are formatted for presentation to the respondent on the computer. Current usage of the term “fixed computer testing” implies that the test/measure is uniformly presented to each respondent and each respondent is expected to answer the same number of questions. The test is presented in exactly the same way with the same items, the same number of items, often in the same order, to each respondent. Thus, each respondent has a uniform testing/response experience. A lay example of fixed computer testing used in many states in the United States is the examination for a driver’s license. Fixed computer testing may serve as an alternative method of administration of a duplicate paper-and-pencil examination version such as in a number of professional certification examinations.

The static presentation of items within fixed testing has potential for exposure to breaches in test security, or in the case of other measures, response set or other types of measurement error, some software allows for use of the domain-sampling model. This process allows for sampling of a fixed number of items with equal characteristics (e.g., difficulty level) from a larger pool of items. Each respondent receives an alternate form of the test/measure with a
different group of questions in different order, thereby limiting exposure to any set of items and responses.

**Computer Adaptive Testing (CAT)**

Building on the premise that the ideal form of testing uses items at precisely the right difficulty level for the individual respondent (Lord, 1980), computer adaptive testing (CAT) utilizes the ever-increasing capabilities of the computer in implementing automated testing tailored to the individual. Most (Nunnally & Bernstein, 1994) CAT draws on item-response theory (IRT) that is overviewed in Chapter 3 of this text. IRT centers on the item as it considers observed performance of the respondent on an item and item difficulty. In classical measurement theory, the greater the number of items, the better the estimate of internal consistency reliability. An advantage of IRT is that a separate standard error of measurement is computed for each score level, which increases the precision of measurement and allows for the use of fewer items on a measure (Reeve, n.d.). This last point is particularly salient in accomplishing efficiency of the measurement process.

Basic assumptions of IRT include the following: (1) the ability or attribute being assessed by CAT is unidimensional, (2) responses to items are independent one from another, and (3) correctly guessing a response is not possible. Basic components of CAT include an IRT model, a large item pool, an established starting point at which the first item is presented to the respondent, specification of how items will be selected for presentation to the respondent, and a scoring schema. In addition, a set of “end-rules” must be created by which it can be determined that the computer has obtained sufficient information from a respondent to meet the designated performance criteria, and thus, to end the testing period (Reeve, n.d.).

The IRT model selected for a CAT can contain one or more parameters considering the item and the respondent; these models can be visualized in item characteristic curves (ICC) representing the underlying mathematical equations as described in Chapter 3. While other models exist (e.g., the graded response, partial credit models, and rating scale model), the most commonly used models are (1) the single parameter model (Rasch model), which addresses item difficulty; (2) the two-parameter model, which adds item discrimination; and (3) the three-parameter model, which adds the chance of correctly guessing a response to an item (Hays, Morales, & Reise, 2000).

A large item pool, typically numbering several hundred items, depending on the nature and purpose of the CAT, is required. This pool must be adequate to allow for calibration and selection of items according to the model selected. Items must be subjected to extensive preliminary testing in a norming procedure as well as to estimate parameters such as difficulty level and/or ability to discriminate among various levels of performance or amount of the attribute being considered.

In CAT, items are presented to the respondent one at a time, similar to the way questions would be asked in an oral examination. The starting point in CAT, or first item presented to a respondent, is typically of moderate difficulty. Upon response, each item is scored and the next item is selected for presentation adapting to the level of the individual’s previous response. Each question presented must be answered to allow the respondent to continue through the test. Generally, correct responses initiate the subsequent presentation of a more difficult item while incorrect responses initiate an item that is easier as the next item. This process continues until a preset performance criterion is reached. End-rules can include factors such as a minimum and maximum number of items to be presented to the respondent, the amount of time that has passed, and/or that a specified level of precision has been reached in estimating performance of the respondent (Reeve, n.d.).

This process means that number and sequence of items presented in a CAT is individually tailored, or adapted, to responses of the individual respondent. The sequence of items is not fixed. Individual respondents may be exposed to a different selection and number of items. Depending on respondent performance to each item, CAT has potential to be an alternative to the longer assessments of fixed tests where all respondents respond to the same number of questions regardless of their performance level. High-achieving
When the purpose is to classify the respondent, for example, as “pass (e.g., ready to practice) or fail (e.g., not ready to practice),” according to predetermined criteria, the items in the pool from which the computer selects have evidence of being good discriminators between respondents in different categories. An example of a CAT to classify respondents is the National Council Licensure Examination (NCLEX-RN), administered since 1993 to nursing school graduates to determine eligibility for licensure. Another example is found in some certification examinations by specialty groups such as the Council on Certification of Nurse Anesthetists (2009).

There are numerous differences between a fixed and an adaptive test. A comparison of selected aspects is found in Table 10.1.

**The NCLEX-RN Examination**

The NCLEX-RN examination for professional licensure is an example of a use of CAT in nursing. It draws on a large pool of items with established difficulty levels. Each administration of this examination contains 15 “pretest items” that are not scored in examination results and do not impact the outcome for the individual. Difficulty levels for “new” items are calculated from administration of these pretest items to “large” numbers of people taking the NCLEX-RN examination. However, the responses to these items are used in

<table>
<thead>
<tr>
<th>TABLE 10.1</th>
<th>Comparison of Selected Characteristics of Computer-Based Tests/Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed</strong></td>
<td><strong>Adaptive</strong></td>
</tr>
<tr>
<td>Presentation</td>
<td>Same for each respondent</td>
</tr>
<tr>
<td>Number of Items</td>
<td>Preestablished and same for each respondent</td>
</tr>
<tr>
<td>Items</td>
<td>Same for each respondent—selected by test developer</td>
</tr>
<tr>
<td>Item Selection</td>
<td>Prior to test administration</td>
</tr>
<tr>
<td>Order of Items</td>
<td>Same for each respondent</td>
</tr>
<tr>
<td>Evaluation of Respondent</td>
<td>At conclusion of test</td>
</tr>
<tr>
<td>Performance/Scoring</td>
<td></td>
</tr>
<tr>
<td>Respondent Mobility Within Test/Measure</td>
<td>Total—can respond in any order</td>
</tr>
</tbody>
</table>

**Part III Measurement via the Digital World**

respondents do not get bored by easy questions and lower-achieving students do not become frustrated by difficult questions. Scores are based on which, not how many, test questions are answered correctly (Tonidandel, Quinones, & Adams, 2002). CAT offers a very different paradigm than that of fixed testing or other types of measures built on classical measurement theory where each test is its own yardstick and reliability and validity are not generalizable across populations, applications, or testing situations. In CAT, the large item pool places item scores on a common metric (McHorney, 1997).

CAT has two major purposes: (1) to estimate ability, or (2) to classify respondents as to whether they meet prespecified criteria. Along with content from various areas of the test/instrument, these purposes are integral in the process by which the computer selects items for presentation to respondents. In the first case, to estimate ability by ranking level of proficiency, the first item presented to the respondent is of moderate item difficulty. If answered correctly, the computer next selects a more difficult item. If answered incorrectly, the computer next selects a less difficult item to present to the respondent. This process is iterative, allowing for ongoing evaluation of responses to items by the computer that determines which items are presented to the respondent until sufficient information is obtained to ascertain the ability of the respondent and the test ends.
calculating the difficulty level of the item; those items meeting preset criteria become part of the item pool for the NCLEX-RN examination (National Council of State Boards of Nursing [NCSBN], 2009).

The NCLEX-RN is dynamic in that the response to each question results in the computer reestimating that respondent’s ability. This process allows for ongoing fine-tuning of the estimate of ability with each response to items across the test. There are three criteria used by the computer to select the next item from the item pool for each respondent:

1. If the respondent has attempted the NCLEX-RN examination before, any items presented to the respondent in the year prior to test administration are excluded.
2. Items from various content areas are selected to approximate the percentages listed in the test plan.
3. The next item is one that the respondent has a 50/50 chance of answering correctly (NCSBN, 2009).

There are several components to the stop rule for the NCLEX-RN. One is test length with 75 items as the minimum and 265 as the maximum. The second component is that once the respondent has answered enough questions to determine his or her ability with 95% certainty, no additional items are presented. The third component is time—5 hours is the maximum time allowed (NCSBN, 2009).

The goal is to administer test items covering the test plan for content to the point where respondents are getting about 50% correct, which reflects ability level; passing candidates answer 50% or greater of the more difficult questions correctly while failing candidates answer about 50% of easier questions correctly. This ability level is then compared to the passing standard to determine the outcome of the test. The passing standard is periodically adjusted to reflect level of ability for competent practice by entry-level licensed registered nurses.

Respondent skills needed for CAT are different from those needed in paper-and-pencil tests, or in fixed format computerized testing. For example, in preparing nursing students for the NCLEX, faculty may wish to facilitate this transition by moving away from sequencing of a set of related items to a more independent item format. Respondents need to be aware that once they have responded to an item, they will not be able to go back and reconsider their response. Practice with computer-based testing is also facilitative and highly recommended (Frith, Sewell, & Clark, 2006). Computer skills needed by CAT respondents are typically minimal such as being able to use the tab key, the space bar, and the enter key. Responding to alternate item types such as fill-in-the-blank or hot spot items may additionally require skill such as being able to type in a short response or drag and drop.

The PROMIS Initiative

The literature of the late 1990s and early 2000s that reflects the increasing popularity and use of item-response theory (e.g., Hays et al., 2000; McHorney, 1997; Ware, Bjorner, & Kosinski, 2000) has led to serious discussions about the potential uses of IRT to measure patient outcomes using computer adaptive testing (CAT). Many challenges were anticipated in doing this (Ware, 2003), but the major reason for the appeal was the ability of CAT to offer a short, efficient test tailored to the individual ability of each respondent (Cook, O’Malley, & Roddy, 2005). The high cost of establishing a sufficiently large enough item bank and maintaining it were the most frequently cited major obstacles to such an initiative (Hays et al., 2000).

In 2004, the National Institutes of Health launched the NIH Roadmap for Medical Research with an initiative projected to improve the assessment of patient-reported clinical outcomes. Known as Patient-Reported Outcomes Measurement Information System (PROMIS) initiative, this initiative has concurrent work ongoing in developing (1) CATs for various concepts of interest across numerous chronic illnesses, and (2) an information system for gathering and analyzing data obtained that is known as the Assessment Center. The Domain Framework of PROMIS has three main sections—Physical Health, Mental Health, and Social Health. Within each domain, CATs are
Part III Measurement via the Digital World

of CATs available and the need for patient subjects to have Internet access and the capability to be able to use the Assessment Center to report their responses.

Benefits and Challenges in Using CAT

The two benefits of CAT cited most frequently are greater efficiency and greater precision in measurement with a personalized test. While CAT is most feasible with large numbers of respondents such as in a clinical trial, there is some evidence of its potential utility in individualized testing in classroom and clinical settings.

Using data from 621 medical students, Kreiter, Ferguson, and Gruppen (1999) demonstrated how item banks could be used to transition to CAT for in-course assessment. With a 200-item bank, they found that the precision of measurement was comparable to a paper-and-pencil fixed test with approximately half the number of items on the traditional test. They noted the size of their item bank should be extended and that there was a clear need for adding items with higher difficulty levels. However, since in-course content is not static with revisions and addition of new knowledge on an ongoing basis, there is real doubt that CAT will replace traditional testing in the classroom (Nunnally & Bernstein, 1994).

Benefits of CAT cited for the NCLEX test include that economy of number of items that are not appropriate for the respondent—that is, in NCLEX the number of easy items presented to respondents with high ability—is limited. Further, guessing is minimized by limiting the number of challenging items presented to respondents with low ability (NCSBN, n.d.).

A number of potential advantages of using IRT to measure self-reported health outcomes by using CAT have been suggested by Hays et al. (2000). These advantages include the ability to (1) obtain more comprehensive and accurate evaluation of item characteristics, (2) assess group differences in item and scale functioning, (3) evaluate scales containing items with different response formats, (4) improve existing measures, (5) model change, and (6) evaluate person-fit. They also note the biggest practical problem in applying IRT, and possibly CAT,
lies in the available software products that are complex and challenging to learn as well as use. Additionally, these factors contribute to the generally high costs of resources needed.

An advocate for the future use of CAT in measuring health outcomes is McHorney (1997). She points to the economic benefits of not having to administer, score, and analyze health questionnaires, the potential for presenting respondents with items at their ability level rather than boring them with or frustrating them with items below or above their level, as well as the capability for immediate feedback on scores as particular benefits.

Ware et al. (2000) generally endorses use of CAT as a way to facilitate comparison of results across individual assessments as well as across diverse populations. A further goal is to make more practical health assessment measures accessible as well as to increase the ability to identify those people whose health status indicates they might most benefit from treatment. Their results reflect the significant time savings resulting from use of CAT and support their call for more practical applications of IRT and CAT and greater simplicity of software required in their use.

Two other reports, both using computer simulation, point to the potential for use of CAT in clinical applications. Gardner, Kelleher, and Pajer (2002) found that a CAT simulation required an average of 5 or fewer questions than a fixed computerized version of a standard measure used with parents as respondents to screen for mental health problems in children. Dijkers (2003) found that CAT simulation was significantly more time-efficient than the traditional mode of assessment of patients with spinal cord injury using a widely used measure of functional status (the Functional Independence Measure [FIM]). Further, results of the CAT simulation closely approximated the results from traditional assessment. Both of these studies had very large numbers of respondents at 21,150 (Gardner et al., 2002) and 5,969 (Dijkers, 2003) and offer a demonstration of the economy of secondary analyses and the use of computer simulation in selected studies of aspects of the measurement process.

There are other factors related to IRT that are identified as potentially limiting factors in its use for CAT related to measurement of generic health outcomes. Among these are the following: (1) many generic concepts are not unidimensional; (2) the ordered continuum of IRT items is very different from the more traditional Likert-type response format; (3) time and complexity required in test development is large; (4) there is a large number of respondents required for modeling of the test; (5) there is the requirement for a large item pool; and (6) the resulting tests created would be generic as each would be individualized to the respondent as opposed to the more proprietary approach common today (McHorney, 1997).

Extensive resource commitment is needed to support the development of CAT such as is seen in the complex processes of the PROMIS initiative. Nunnally and Bernstein (1994) note that clear advantages to classical testing methods, which are robust, remain.

**SUMMARY**

Computer-based testing is a rapidly evolving area of measurement. Knowledge of major types of computer-based testing is foundational to selecting appropriate approaches to measurement as well as for understanding the rapid advances that are taking place.

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The Internet has opened up important possibilities for data collection. The use of Internet or e-mail based survey research can be less expensive and more efficient than mail surveys and has grown in popularity (Draugalis, Coons, & Plaza, 2008). When done correctly, the Internet can offer researchers international access, fast interaction with respondents, and almost complete automation of data collection and data management (Joinson, 1999). However, the ease and accuracy of data collected will be influenced by the nature of data collected (i.e., qualitative vs. quantitative), the computer proficiency of the researcher and respondent, and the sophistication of the computer hardware and software available to both the researcher and the respondent.

Successful data collection over the Internet will need to address the following issues: (1) developing an Internet data collection protocol that adequately addresses the needs of the investigator while taking advantage of the benefits the Internet offers, (2) developing a recruitment protocol that ensures a representative sample, (3) ensuring that data collected over the Internet are reliable and valid, (4) converting paper-and-pencil data collection methods for the Internet, (5) making Internet data collection useful and easy for respondents and researchers, and (6) ensuring that data collected using quantitative and qualitative approaches are of high quality (Strickland et al., 2003).

**ADVANTAGES OF INTERNET-BASED DATA COLLECTION**

There are many advantages to collecting data for research over the Internet (Schmidt, 1997; Wright, 2005; Wyatt, 2000). Among the most important benefits are:

- Access to unique, diverse, and large populations of potential respondents that are not restricted by geographic locality
- Savings in both time and money by allowing quick access to potential participants and by eliminating the need for paper resources, publishing costs, travel, survey mailings, and questionnaire retrieval collection costs
- Ability to post questionnaires and survey information in formats that were previously difficult to achieve
- Ability to capture data directly in electronic formats that make data entry and analysis faster and cheaper
- Ability to implement dynamic surveys and to allow interactive data capture with rapid checking of responses
- Ability to rapidly update questionnaire content and question ordering according to user responses
- Ability to use multimedia and forced branching in surveys, and with Java applets that allow complex experiments with complete control over the scheduling of stimuli and responses without the need to mail each participant a floppy disk

There are now newer online survey creation software and Web survey services with costs that vary from very little to several thousands of dollars depending upon the survey needs of the investigators. Dozens of online survey software packages and Web survey services are available to researchers. Wright (2005) presents 20 such services and their Web addresses, as well as a comparison of features, pricing issues, and limitations of the 20 online product and service companies at http://jcmc.indiana.edu/vol10/issue3/wright.html.
The advantages of Internet data collection far outweigh disadvantages. However, there are a number of potential pitfalls. These include incomplete responses, unacceptable responses, multiple submissions, and security and data integrity issues. Common Gateway Interface (CGI) programs with automated Web surveys can be written to ensure that either all, or at least necessary, questions are answered by the respondent. A properly written CGI program also can catch unacceptable responses. A good CGI program can identify most multiple submissions of identical (or similar) data and filter out duplicate data, and identify the location of the respondent as a way of deleting multiple submissions. However, it is not always possible to identify the malicious responder who intentionally tries to foil the researcher by submitting more than one completed survey (Schmidt, 1997).

Data security is another issue that needs special consideration. Because the HTML pages that the server distributes are publically accessible, there is nothing to prevent anybody who has access to your site from downloading and examining the source for the HTML pages. Others also may send data to your CGI program for processing. The CGI program should be written in a manner so that only data from authorized Web servers are accepted and included in the survey results. The CGI program also needs to be written to guard against use of hidden fields for passing e-mail information (Schmidt, 1997).
may occur with Internet sample recruitment. Internet samples are likely to be more biased than samples drawn from the general population. Use of e-mail lists obtained from virtual groups and organizations can also be biased. Although certain organizations may be able to provide a sampling frame with e-mail lists of their members, problems such as multiple e-mail addresses for the same person, and invalid or inactive e-mail addresses can make random sampling online problematic. Another problem is that some persons may only frequent online communities sporadically and participate intermittently, while others are “regulars.” “Lurkers” also are a potential problem who may read posts and complete an online survey, but do not send messages.

Response rates for Internet studies are a concern when conducting Internet-based research. Some studies indicate that response rates for samples recruited for Internet studies may not match those of other survey methods (Cook, Heath, & Thompson, 2000; Leece et al., 2004), with some rates better in some studies (Thompson, Surface, Martin, & Sanders, 2003) while response rates in others are the same or lower (Kaplowitz, Hadlock, & Levine, 2004). However, just as in mail surveys, the nature of contacts made prior to the survey can encourage participation and better response rates. A meta-analysis of response rates in Internet-based surveys indicated that more contacts, personalized contacts, and precontacts were most associated with higher response rates in Internet studies (Cook et al., 2000). Kroth and colleagues (2009) found that combining Internet-based and mail surveys improved response rates. Offering a financial incentive such as prizes for participation in Internet surveys may increase multiple responses as some participants try to “stack the deck” to increase their chances of winning (Konstan et al., 2005). Incentives such as a coupon that is redeemable for merchandise may be a more effective and credible alternative.

COLLECTING QUANTITATIVE DATA OVER THE INTERNET

Survey data and empirical data for most quantitative studies can be collected over the Internet (Senior & Smith, 1999), such as for psychological studies or for health assessments. Use of existing paper-and-pencil questionnaires is common over the Internet since they tend to consist of structured and close-ended questions. Questionnaires are particularly convenient for use over the Internet since they can be easily posted to newsgroups, e-mail lists, e-mailed directly to participants (Sheehan & McMillan, 1999), or placed on a Web site or gopher site for download (Lakeman, 1997; Strickland et al., 2003). It is quite common for existing measurement instruments to be adapted for use over the Internet.

It is important for such questionnaires and the data collection methods to be (1) appropriately revised to address the aims or purposes of the data collection protocol, (2) reliable and valid, (3) adaptable for Internet data collection, and (4) practical for respondents and the researcher. In addition, the Internet protocol needs to ensure the quality of data collected. It is often necessary to modify the format of existing questionnaires for use on the Internet.

Before initiating data collection over the Internet, a detailed and thorough protocol for data collection needs to be carefully delineated. The steps necessary to successfully place each survey questionnaire on the Internet and to download data must be integrated into the protocol. Specification of each variable for which data are required is necessary, and they should be individually linked to a data collection form or questionnaire that is appropriate for the target population. A sound Internet data collection protocol will consist of the following: (1) details of how potential participants will be screened to ensure that Internet data collection is appropriate, (2) specifications regarding how respondents will be oriented and gain access to the data collection Web site, (3) approaches for generation of respondent identification numbers that are linked to each data source, (4) safeguards to ensure that respondent confidentiality will be maintained over the Internet, (5) details of when and in what order respondents should complete each questionnaire, (6) notation of how and in what form Internet data will be retrieved for analysis, and (7) specification of how Internet data will be permanently removed from the Web site. The involvement of an information services specialist who is informed about the research
protocol and who has experience with setting up Web sites for data collection is crucial for the development of an Internet data collection protocol that allows data to be easily entered, easily downloaded, and kept secure and confidential (Strickland et al., 2003).

Instruments that have prior evidence of metric properties of high quality need to be selected for Internet data collection. The investigator also must consider whether the Internet is a good forum for collecting the data that is required for each measure and if this approach is likely to influence the quality of the data obtained. In most situations, questionnaires and forms that have been reliable and valid for self-report using paper-and-pencil methods will also be reliable and valid for completion over the Internet. However, this is not always the case. It is ideal to assess the reliability and validity of questionnaires that are placed on the Internet site prior to using them in a major Internet study. When questionnaires have formats amenable to internal consistency reliability assessment, the alpha reliability coefficient needs to be calculated once data have been collected. If the internal consistency is poor, this would be an indication that the data are either not reliable or lack insufficient variability. In either case, it would not be a good indication that the questionnaire is ready for use over the Internet.

The development of HTML made it possible for respondents to complete questionnaires over the Internet for interactive documents, or “forms.” With HTML, it is now possible to place questionnaires and forms on the Internet, which are visually and functionally identical to conventional questionnaires. Respondents can check questionnaire boxes, radio buttons, and text-entry boxes with ease and minimal chance of error over the Internet (Houston & Fiore, 1998). In most cases, directions for forms and questionnaires will need to be made compatible for use on the Internet. For example, changes would need to be made so respondents can easily check and change their responses if they desire. Prompts need to be included that encourage completion of all items unless intentionally left blank. Special links between forms also may be required.

Questionnaires can be placed on the Internet in a manner to reduce errors and missing data by integrating approaches for analyzing responses prior to final acceptance to eliminate errors and inconsistencies in responses (Houston & Fiore, 1998), embedding answer reliability checks in questions, and using forced-choice answers for questionnaires or rating scales (Szabo & Frenkl, 1996) along with an option that notes that an item was intentionally unanswered. When questionnaires have been carefully designed for Internet data collection, data collected have been shown to have less missing data (Stanton, 1998).

If a longitudinal study is being conducted, the Internet data collection protocol must integrate the timing of data collections. In this regard the communication of data collection points to the participants is particularly important. An approach to remind study participants when to complete follow-up data collections at the scheduled times will need to be set up. In addition to reminders for timed data collections, it may be necessary to continuously remind participants to completely finish their Internet questionnaires at a specific data point when they are completing questionnaires at their leisure. To accomplish this, e-mail reminders can be linked to the Web site. It may be necessary to get post office addresses of respondents as well as e-mail addresses since some participants may use public computers and may not have access to their own personal computer.

The most effective data collection protocols are easy and practical for respondents and for the investigator. Data collection instruments are most practical for respondents when they are accessible, appropriate for the population that will complete them, easy to understand and complete, simple, and are not burdensome (Strickland, 1997). This is also applicable when data are collected over the Internet. In the best circumstance, questionnaires and forms should not be above the fifth-grade reading level and should consider the health and capabilities of the target population. The mental or physical limitations of potential respondents that are likely to compromise Internet data collection are a consideration. Young children, ill or frail patients may find Internet data collection too challenging, although Fleitas (1998)
found that chronically ill children accommodated to Internet data collection very well. The amount of time required for completion of data collection over the Internet can also interfere with the quality of data collected, particularly when too much energy and time are required since this could increase the dropout rate (Strickland, 1999). However, the issue of fatigue can be addressed if respondents can return to the Web site and complete questionnaires at their leisure. If this is done, a mechanism to remind respondents to return to the Web site to complete questionnaires will be required to prevent an increase in missing data.

Access to a computer may be a practical barrier to participation for some potential respondents in studies that involve Internet data collection. As noted above, access to the Internet is often available through public libraries, but respondents must be willing to travel to another site to participate in the study.

The costs associated with the collection of data over the Internet will include the computer equipment, software, the technical expertise of an information services specialist, and support personnel to assist with monitoring the Web site. However, these expenses may be offset by the fact that Internet data collection offers the advantage of the ability to download questionnaires and forms directly into data management programs, which can greatly reduce cost. If the Internet survey uses a standardized instrument that is usually purchased, there will be a cost associated with getting approval to place it on the Web site as well as of scoring. Although data collection over the Internet may be more costly in regard to purchasing equipment and computer expertise and setting up the Web site, it is likely to be less costly in regard to recruiting and contacting participants, and data management, particularly when a study requires a large sample (Fawcett & Buhle, 1995; Kelly & Oldham, 1997; Wilmoth, 1995). Since the Internet has the advantages of reduced cost, global access, and real-time data collection (Kelly & Oldham, 1997), the human effort required and the financial cost of data collected will be greatly reduced in most cases. Therefore, the potential sizes of clinical and survey studies that can be practically implemented are greatly increased.

When the quality of the data collected within a study is good, this improves the quality of the overall study. Lack of adequate computer skills of study participants can threaten the quality of an Internet study. Some individuals who decide to participate in an Internet study may not have adequate computer skills to navigate the Internet to even get to the Web site. It is also possible that they may not have some of the basic skills required to respond to questionnaires and forms on the Web site. Training of respondents would increase the adeptness of the process of Internet data collection, and may need to be done in real time. It is becoming more common for clinical data to be collected over the Internet. Therefore, clinicians also need to be trained to directly enter data into the Internet database to increase data quality. Real-time data entry by clinicians can reduce transcription errors and “semantic errors as the clinicians managing the patients are directly entering data themselves” (Kelly & Oldham, 1997).

Maintaining the quality of research data can be challenging when large clinical datasets are being compiled. It will be necessary to carefully and continuously record, collate, enter data into a database, and validate it (Kelly & Oldham, 1997). Audit and progress charting can be facilitated by data collected via the Internet, which can ensure the quality and completeness of study data. Descriptive statistical reports can be efficiently and effectively generated based on Web site data on a regular basis throughout the study period to monitor study progress. These reports should include the number of respondents, percentage of respondents completing questionnaires at each data collection point, and the amount and nature of missing data. Internet questionnaire completion results in less risk of coding errors and easy downloading of data for use with other software programs for validation, reliability checks, and analysis. As noted previously, other strategies for ensuring data quality include (1) encouraging participants to complete all questions and questionnaires through the integration of Web site prompts, (2) ensuring that participants have completed questionnaires at the proper time by monitoring the Web site frequently, and (3) using data generated within the study to assess instruments with scales for internal consistency reliability. It should be noted that an important aspect of
Internet data quality is that data collected over the Internet are less likely to be affected by social desirability and inhibition than that collected via paper-and-pencil methods (Im & Chee, 2003).

COLLECTING QUALITATIVE DATA OVER THE INTERNET

Qualitative data collection over the Internet requires that the process adhere to the philosophy of the approach used. Prior to selecting the Internet as a means for data collection, the researcher should weigh the benefits of Internet data collection in relation to whether the Internet will allow the research process to remain true to the philosophy of the qualitative approach desired. In some qualitative studies it is possible that all the data required for the study could be collected over the Internet. This could be the case with many phenomenological studies, which focus on the meaning of one’s lived experience (Morse & Field, 1995) where individual interviews are usually done. Qualitative focus groups may also be appropriate. Moloney and associates (2003) used online discussion boards as virtual focus groups in a study of perimenopausal women with migraines. Other qualitative approaches may only be amenable to having part of the required data collected over the Internet. The grounded theory approach is a good example since part of the data collected could be obtained via the Internet because this approach often combines techniques such as interview, observation, and record review. On the other hand, since the ethnographic approach focuses on studying behaviors from within the culture, the Internet may not be highly amenable to use for data collection.

Although one could argue that telephone data collection has more advantages than Internet data collection of qualitative data, the Internet has the advantage over telephone interviews of costing less than making contact via telephone, particularly when subjects are from other states or geographic regions. Clearly, an advantage of Internet data collection is that respondents can be recruited nationally or internationally, if appropriate, with little additional costs. Therefore, the Internet can afford an investigator access to respondents who would not have been available for recruitment locally. However, there are some caveats that need to be considered when respondents are recruited over the Internet. Demographic and screening data must be carefully obtained to ensure that respondents are part of the desired target population. In addition, geographic location and culture needs to be considered because these could be important factors in the nature of the experience communicated by the respondent (Strickland et al., 2003).

Real-time Internet data collection is now available in today’s highly technological society. Also known as synchronous communication, real-time Internet data collection can occur with the respondent providing responses verbally and in writing. When the real-time data collection format is used, open-ended questions can be submitted to the Web site in advance or at the time that the computer interaction occurs. In either case real-time data collection requires the interviewer and respondent to schedule a time for the subject to respond in real time so that both the researcher and the respondent are available simultaneously. When the respondent types in the responses to the questions, they appear on the interviewer’s screen instantly. Therefore, the interviewer can clarify confusing written comments or probe comments that require further explication at the time the respondent supplies them over the Internet. Real-time Internet data collection can increase the quality of data and provide the interviewer with more control over the data collected. This approach is likely to keep the respondent engaged and on the topic, thus enhancing the possibility that answers will be provided to the researcher’s probes or clarifying questions.

When real-time voice capabilities are used, more sophisticated computer equipment and programs are required. Even verbal interaction can occur between the interviewer and respondent if microphones and appropriate software are available. The cost of data collection will be higher with voice exchange capabilities than without it. This is because the researcher must have a live microphone. If there is a need for verbal interchange between the researcher and respondent, then the respondent also must have a microphone. In either case the respondent will need a computer system with an active speaker so that probes and clarifying questions from the
researcher can be heard. In addition, real-time computer data collection requires a fast Internet connection and fast computer processor. Since fewer people possess this type of equipment, this limits the potential number of study participants (Lakeman, 1997).

Asynchronous communication may be the preference for some qualitative studies. In this approach, the investigator would prepare open-ended questions to which the respondents would provide answers over the Internet in written form at a later convenient time. Asynchronous communication Internet data collection requires the researcher to review the respondent’s comments after they have been entered at the Web site. The qualitative researcher will need to check the Web site frequently so that clarifying questions and probes can be provided in response to the subject’s answers to the original set of open-ended questions. Hence, probes and clarifying questions also are submitted at a later time. A major disadvantage of asynchronous communication Internet data collection is that it is easy for the respondent not to respond at all or to only provide partial answers to the information requested. Respondents may also wander off the topic rather than providing information relevant to the study. In this situation, the researcher has less control over the data collection process.

**RELIABILITY AND VALIDITY OF DATA COLLECTED OVER THE INTERNET**

When questionnaires and forms are complicated or have confusing formats, they may present special problems for the Webmaster to place on an Internet site. In addition, they are also likely to be difficult for respondents to complete accurately. If reliable and valid quantitative data are to be collected over the Internet, it is necessary for respondents to have the computer skills to navigate the Internet. In addition, they need to have the reading skills required to understand information on the Web site, particularly the questionnaires placed on the Web site.

Data fraud, data generalizability, and self-selection bias (Smith & Leigh, 1997) are other issues that may affect the validity of Internet data. If the proper safeguards are not established on the Web site, it is possible that some individuals could complete the questionnaires multiple times. To prevent this from happening, software can be set up to identify the domain address of each respondent so that multiple sets of responses from the same Web address can be identified and deleted from the database. Data fraud and duplicate data collection could also be avoided by first screening participants and then issuing a login name and password. The Web site could be cued to invalidate the password after each questionnaire is completed.

The psychometric properties of data collected regardless of whether it was collected over the Internet is always of concern to researchers. Several investigators have found that collection of data over the Internet can be highly reliable, valid, and comparable to data collected by paper-and-pencil questionnaires or face-to-face interviews. Ritter and associates (2004) found that 16 questionnaires that they administered via Internet and mailed survey showed no significant differences in results. This was even the case when sensitive data were collected, such as samples exposed to adverse life events (Hiskey & Troop, 2002).

**ETHICS**

Individuals completing surveys over the Internet should provide informed consent for participating in the Internet-based data collection. It is possible to send the informed consent form over the Internet directly to the potential respondent. A link can take the user directly to the questionnaire for completion after consent is provided. A separate submission can be provided requiring a click to signal informed consent prior to allowing access to the survey for completion. Another approach that can be used is to instruct the user not to submit his or her responses unless he or she has read the informed consent form and agrees to participate.

Respondents should be informed that their identity will remain anonymous unless they voluntarily supply identifying information. This is the case because there is no way of verifying the identity of the user submitting information to the researcher’s CGI (Schmidt, 1997).
Hence, public library computers represent a feasible way for individuals to participate in Internet research even if they lack personal computer access. Although this is feasible, it requires a greater commitment by researchers and participants.

Although data collection over the Internet has many potential advantages, its use should be weighed in relation to its disadvantages given the particular situation for which data are collected. Careful consideration should be given to the purposes of the data collection, the nature of the target population, the type of data required, the availability of computer resources, and the degree to which reliable and valid data can be collected with the intended protocol before a final decision is made regarding using the Internet as an approach to data collection.

REFERENCES


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Part IV

Instrumentation and Data Collection Methods
Observational Methods

There are many phenomena to be observed and measured when doing research in health disciplines. This chapter focuses on observational methods that are intended to monitor and record human behavior and related events and objects. The events and objects in a person's life are observed daily, and these observations are used to help form opinions, attitudes, and beliefs, and to make decisions. However, in the scientific sense, observation is not a causal matter. Observation is a process whereby data are gathered through the senses in a systematic manner. It involves identifying and recording units of behavior or characteristics occurring in a concrete situation that are consistent with empirical aims of the observer. Behaviors may be observed in naturalistic settings, or observations may be made of experimentally induced behaviors.

In nursing, observations are made of specific events or the behaviors of individuals, and may be used as an alternative to self-reports (Polit & Beck, 2008). Measurement through the use of observations is most prevalent in qualitative research, but is also used in most types of research studies (Burns & Grove, 2009). Observational methods are particularly useful when measurements are taken with noncommunicative subjects, such as with newborns or young children (Lobo, 1992), and patients who are comatose or whose cognitive functioning may be compromised (Flannery, 2003). Observational measures are also useful in the assessment of physiological phenomena (Dunbar & Farr, 1996), such as the assessment of pressure sores, or over patient behaviors, such as maternal behaviors (Stiles, 2004) or in Alzheimer's patients (Sutherland, Reakes, & Bridges, 1999). Most observations are concerned with collecting data about behavior. Behaviors observed include the interactions, communications, activities, and performance of living organisms in various situations. Although behavior is frequently the central focus of observation, environmental surroundings as well as the conditions and characteristics of the individual or event may be observed. Observational methods may be used in laboratory or in natural or field settings. Nurses make observations in clinical settings and by nurse educators and researchers on a daily basis. The nurse may want to observe clients' physical conditions via observations of breath sounds, skin turgor, visual acuity, or other observable signs. Such physiologic characteristics of clients are either directly observed through the senses or aided by equipment such as stethoscopes, x-rays, and other devices. The nurse educator uses observations to ascertain the skill attainment of students in the clinical setting, often aided by rating scales or checklists for recording observations. Observational methods can be employed by the nurse researcher to collect data for the measurement of clinical variables under study, such as behaviors of mothers and infants, communication patterns in clinical settings between practitioners, or mothers' behavioral responses to the attachment behaviors of their infants.

Observations can be conducted either directly by an observer who perceives and records the phenomenon of interest, or indirectly through observing the products of behavior and by collecting reports of behavior with interviews or questionnaires. Direct observation includes rating onsite perceptions and the use of audio and video recording devices, which serve as the basis for making observational rating records. Products of behavior include archive data and physical traces. Examples of archive data sources are records of births, deaths, and morbidity, hospital records, and other documents such as newspapers (Tuchman, 1994). Physical
traces refer to deposits or erosion of environmental materials that reflect behavior, such as the number of cigarette butts left in a patient’s ashtray as a measure of smoking behavior and the number of pieces of incoming mail as a measure of the extent to which a psychiatric patient had contact with the community. This discussion is concerned only with direct observation as an approach to data collection.

**OBSERVER ROLES**

There are two observer roles that may be assumed: nonparticipant and participant. The *nonparticipant observer* attempts to adopt a completely passive role while observing phenomena of interest. The goal of the nonparticipant observer is to become an unobtrusive bystander who does not intervene in the phenomenon that is the focus of study while observing and recording information (Polit & Beck, 2008). Hence, the nonparticipant observer simply observes the situation without intentionally influencing the activities and behaviors under study.

Nonparticipant observers may either conceal their role or make no attempt to make observations covertly. Concealment of the observer role may be done to reduce the impact of the observer’s presence on the behaviors of interest, because individuals may alter their behavior if they are aware of being monitored. When behavioral distortions occur due to the presence of an observer, this is known as reactivity or reactive measurement effects (Polit & Beck, 2008). A concern associated with concealment of the observer role is the ethics of observing and recording the behavior of individuals without their knowledge.

*Participant observers* try to become acceptable actors within the activity structure of the group under study. The observer becomes an intimate participant in the experiences of those being studied. An attempt is made to view the world of the subjects from their perspective by taking a flexible and relativistic stance. This demands that the participant observer respect and be sensitive to the subjects’ style of dress and modes of gesturing and learn their language.

To immerse themselves in the experiences of their subjects, participant observers use several approaches to reveal all of the relevant aspects of the phenomenon studied. Direct participation in the activities of the subjects is attempted, introspection regarding experiences is used, interviews are conducted, and documents are collected and analyzed when available and direct observation is employed. The participant observer’s role may be concealed or revealed to subjects; however, in most cases no attempt is made to conceal the observer’s role. Identification of the observer has the advantage of allowing for probing and the elicitation of data that would not be readily available to the concealed observer.

Subject reactivity is perhaps the greatest overall limitation when either the nonparticipant or participant observer approach is used. Responses of subjects have been shown to differ markedly, even in naturalistic situations, when persons are aware that assessments are being made of their behaviors (Atkinson & Hammersley, 1994). The presence of observers may not necessarily influence the behavior of subjects directly but may provide cues to others in the setting who can influence the subjects’ behaviors. For example, parents can influence observational data that are obtained on their children.

Some investigators use recording devices, such as tape recorders, audiotapes, and still and motion photography to aid observations. Subjects also are reactive to these devices and have been found to respond differently, depending upon whether they knew that recordings were being made (Lisovski, 1989).

To reduce subject reactivity, observations should be made as unobtrusively as possible. Several techniques may be employed to reduce reactivity. Whenever possible, continuous direct observation should not be employed. Observations of many phenomena can be made intermittently without negatively affecting the integrity of the data obtained. Observers can be instructed to restrict their observations to a prescribed number of seconds—for example, 10 s—and then to look away from the subject. Also, the interval between observations would be specified. Looking at and then looking away from the subject reduces reactivity, since the persons observed do not feel that all of their activities are being constantly monitored. This approach will not be useful in situations in which continuous
observations are required, such as in the study of some behavioral interactions.

Subjects usually will habituate to an observer’s presence after about 10 min. Therefore, observers should be in the setting for at least 10 min before actual data collection begins. During the preliminary period, observer behaviors should be consistent with those that will be displayed during the observational period. A change in the observer’s behavior at any point during the observational period increases the subject’s reactivity. Hence, the observer should remain constant in appearance, activity, and smell. Physical movement should be minimized as much as possible, no perfume should be worn, and jewelry should be appropriate for the situation. As much as possible, the observer’s clothing and style of dress should be consistent with those worn by subjects in the observational situation. For example, a researcher observing the behaviors of low-income mothers should not wear expensive clothing and jewelry within the observational setting. Whenever the observer is required to leave and re-enter an observational setting (e.g., when observations are made over several days or weeks), no major changes in clothing or hairstyle should be made. In most observational situations, clothing should be plain and, whenever possible, the same or a similar style of clothes should be worn during each observational period.

**Observing and Recording**

The selection of phenomena to be observed depends upon the clinical, educational, or research problem that is the focus of investigation. Even after the problem has been specified, there often is a need to further delineate and select the phenomena to be observed. For example, the Clinical Performance Examination for Critical Care Nurses (Mims, 2001) is an observational rating scale developed to measure clinical performance of nurses employed in critical care settings. The tool is composed of five categories of behaviors important in clinical performance of critical care nurses: assessment, clinical/technical skill, communication, documentation, and general employment policies. These categories must be rated by an observer in order to obtain a measure of clinical performance of a nurse in a critical care setting.

When selecting phenomena to be observed, decisions must be made concerning what constitutes a unit. Units of observation range from small and specific behaviors (molecular approach) to large units of behavior (molar approach). The molecular approach might, for example, require recordings of each movement, gesture, phrase, or action and each of these may be broken down into smaller units. In the molar approach a large unit of behavior, such as seeking help, may consist of a variety of verbal and nonverbal actions that together are construed as signaling the behavior of interest. The molecular approach has the potential disadvantage of causing the investigator to lose sight of a related composite of behaviors that are central to the study at hand. The molar approach has the potential problem of allowing for distortions and errors by the observer because of the likelihood of ambiguity in the definition of units (Polit & Beck, 2008). The approach to selecting units of observation largely depends on the investigator and the purpose for which observations are to be made.

**SELECTING SAMPLES**

When observational methods are employed, the approach to sampling and data collection will depend upon the problem that is studied, how variables are defined and operationalized, and the setting in which observations are to be made. Decisions about sampling and data collection will directly influence the reliability and validity of results as well as their general application.

**Sampling** requires the observer to follow specific rules that dictate the nature of the situation to be observed such that the observer is able to record or elicit a set of behaviors that are presumed to have some degree of relevance for addressing a specific concept, hypothesis, proposition, or theory. These rules delineate a procedure that must be followed so that the general application and theoretical relevance of the behaviors to be observed or elicited are increased. The observer may take note of one situation or a series of situations. The investigator
draws the sample from a large population of behaviors, social situations, or events, or a small number for intensive observation. Before beginning to sample, the investigator must be able to enumerate the specific units that make up the larger population. This implies that the investigator has a clear definition of the population to which findings are to be generalized. If, for example, one is studying the role and functions of nurses who work in acute care settings, a workable operational definition of acute care settings must be formulated. Depending upon the theoretical intentions of the investigation, an acute care work setting may be operationalized to include all types of units traditionally found in general hospitals, or it may be limited to medical and surgical units. An operational definition of nurse also is required.

After the operational definition of the population under study has been specified, the investigator develops a complete list of all the elements that make up the population. In the example cited previously, this listing would be all of the acute care work settings in the geographical area that is to be sampled. Once the population has been defined and specified, then the investigator randomly selects units from that population to be included in the sample for observation. Random sampling gives each unit in the population the same chance of inclusion in the final set of observations. Several approaches to random sampling might be employed. Other approaches to sampling may be used, such as cluster sampling and stratified random sampling. It should be noted that the sampling process employed in observational approaches most often is multistage. The sampling procedure frequently is constrained by time and place, that is, by a specific time and by a specific geographical locality.

**TIME SAMPLING**

For some investigations, there may be a need to observe a behavior or activity that occurs continuously over several days, weeks, or months. When this is the case, it is not likely that an observer will be able to monitor the phenomenon of interest continuously. Time sampling can be used to select from the population of times those segments during which observations will be made. The time segments are selected randomly and may be parts of an hour, a day, or a shift, for example. Time segments selected will largely be determined by the focus of the investigation. If mother-infant interactions during feedings are to be studied, it is possible that the times chosen for observation might be for 1 min every 5 min. If a play therapy hour for a young child is to be observed, the time segments selected might be the first 10 min, the middle 10 min, and the last 10 min of the hour session. Anderson and colleagues (2004) used 15-min time sampling to study mother-infant separation after birth using an observational approach.

The observer should consider rhythmicity of phenomena whenever time sampling is used. Certain activities or phenomena may occur on a specific time schedule, or phenomena may be quite different depending upon the time at which observations are made, such as with the administration of medications or treatments. Time of day of the observation may also be important. For example, a nurse researcher studying confusion in the elderly must consider the possibility that late afternoon and evening observations are more likely to reflect higher levels of confusion than observations taken during the morning hours after a restful night of sleep. Depending upon the purpose of the observations, the rhythmicity of phenomena may have a significant impact on the data. For example, data collected about the frequency of nurse-patient interaction on an acute care unit could be quite different from the usual if observations were made only during weekends, when the nurse-to-patient ratio might be lower than usual, or confined to times when medications or treatments were administered and nurse-patient interaction might be higher than usual. With such observations, random time sampling becomes particularly important.

**EVENT SAMPLING**

An alternative approach to time sampling, event sampling may be employed in situations in which events of interest occur relatively infrequently and are at risk of being missed if a strict time
sampling procedure is used. In event sampling, integral events or behaviors are specified for observation. The observer must be in a position to take advantage of specific events; therefore, an awareness of the occurrence of the relevant events or behaviors is needed. For example, if an observer is recording the roles and functions of nurses in acute care settings, several events may be selected for observation, for example, change of shift, nursing rounds, care of a dying patient, or nurse-physician interactions. Observation of such events would be likely to provide the observer with data that would not be obtained if a time-sampling procedure were used. Time sampling and event sampling are the most commonly used approaches for selecting observations.

**OBSERVATIONAL APPROACHES**

There are two basic approaches to the collection of data through observation: structured and unstructured. The structured approach is more amenable to use by the nonparticipant observer, while the participant observer uses the unstructured approach more frequently. Structured _observational_ approaches specify behaviors or events for observation in a rather detailed manner, and a protocol for observing and record keeping is delineated in advance. Since structured observations are highly dependent upon the protocol and observational aids developed prior to observations, the kinds of phenomena observed are likely to be restrained. Checklists and rating scales are the most frequently used observational aids employed. Checklists facilitate the classification or categorization of behaviors or characteristics observed. Each categorical system is designed to guide the observer in assigning qualitative phenomena into either a quantitative or qualitative system. Well-developed categorical systems facilitate accurate notation of phenomena within a common frame of reference. In most instances, checklists are devised to prompt the observer to record the absence or presence of a behavior or event; however, the frequency of occurrence may be recorded. The categorical systems of checklists used in observation should be nonoverlapping, mutually exclusive, and exhaustive.

Rating scales require that the observer classify behaviors or events in terms of points along a descriptive continuum. Observers may use rating scales during direct observations, or the observer may use rating scales to summarize an interaction or event after observation is completed. Rating scales are employed to record quantitative aspects of the phenomenon of interest, such as its intensity or magnitude, and thereby extend category systems beyond those generally found in checklists. For example, Pressler and colleagues (1998) used a rating scale format in their adapted scoring of the Neonatal Behavioral Assessment Scale (Brazelton & Nugent, 1995) during their assessment of reflex responses in newborns. Although rating scales are designed to generate more information about the behavior or event observed, immense demands are placed on the observer when the activity level of objects observed is high. In such instances, the use of recording devices can facilitate observation. Recording devices such as video recorders have the advantages of allowing the observer the opportunity to record behaviors frame by frame and review recordings later, particularly for interrater and intrarater reliability assessment of observer ratings.

Unstructured _observational_ approaches involve the collection of large amounts of qualitative information that describes the object, event, or group being observed. There is no specific protocol for observations, nor are specific approaches to observing phenomena delineated. Hence, there are few restrictions on the types of methods used and on the types of data obtained. Interviews, life histories, visits, attendance at social events, and record review may be employed, as well as other appropriate strategies for data collection.

Logs and field notes are the most common methods of record keeping in ethnography, employed with unstructured observations. However, observational aids such as tape recordings, video recordings, maps, and photographs also may be used. Use of technology helps to capture and fix “reality” (Angrosino, 2007) so that records can be more accurate. A log is a record of observations of events, objects, or conversations, which is usually kept on a regular basis during the time that the observer is in the observational setting. Field notes are more inclusive than logs.
and tend to extend observations by analysis and interpretation of relevant occurrences. Use of field notes is a method that combines data collection and data analysis.

Unstructured observation is very useful in exploratory investigations in which the identification and conceptualization of important variables are desired. This approach is flexible and allows the observer to obtain a more complete understanding of the complexities of the situation at hand. Proponents of unstructured observation point out that this approach allows for a better conceptualization of a problem. However, this approach to observation is more highly dependent upon the interpersonal and observational skills of the observer than structured observations. Two major concerns associated with employment of unstructured observation are observer bias and observer influence on the phenomenon that is observed.

**RELIABILITY AND VALIDITY OF OBSERVATIONS**

When structured observational approaches are used, the reliability and validity of observations depend upon the reliability and validity inherent in the observational aids and in the ability of the observer to identify and record the specified behaviors or events. Thus, the use of well-constructed, well-developed observational instruments and well-trained observers takes on special significance. Care should be taken to select reliable and valid observational aids, and observers should be trained prior to the initiation of data collection.

Observer training sessions should be held to familiarize observers with instruments, the nature of behaviors or events observed, the sampling procedure, and the purpose of the project. Trial experience in the use of instruments should be provided until observers have sufficiently mastered the art of observing and recording the phenomenon of interest. If more than one observer is employed, training should continue until there is sufficient interrater reliability. During research studies in which observational data are collected over several months or years, frequent assessment of interrater and intrarater reliability should be done due to the possibility of observer drift over time. It is not unusual for observers to make subtle unconscious changes in how they rate categories of behavior. When this occurs, the reliability of observation data decreases over time. Retraining of observers may be required.

Reliability and validity of unstructured approaches can be facilitated and assessed through the process of triangulation. Triangulation involves combining the use of two or more theories, methods, data sources, investigators, or analysis methods in the study of the same phenomenon (Morse, 1991; Sandelowski, 1996). Data triangulation in particular can be particularly used in this regard. This approach involves the collection of data from multiple sources for the same study or purpose. Such data would need to have the same foci since the various sources of data are intended to obtain diverse views of the phenomenon under study for the purposes of validation. The reliability and validity of findings are evaluated by ascertaining the frequency of an observation by examining data obtained from multiple methods and multiple data sources. The more frequently an observed behavior occurs across time and space, the more likely it will be valid. The lack of multiple instances of observation detracts from the validity of an indicator. Frequency of occurrence of a phenomenon should be observed across subjects or over and over again within the same individual. Comparing records from different data sources, for example, interviews, diaries, or other documents, can assess validity of indicators. For example, Larson and colleagues (2004) assessed the similarity of findings when assessing nurses’ hand hygiene practices by direct observation in comparison to by self-report and found significant differences in results. An indicator that results from an unstructured observation can also be assessed by the observability of behaviors or activities on which it is based. Less credence can be placed on those indicators that result from the observer’s imputation of motives, attitudes, or intentions to others.

Lincoln and Guba (1985) suggest the use of member checking to improve the trustworthiness of data and interpretations during naturalistic observation. Member checking involves testing
analytic hypotheses, interpretations of data, and conclusions with the subjects from which data were generated. This approach allows subjects to assist the observer in making sense of the data and subjects are given an opportunity to respond to and assist in the interpretation of the data by getting their feedback regarding the observations made (Connors, 1988; Emerson, 1987).

ADVANTAGES AND DISADVANTAGES OF OBSERVATIONAL METHODS

Several advantages and disadvantages of observation have been addressed during the discussion. This section will serve to highlight some of the major benefits and problems associated with observational approaches. Observation provides a variety and depth and breadth of information to research that is difficult to obtain with other data-collection methods (Morse & Field, 1995). The approach can be quite flexible and allow an observer to get inside a situation in a manner that can reveal information not readily obtained by other methods. Hence, observational approaches can effectively facilitate and enhance conceptualization and understanding of phenomena. This approach is of particular benefit, because there are many problems that cannot be studied sufficiently by other means. While observational techniques enhance information obtained considerably, observations are often time-consuming and costly. Therefore, an investigator needs to carefully weigh the advantages and disadvantages of observation and justify that its advantages outweigh its costs (Morse & Field, 1995).

The major disadvantage of observational approaches is that data obtained through observation are readily amenable to bias and distortion. Perceptual errors by observers and insufficient skill in observing threaten the quality of data. This is less of a problem when the structured approach to observation is used rather than the unstructured. When the observer’s presence is known, reactivity to the observer by subjects may distort behavior. However, concealment of the observer’s presence or identity presents ethical concerns regarding the subject’s consent to be observed. Concealment of observer identity also can limit the depth and amount of data obtained. The structured approach provides for better control of reliability and validity of measurements than the unstructured approach; however, it limits the kinds of phenomena that will be monitored and recorded. The unstructured approach provides for a large variety of data sources and data collection methods, but reliability and validity of measures are difficult to assess and control.

The problems and difficulties associated with observational methods need not be prohibitive. A clear conceptualization of the problem to be studied, operationalization of key variables, and a logical protocol for observing, recording, and interpreting data can help alleviate or decrease a number of concerns.

ETHICAL ISSUES

Some of the features of observational research make it prone to ethical malpractice. Observations can be done in a rather inconspicuous manner, and observers can easily gather data without the knowledge of the public or their consent, such as the observation of child behavior in public parks during disguised or covert research. This also applies to the misrepresentation by a researcher of his or her identity during the data collection process. Questions have also been raised about areas of life where it may not be ethical to make observations at all. Some scientists question whether observations should be made of suicides, sexual encounters, and other socially sensitive behaviors in private places (Adler & Adler, 1994).

The use of technology for the recording of observational data also raises ethical concerns. Whenever observational data are collected with the use of cameras and other video and audio equipment, the researcher should obtain written consent for such recordings before the observations are done and provide assurance that recordings will be used in the manner that was specified in the consent documents. A statement regarding the disposition of recordings during and after the study is completed should also be included in the consent form. In general, such
recordings should be kept under double locks for storage and destroyed as soon as possible after data have been coded and placed in data files. If audio or video recordings will be used in a manner for which original consent was not provided, then additional consent needs to be obtained to use them for a different purpose.

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Recorded words and sentences provide rich data about the personalities, thoughts, and attitudes of their writers (or speakers), as well as extensive information about their interpersonal, social, political, and cultural contexts. Content analysis is a data analysis strategy that is used in many disciplines, most commonly linguistics, political science, business and the study of complex organizations, psychology, history, communications, and education. It has been used in nursing and health research because it provides an approach to accessing the information in a variety of different data sources in a way that is more systematic and objective than intuitive reading or listening, and because of its utility as a data analysis strategy in qualitative research.

Content analysis refers to the set of techniques that are used to identify, measure, describe, and make inferences about specified characteristics within or reflected by written or verbal text. It also is used to discern patterns, categories, and/or themes in recorded language. It is used as a technique in both qualitative and quantitative research, and distinctions are often made between quantitative and qualitative content analysis approaches. In qualitative research, content analysis is used as an early step in identifying themes that are present in open narrative or textual data. The objective is to discern the meaning in the narrative, so the products of a qualitative content analysis tend to be expressed as ideas rather than numbers. Qualitative content analysis tends to be inductive, in that categories for describing the data evolve during the analysis. Inductive approaches to content analysis focus on developing the categories and interpretation as closely as possible to the recorded (printed or verbal) material. As the material is reviewed and analyzed, tentative categories are generated; then with the analysis of more material, categories are revised and a final set is determined (Mayring, 2000). (See Chapter 8 for more detail.)

As used in quantitative research, content analysis involves the systematic and objective reduction or simplification of recorded language to a set of categories that represent the presence, frequency, or intensity of selected characteristics. The products of a quantitative content analysis are generally expressed numerically. Quantitative content analysis tends to be deductive, in that theory-based categorical schemes and coding rules are developed before conducting the analysis of data from subjects or documents. Quantitative content analysis tends to be more highly structured. Three key interrelated processes are involved: conceptualizing and identifying characteristics of the content that are to be measured; determining the measures and explicit rules for identifying, coding, and recording the characteristics; and sampling, coding, and tabulating (or otherwise describing) the units (Neuendorf, 2002). Both inductive and deductive approaches to content analysis can be used in qualitative and quantitative studies.

Content analysis has several distinctive features that make it a useful measurement technique for nursing research, education, and practice. First, it is applied to recorded information, that is, information written as text or recorded in a way that allows exact replay of the original communication. Either preexisting materials that have been written or recorded for another purpose or materials produced for a particular investigation can be used. Examples of materials that can be content analyzed include books, plays, newspaper articles, editorials, films, Web pages, letters, notes, diaries or other personal documents, speeches, documents such as laws or minutes of
meetings, written or tape-recorded responses of subjects to questions, and audiotaped or videotaped recordings of communication. Materials originally produced for a variety of different purposes can be content analyzed to answer questions relevant to nursing and health care, and to add richness of meaning to nursing knowledge development.

Second, emphasis is on the content of the written or verbal communication rather than its process or paralingual features (e.g., pitch, volume, rate, accompanying gestures). This is not to negate the importance of paralingual elements but to suggest that the procedures of content analysis are best suited to a content focus. Paralingual cues can be adequately analyzed only if they are consistently noted in textual form. Such notations are sometimes present in carefully recorded field notes of qualitative researchers and in some legal proceedings, but are rarely found in print documents recorded for other purposes. They are more readily apparent in audio and video recordings. Process analysis represents a different focus, which is best handled using other tools and techniques designed specifically for that purpose, for example, the classic Bales’s (1950) Interaction Process Analysis. However, inferences about historical trends and cultural differences can be made by comparing content expressed at different times or by different communicators. The analysis of materials can be directed toward either the manifest (overtly expressed) content of the communication or its latent (unintentionally or unconsciously expressed) content. The analysis of latent content is difficult and somewhat risky, because it requires making inferences about what was intended or meant from that which was actually stated and is analogous to “reading between the lines.”

Third, the procedure of content analysis, specifically quantitative content analysis, is designed to maximize objectivity by incorporating explicit rules and systematic procedures. It is systematic and standardized, in that specified criteria are consistently applied in selecting and processing the content to be analyzed. It is not arbitrary.

Fourth, content analysis involves deliberate simplification or reduction that results in the loss of some of the individuality and richness of meaning in the original material in the interest of discerning regularities, patterns, and themes. The degree of simplification and the nature of the regularities discerned are determined by the purpose for the analysis and are not inherent in the procedure itself. Finally, content analysis is unobtrusive and can provide insight into complex interactions.

The earliest applications of content analysis were in the fields of journalism and political science in studies of the mass media and propaganda, and in anthropological field studies to categorize observational and interview data. More recent applications have ranged widely from studies of personality and psychological states and dreams of individuals to communication patterns within small groups and organizations, comparative cross-cultural studies, and studies of historical trends and social change. Because content analysis can be successfully applied to many types of recorded information, its potential uses in nursing are many. The most frequently cited examples are research-oriented and include studies of trends in the profession (e.g., McEwen, 2004); characteristics, opinions, experiences, and expressed values of individuals and groups (e.g., Bucknall, 2003; Nelson, 2009; Royer, Phelan, & Heidrich, 2009; Strong et al., 2009; Wexler, Elton, Peister, & Feldman, 2009); the impact of policy on health care and current issues and trends (e.g., Kirchoff, Beckstrand, & Anumandla, 2003); analyses of processes and outcomes of care; and evaluation of the effectiveness of interventions or programs (e.g., Roe et al., 2009; Steiner et al., 2009). Content analysis of qualitative data from interviews or focus group sessions can also be used during the preliminary stages of developing a quantitative measurement instrument, and as a means for validating other measures of the same concept or characteristic.

**PROCEDURE**

Content analysis involves a multistep procedure that is guided in all of its aspects by the purpose of the investigation, the questions to be answered, and the hypotheses to be tested. For the current
discussion, it is assumed that the purposes of the investigation have been identified, the data source(s) of relevant recorded information have been located, and the investigator is ready to proceed with the content analysis. The procedure described below focuses primarily on techniques used in quantitative research. More detailed descriptions of the techniques and strategies used in content analysis can be found in Krippendorff (2004), Krippendorff and Bock (2009), Franzosi (2008), and Weber (1990). Content analysis in qualitative research is discussed in Chapter 8.

Step 1: Define the Universe of Content to Be Examined

The universe of content refers to the totality of recorded information about which characteristics will be described or inferences drawn. Examples would include all presidential addresses at American Nurses Association conventions, all nursing ethics texts published in the past decade, all tape-recorded responses to a telephone interview, or all free-text nurses’ notes generated by a medical intensive care unit staff during a given month. The universe of content is chosen based on the nature of the information included, its relevance to the purposes of the investigation, its completeness and ease of access, and the conditions under which the materials were produced. In many instances, permission must be secured in advance to use the materials for the proposed investigation.

Step 2: Identify the Characteristics or Concepts to Be Measured

These selections are conceptual decisions, so they vary widely from one investigation to another and from one field of study to another. This step in the analysis consists essentially of answering the question “What do I want to learn about the content of the recorded information?” It is the initial phase of partitioning or subdividing the content into units and categories. There is no limit to the number of characteristics that can be examined; however, the selection should be dictated by the purpose for the investigation, and guided by the theoretical basis for the investigation and relevant literature.

Step 3: Select the Unit of Analysis to Be Employed

Once the universe of content available and the variables to be measured have been identified, a decision must be made about which elements or subunits of the content will be analyzed or categorized. The selection is based on the type of unit that can be used most reliably as evidence for the presence, frequency, or intensity of the characteristics to be studied. Possible units of analysis range in scope and complexity from letters or syllables—used primarily in linguistic research—to entire speeches or texts. The units most potentially useful in nursing are words, items, phrases, and themes. Words are commonly chosen units for analysis, because they are easy to work with and are amenable to computer analysis, which is growing in popularity as an analytic technique (see Gottschalk & Bechtel, 2008; West, 2001). Words often have multiple meanings and uses, however. A frequently used procedure is to identify words or word combinations that are synonyms for or indicators of a more abstract concept or characteristic. Themes can be phrases, sentences, or propositions about something. Because they are more complex than words, they are more difficult to use reliably; however, they tend to impart more meaning than words taken alone. The term “item” refers to an entire production (e.g., story, book, nurse’s note in a patient chart, interview, patient discharge summary, or response to an open-ended question) that is analyzed as a whole in terms of one or more given characteristics.

Depending on the number and complexity of the characteristics being measured, more than one unit of analysis can be used to measure a given characteristic. In some instances, a given unit may be appropriate for measuring one characteristic of the content but not for another, and several units may be used within the investigation, each for a separate subanalysis.

Careful delineation of the unit to be analyzed or categorized is essential if unitizing reliability is to be achieved. Unitizing reliability refers to
“consistency in the identification of what is to be
categorized across time and/or judges” (Garvin,
Kennedy, & Cissna, 1988, p. 52). It is assessed
by determining consistency with which several
judges identify the same units within the text as
the appropriate ones for coding (Burns & Grove,
2009). Acceptable unitizing reliability requires
a clear and clearly communicated specification
of what is to be coded. The level of unitizing
reliability in a content analysis is influenced
by the degree of observer inference needed to
identify the unit to be coded, the degree of speci-
cficity in delineating units, the exhaustiveness
of the coding system, and the type of data. In
general, the less inference required, the greater the
specificity, the more exhaustive the coding sys-
tem, and the greater the ability of the data to be
examined repeatedly (e.g., taped vs. untaped live
interviews), the easier it is to establish unitizing
reliability.

Step 4: Develop a Sampling Plan
Once the unit of analysis has been identified, it
is necessary to determine how the universe of
content will be sampled. In some instances, the
entire universe will be examined. This is gener-
ally true when content analysis is being applied
inductively to interview data. In other applica-
tions, only selected portions will be analyzed. As
noted above, unitizing reliability may be easier
to achieve if the entire population of units is
categorized.

A specific plan must be designed with explicit
instructions provided as the basis for selecting
the content to be analyzed. If sampling is neces-
sary, then random sampling of elements of the
universe of content is preferable to nonrandom
procedures. A frequent procedure is to use sys-
tematic random sampling. After a randomly
determined starting point, every nth unit (word,
phrase, paragraph, etc.) is sampled.

Multistage sampling may be employed. For
example, a random sample of textbooks about
rehabilitation might be selected from those avail-
able; then a random sample of three chapters
selected from each book; then content of every
third paragraph within those chapters analyzed
using the themes within each sampled para-
graph as the unit of analysis. In the interview
example, the nurse might select a 5-min segment
from each recorded interview. A decision would
have to be made whether to begin the segment
at the same point in all interviews (e.g., the first
5 min), or randomly select the starting point for
the segment (e.g., determine the starting point
by a random process such as using a table of ran-
dom numbers to select a tape-counter reading at
which to initiate the analysis).

Step 5: Develop a Scheme for
Categorizing the Content and
Explicit Coding and Scoring
Instructions
In deductive content analysis this step is largely
carried out before the data collection begins. Cat-
egories are derived from the theory guiding the
investigation before the data are analyzed. The
coding scheme includes explicit definitions, cod-
ing rules, and examples for each coding category.
The scheme may be predetermined, but often
must be modified partway through the data anal-
ysis to accommodate unanticipated nuances in
the data. In the case of computer-assisted content
analysis, a set of dictionaries must be estab-
lished, together with the rules for applying them.
Either predeveloped dictionaries can be used, or
a unique set can be created for the purpose at
hand. In either case, it is necessary to assure that
the categories are clearly defined, so that the same
unit of data will be assigned to the same category
consistently by more than one judge. This type of
coding reliability is termed interpretive reliability
(see Burns & Grove, 2009).

In inductive content analysis, codes and cat-
egories (and ultimately the more encompassing
themes) are generated from the data themselves.
The process is one of shuffling and sorting data.
Categories “emerge from the data,” hence are not
preset. The original categories and themes may
be subsumed as more data are gathered and com-
pared with the existing scheme. Mayring (2000)
recommends revising categories after 10%–50% of
the data are analyzed. Procedures and strat-
egies used for qualitative content analysis in
nursing have been described in detail by Morse
and Field (1995) and Graneheim and Lund-
discuss and compare qualitative content analysis with grounded theory and narrative analysis as three strategies for the interpretation of qualitative data. Inductive and deductive strategies may be combined in a given study. In either case, the categorical scheme links the theoretical or conceptual background of the investigation with the data and provides the basis for making inferences and drawing conclusions.

Having identified the characteristics to be measured (Step 2), the categorical scheme provides the basis for measuring the existence, frequency, intensity, or nature of each characteristic. The categories are constructed so that each unit of the content can be assigned unequivocally to one category; that is, the categories for a given characteristic must be exhaustive and mutually exclusive, and criteria for assigning the content to a category must be clear and explicit. It is generally recommended that the categories in content analysis be as close as possible semantically to the wording in the original text so the meaning is distorted as little as possible.

Several strategies are suggested to aid in constructing a categorical scheme for content analysis:

1. Carefully read or listen to the available material to develop a sense of the language being used and the divisions into which the data might fall, bearing in mind the conceptual orientation underlying the investigation. A myriad of computer programs exist to assist with this process (see American Evaluation Association, 2009). Examples of programs that assist with qualitative content analysis include ATLAS.ti (http://www.atlasti.com), winMAX (http://www.maxqda.com/index.php), WordStat (http://provalisresearch.com/wordstat/Wordstat.html), The Ethnograph (http://qualisresearch.com), and NUD*IST (handling Nonverbal Unstructured Data by Indexing, Searching and Theorizing: http://www.qsrinternational.com).

2. Examine existing categorical schemes developed by other content analysts. A number of content dictionaries potentially applicable to nursing have already been developed, and some are available as computer programs. These dictionaries group words with similar meanings under a given conceptual heading. The work of Gottschalk (1995) has produced several reliable and valid categorical schemes for measuring psychological traits through the content analysis of verbal behavior.

3. After developing a set of categories, ask experts in the field of the investigation to evaluate the relevance, clarity, and completeness of the scheme.

4. When developing categories from the data themselves in an inductive approach, avoid premature closure by sharing the categories and their basis with a trial audience. Avoid overly delayed closure by keeping the study’s purpose and research questions clearly in mind and collaborating with a group of colleagues.

**Step 6: Pretest the Categories and Coding Instructions**

If the categorical scheme is predetermined, it is pretested by applying it to small portions of the content to be analyzed. Preferably at least two coders should be asked to analyze the same material so that interrater reliability can be assessed and discrepancies clarified. As a result of the pretesting, categories or instructions may have to be redefined, added, or deleted and the entire scheme pretested again before use.

The advantage of a clearly thought-out and well-delineated coding scheme is that it enhances the likelihood that interpretive reliability will be achieved. Interpretive reliability refers to the consistency with which units are categorized and meaning assigned to them (Burns & Grove, 2009; Garvin et al., 1988), and encompasses both intra- and interrater reliability. The term “interpretive reliability” encompasses both global (“the extent to which coders can consistently use the whole coding system across all categories” [Garvin et al., 1988, p. 54]) and category-specific (the extent to which coders use a given category with consistency) elements. Both global and category-specific reliabilities are improved by clear coding rules, rigid and exhaustive definitions, structuring the coding task as a series of dichotomous decisions, and coder training.
Step 7: Train Coders and Establish an Acceptable Level of Reliability

Careful coder selection and training is an essential step if persons other than the investigator are to perform the analysis. Neuendorf (2002) recommends that during an initial training session coders’ ability to agree on coding of variables be assessed, then they should be asked to code independently in order to assess interrater reliability. They should be asked to discuss any coding decision with which they encountered difficulty or ambiguity. Subjective perception, which is influenced by culture and experience, plays a role in much content analysis; therefore, it is crucial that explicit instructions be provided and several trial runs be carried out before the actual analysis begins. Interpretive (both inter-and intrarater) reliability must be assessed throughout the training period and acceptable levels established before training ends. In some instances, it may be necessary to limit the number of categories and/or coders to maintain acceptable interpretive reliability.

Step 8: Perform the Analysis

The data are coded according to prescribed procedures or subjected to computer-assisted analysis. Each element of the content universe being analyzed (i.e., each document, book, verbal response) is coded using the same procedure. If many content characteristics are being examined, the same content may be processed several times to extract all of the information needed. Because fatigue, boredom, and concurrent experience may influence coding, periodic checks of interrater and intrarater reliability must be performed throughout the coding. It is suggested that at least 10% of the material be coded by more than one individual to allow assessment of interrater reliability. Refresher training may be needed. Because intrarater reliability tends to decline over time, the investigator working alone should periodically reassess it.

In more quantitative applications of content analysis, tabulation of data often involves, as a first step, a frequency count of the recorded or observed occurrences of each category or quality. The nature of subsequent analyses is determined by the purpose of the investigation. Such frequency counts may also be used in analyses that are primarily qualitative. Computers are increasingly being used in both qualitative and quantitative content analysis. Computer software is extensive and is useful for coding and analyzing data, automatic indexing, text-oriented data retrieval and database management, concordance generation, and idea processing. Automatic data analyses can also be executed using software programs that count frequencies of word use, observations, or content categories. Although several published content-category dictionaries exist, it is generally recommended that the researcher create a context-specific dictionary for the particular study. Published dictionaries, however, are efficient and provide standardized classification instruments that can facilitate comparison across studies.

RELIABILITY AND VALIDITY

In content analysis, both unitizing reliability (consistency in identifying the unit[s] to be categorized) and interpretive reliability (consistency in assigning units to categories) are important. The former is a precondition for the latter (Garvin et al., 1988). Both unitizing and interpretive reliability come into play in determining the level of more traditional types of reliability in content analytic schemes and procedures. Stability reliability (assessed by intrarater and test/retest techniques) and reproducibility reliability (assessed by interrater techniques) are both relevant for the content analysis, and require clear delineation of the units to be categorized and the rules for assigning them to categories. Split-half reliability assessment techniques are not appropriate for content analysis (Krippendorff, 2004).

As applied to content analyses, validity refers to the correspondence of variation inside the process of analysis to variations outside that process, correspondence of findings and conclusions to the data, and generalizability of results. Validity is heavily context-dependent. Types of validity include (1) data-related validity—how well the data analysis method represents the information inherent in the available data; (2) semantic validity—how sensitive the method is to relevant symbolic
2. Many materials have been prescreened or edited by others, so are subject to incompleteness or bias.
3. Data in the original sources may not have been compiled systematically. When doubt exists about the accuracy or completeness of a data source, it is recommended that either multiple sources be content analyzed or content analysis be combined with other techniques.
4. Judgment is required to reduce the data and interpret the meaning of another's communication. There is a risk of losing or modifying the meaning of the communication, due to incomplete information and/or subjectivity on the part of the coder or analyst. Accuracy of interpretation can be hampered when subcultural or major temporal differences exist, because meaning tends to be situational.
5. Legal or ethical problems may be encountered regarding the use of information gathered for another purpose. This is particularly true when personal information is involved and is protected by law; for example, health records are protected under the Federal Health and Information Privacy and Protection Act (HIPPA).

**ADVANTAGES AND DISADVANTAGES**

Major advantages of content analysis as a data collection and analysis technique include the following:

1. The technique allows use of existing information that is available and easily accessible at relatively low cost. Available information can be used for multiple purposes.
2. Characteristics of individuals and groups can be studied unobtrusively, that is, without requiring subjects to do anything out of the ordinary or even making them aware that they are being studied.
3. Information produced for nonscientific purposes can be made usable for scientific inference.
4. Available data sources cover long time frames, thereby allowing study of trends not otherwise amenable to analysis.
5. Computer software applications can greatly simplify difficult categorization and coding procedures.
6. In content analyses, categorical schemes are generally developed or modified after data are collected and thus do not constrain or bias the data.

Major disadvantages are as follows:

1. The procedure is very time-consuming and labor-intensive; however, computer applications are markedly reducing the time and effort involved.

REFERENCES


The interview is the method most often used by nurses in their practice to obtain information, and is the primary method for data collection in qualitative research. The interview is a verbal interchange in which one individual, the interviewer, attempts to elicit information from another, the respondent, usually through direct questioning. Interviews can be face-to-face or telephone encounters, or in some cases are administered via computer (assuming nearly synchronous interaction can take place). Because interviewing is such a commonplace occurrence, it is easy to forget the care and precision that must be used when interviewing in the context of research. In this book the interview is considered to be a measurement instrument designed to yield data to accomplish specified purposes, so it is subject to considerations of reliability and validity as other measurement tools. A detailed consideration of the interview in qualitative data collection can be found in Chapter 8.

The interview is used for a variety of purposes in nursing and health services research: to obtain factual (as perceived by the respondent) information, to learn the respondent’s definition of a given situation, or evaluation of a health care encounter. Because it is flexible, the interview is particularly useful for gathering information from respondents who may have difficulty recalling specific events or may be explaining or reconstructing complex processes or situations. The interview also allows topics to be pursued with considerable depth and detail. Interviews may be used to elicit an individual’s attitudes, opinions, level of knowledge, and standards. Although similar kinds of information and characteristics can be gathered and assessed using questionnaires, the interview is often the method of choice, because misinterpretation or inconsistency can often be identified “on the spot” and communication clarified. The interview is uniquely useful for several populations of interest to nursing and health care research and practice. For example, interviews are very useful for gathering information from persons who cannot read or write, or have difficulty concentrating or understanding or expressing complex ideas (e.g., young children, the very ill, the elderly, the blind, the illiterate, patients with dementia) (see Docherty & Sandelowski, 1999; Irwin & Johnson, 2005; Mishna, Antle, & Regehr, 2004).

The interview has some limitations as well. For example, because the interview usually involves face-to-face interaction, the respondent is always aware that information is being sought and responses noted; therefore, it is difficult for the researcher to be unobtrusive about information gathering. Also because the interview is an interpersonal interaction, the respondent is always influenced to some degree by the verbal and nonverbal behaviors of the interviewer, the nature of the questions asked, and the setting in which the interview occurs (Gubrium & Holstein, 2002). All of these issues may make the interview problematic when anonymity is desirable, for example, when conducting research on sensitive, embarrassing, or stigmatizing topics, such as sexual practices, illegal or unethical behaviors, or emotionally painful events. Although many strategies have been recommended to help increase willing and accurate responses in such situations (see Chapter 22 in this text; Lee, 1993), the interview may be less useful than more impersonal approaches when willingness to respond truthfully would be compromised. Advances in technology, such as anonymous online surveys and social networking sites, are useful in mitigating the problem. In some cases, because the respondent is aware of being studied, the very act of being interviewed
may alter usual behavior, hence the natural course of events. If that would be problematic, a less obtrusive approach to data collection would be preferable.

The interview is one of the key instruments for many types of qualitative research, including focus group, ethnographic, phenomenological, grounded theory, and historical studies. Therefore, it is important to consider its strengths, limitations, construction, testing, and properties. The following discussion relates to the use of the interview in both quantitative and qualitative studies; however, its use in qualitative research is covered in greater detail in Chapter 8.

**TYPES OF INTERVIEWS**

Interviews are often classified according to the degree of standardization involved. As discussed in Chapter 7, standardization refers to the control that is exercised regarding the development, content, administration, scoring, and interpretation of a measure, and can vary in degree. Interviews vary greatly in the degree to which the content and the procedures for administering, recording, and scoring responses are prescribed from highly standardized (structured) to unstandardized (unstructured). The two polar extremes of the continuum are described below, along with their uses, advantages, and disadvantages.

**Structured (Standardized) Interview**

Structured interviews are those in which the investigator exercises a maximum of control by predetermining a fixed wording and sequence for all questions, and usually by preestablishing the array of possible response alternatives that can be recorded. The interview is presented in the same form to all respondents. The U.S. Census is an example of a structured interview, in which the interviewer is not at liberty to change the wording or order of the questions, and many of the response possibilities are preestablished. Likewise many marketing surveys use structured interviews.

In the structured interview the interviewer asks the question exactly as it is designed. If a respondent does not understand the question, the interviewer is not free to elaborate, but generally can only repeat the question or substitute a predefined alternative. Probes (questions, phrases, or words added to the original question in order to encourage additional or more complete responses) may be included in a standardized interview; however, they are specified in advance and are generally not left to the discretion of the interviewer.

The standardized interview embodies several assumptions. For example, it is assumed that a given verbal stimulus, such as an item or word, will elicit the same range of meanings for each respondent, and that a given wording will be equally meaningful to all respondents. If the meaning of each item is to be identical for every respondent, then the sequence must be identical. Because respondents can differ markedly in their cultural and experiential backgrounds, these assumptions are often invalid and can be met only when respondents are homogeneous and share characteristics and experiences, allowing them to interpret the meaning of questions from the same frame of reference. To the extent that the assumptions are not met when a standardized interview is used, response error is a problem. Response error occurs when respondents’ answers to the items on the interview do not measure what the instrument developer or researcher intends to measure.

A major reason for standardizing an interview is to allow comparability across respondents. If the interview is standardized and differences are discerned among respondents, then it is possible, at least theoretically, to draw the conclusion that any differences found are attributable to actual differences in response, rather than in the instrument or the way it was administered. In fact, the structured interview generally has higher reliability than less structured forms. Since all questions are prescribed, there is less likelihood that differences in the way the interview is conducted will be a source of unreliability. Additionally, there is less likelihood of interviewer bias, which refers to systematic differences that occur from interviewer to interviewer in the way questions are asked and responses are elicited and recorded. Interviewer effects are not eliminated by structuring an interview, although they
may be lessened. Another advantage of the highly structured interview is that interviewer training can be less extensive than for less structured forms, because so little is left to the discretion of the interviewer.

Structured interviews vary in the degree to which the arrays of possible responses, as well as the questions themselves, are standardized. The range is from completely structured response alternatives, in which the respondent must choose a prespecified response, to a completely open-ended response situation, in which the respondent answers as he or she wishes, and the response is recorded as delivered. Between the two extremes are items in which the respondent's answer is coded by the interviewer into one of a defined set of response alternatives. Because the interviewer is responsible for recording the response, the more structured the response alternatives, the more reliable the interview tends to be. However, structured response alternatives may force the respondent to answer in a way that does not reflect the “true” response, and validity may be compromised. It is also possible that a respondent may become frustrated, and decide to terminate the interview early, because none of the alternatives accurately captures the intended meaning.

The primary disadvantage of the structured interview is its inflexibility. If the interviewer realizes that a respondent is misinterpreting a question or senses that the wording of an item may be offensive, the interviewer does not have the latitude to make changes unless the contingency has been anticipated and an explanation or alternative wording has been provided in advance. It can be frustrating to both interviewer and respondent if the interviewer is unable to explain a question or to fit the respondent's answer to the available response alternatives, or the respondent cannot select the “true” answer (rather than simply the best of those provided). The interviewer should note concerns about respondents' misinterpretation or lack of understanding when they occur, because the validity of the interview and the comparability of responses may be seriously compromised.

The structured interview is used most appropriately when identical information is needed from all respondents, when comparisons are to be made across respondents who are relatively homogeneous in background and experience, and when large samples must be interviewed. The structured interview is often used in hypothesis-testing research and when rigorous quantification of information is required. It is also used when standardized instruments are administered in person or by phone, and when outcomes are to be measured across several points in time. For detailed information regarding the structured interview, see Gubrium and Holstein (2002) and Seidman (2006).

Unstructured (Nonstandardized) Interview

In the unstructured interview, the wording and sequence of the questions are not prescribed, but are left to the discretion of the interviewer. There are varying degrees of structure, even in an unstructured interview. The partially structured interview (sometimes called a “focused interview”) generally begins with a list of topics to be covered. The list serves as an interview guide; however, the interviewer may move freely from one topic area to another and allow the respondent's cues to help determine the flow of the interview. Although the interviewer may work from a list, the way in which questions are phrased and the order in which they are asked are left to the discretion of the interviewer and may be changed to fit the characteristics of each respondent. The interviewer has freedom to pursue various topics to different degrees with each respondent, and to try various approaches to encourage the respondent to elaborate. However, the expectation is that all topics or questions will be covered to some degree. Partially structured interviews are often used in clinical history-taking, applicant selection, and in some types of marketing and qualitative research.

Completely unstructured interviews are those in which respondents are encouraged to talk about whatever they wish regarding the general topic being pursued by the researcher. A list of possible questions may be used, but it is not necessary that all be covered with each respondent. The unstructured interview is designed to elicit subjects’ perceptions with minimal imposition.
of the investigator's input or perspective. The completely unstructured interview allows a conversational or storytelling approach, which is compatible with several philosophical perspectives that underlie qualitative research (see Chapter 8; Crotty, 1998; Denzin, 1970; Denzin & Lincoln, 2008). It is a particularly useful adjunct to participant observation in ethnographic or field research.

The assumptions that underlie the unstructured interview are essentially the opposite of those underlying the structured interview. One assumption is that in the unstructured interview standardization of meaning stems not from administering uniform wording to every respondent, but from the latitude to change words to fit respondents’ comprehension, language, and culture. It is assumed that no single sequence of questions is satisfactory for all respondents. Instead, the best sequence is determined by the interviewer, based on the respondent’s readiness to discuss a particular topic. Finally, if all respondents are exposed to essentially the same topics, it is assumed that they are exposed to the same stimuli, regardless of the specific order or wording used. This assumption may or may not be important, depending on the type of research being conducted. For example, it would be irrelevant in phenomenological research.

The primary advantage of the unstructured interview is its flexibility. It allows the interviewer to change questions to fit the respondent’s comprehension, probe the meaning of given responses in depth, and respond to individual differences and changes in the situation. The other major advantage is that it allows the respondent to express his or her perceptions and priorities freely; thus, it is ideal for studies that are focused on subjective meaning and the individual’s definition of the situation. It also is very useful for eliciting opinions in marketing research. Disadvantages of the unstructured interview include inability to make systematic comparisons across respondents, particularly quantitative comparisons; difficulty in establishing reliability; likelihood of interviewer bias; the requirement that interviewers be skilled; difficulty in analyzing data; the time required to elicit systematic information; and the time and expense required to train interviewers.

The unstructured interview is desirable when respondents differ sufficiently in background to preclude consistent interpretation of meaning, when extensive and in-depth information is needed from each respondent, and when the respondent’s meanings and definitions of the situations are important data. The unstructured interview is often used in descriptive and exploratory studies to increase understanding of phenomena that are not well understood. It is also used in preliminary stages of tool development to help generate the items and response alternatives that will later be used in more structured instruments.

Another type of interview that deserves special mention is the telephone interview. Long used as the primary vehicle for consumer marketing research and political polling, it is being used increasingly in other types of nursing and health services research (e.g., outcome studies, evaluations of care received). Telephone interviewing has the advantage of being less expensive and time-consuming than face-to-face interviews. Even long-distance telephone rates have been reduced considerably in recent years, particularly with the more widespread availability of voice-over-Internet services. The telephone interview also allows respondents in a wider geographic area to be surveyed. An important advantage is the ability to elicit responses regarding sensitive topics with minimal response bias. Telephone interviews have been found to be as effective in eliciting sensitive information as more expensive face-to-face and handheld and in-home computer-assisted self-interviews (Bernhardt et al., 2001; Ellen et al., 2002; Sturges & Hanrahan, 2004). Both tend to elicit more frequent reporting of stigmatized behaviors than face-to-face interviews (Newman et al., 2002). On the other hand, some characteristics, such as level of physical disability, may be underreported in phone interviews, compared with face-to-face interviews.

A disadvantage of the telephone interview is that potential respondents are limited to those with phones. Key segments of the population (e.g., the poor, the transient, the homeless) may be excluded. The extent to which this omission is a problem depends on the purpose of the study. For example, community-based
epidemiological research surveys may be badly biased by the omission of these subpopulations, and the results may therefore present an inaccurate representation. The growing use of cellular phones can both simplify and complicate telephone interviewing. Although respondents are theoretically more accessible when their cellular phone numbers are available, the numbers tend to change more frequently than landline phone numbers. Difficulty in cellular transmission can also cause frustrating interruptions mid-interview. For detailed discussion of the telephone interview, the reader is referred to Dillman (1978, 2000).

Recent advances in computer technology have expanded the modes available for conducting interviews, particularly structured interviews. The ease of providing audio delivery of computerized information, and innovations in touch-screen computer technology to facilitate interaction between respondent and computer, have greatly expanded the use of computer-assisted self-interviews (CASI) in hospital, ambulatory, and home settings. The cost of the technology is decreasing rapidly, thus making computerized interviews a much more feasible option than previously. Voice-over-Internet (also termed “voice-over-broadband”) phone services such as Vonage™, which require a high-speed Internet connection (cable or DSL) and use landlines (and cellular phones in some countries), provide a relatively inexpensive way for small businesses to make an unlimited number of telephone calls for a fixed monthly fee within the United States, Canada, Puerto Rico, and selected European countries (see http://www.vonage.com).

Although there may be start-up costs for equipment and software that permit audio delivery of interviews or touch-screen response options, these newer technologies are ultimately cheaper than one-on-one interviews, particularly if respondents are numerous, geographically distant, or dispersed. The availability of audio computer output means that computer-assisted interviewing is possible for respondents with limited vision and those who are unable to read. It also means that the interview can be conducted in another language without a bilingual interviewer being present. Lack of respondent computer experience does not seem to pose a serious limitation for computer-assisted interviewing, even for economically or socially disadvantaged populations (Thornberry et al., 2002). A disadvantage of computer-assisted self-administered interviews is that computers must be available, secured, and located in places (e.g., kiosks or booths with earphones supplied) that will allow privacy during data collection. The evolution of handheld devices (e.g., smart phones, personal digital assistants or PDAs) has increased the feasibility of conducting computer-assisted interviews cost-effectively and in areas with limited space.

**TYPES OF QUESTIONS OR ITEMS**

The question or item is the basic element of the interview. Two major types of questions are included in interviews: the fixed-alternative or closed-ended (structured response alternatives) question, and the open-ended (no response alternatives) question. A semistructured question contains elements of the other two types: that is, some response alternatives are provided, but the respondent is not constrained to choose one of the given answers. There is usually an open-response category included, usually designated “other.” The closed-ended question is one that supplies the respondent with two or more specified alternative responses from which to choose. Dichotomous, multiple-choice, and scale items are included in this category. The open-ended question has no specified alternative responses, so the respondent is free to choose how to word the answer. Sometimes the question is worded to sound as though it is open-ended, even though there are fixed-response alternatives into which the interviewer must place the respondent’s answer. In this case, it is the interviewer, not the respondent, who determines the fit of the answer to the response alternatives, thus permitting potential for interviewer bias.

The structured interview includes either closed-ended or open-ended items, or a combination of the two types. The unstructured interview generally includes open-ended questions but
may include both types. Examples of open-ended questions are as follows:

- What sensations did you experience during your cataract surgery? Please give me some words that describe the sensations you felt as the surgeon began the procedure.
- How would you describe your relationship with your nurse manager?
- What are the things you do to reduce stress now that you have stopped smoking?

From a measurement perspective, the two types of questions have strengths and weaknesses. The closed-ended question provides uniformity, therefore increased reliability. It is easier to code responses to closed-ended questions; however, the questions themselves may be more difficult to construct, because an appropriate set of response alternatives must be developed. This may take considerable time and effort, often involving preliminary qualitative research. The activity may also be highly subject to cultural bias. It is possible that some responses may be overlooked, and some superfluous responses may be included. These problems can often be minimized by subjecting the questions to experts for review, and by including one open-ended category among the response alternatives. It is also possible that the responses generated may inadvertently reflect a cultural bias, or even be offensive to some potential respondents. The experts who are most helpful in reviewing response alternatives are often those experiencing the phenomenon being studied. Advisory groups of patients with a given diagnosis or from a given ethnic group may provide very helpful input regarding the relevance, completeness, comprehensibility, clarity of meaning, and appropriateness of both questions and response alternatives.

Closed-ended questions are used most appropriately when the range of possible alternative responses is known, limited, and clear-cut. Because the question writer determines the possible responses available to the respondent, the closed-ended question helps establish the respondent's frame of reference, thereby avoiding responses that are irrelevant or incomparable. On the other hand, since responses are predetermined, they may not be valid indicators of a particular respondent's view. Validity may also be compromised when a subject is forced to choose a response, recognizing that it does not reflect the "true" answer that would be given under other conditions. Validity is also compromised when the respondent is enabled (or forced), by virtue of the response alternatives provided, to address a subject on the basis of little or no knowledge. Including filter questions may help eliminate this problem. A filter question is used to determine an individual's level of information about, or experience with, a given topic before proceeding to other questions about it. For example, a question such as "Have you ever had surgery?" might be used as a filter to limit portions of the interview to those with prior surgery experience.

Closed-ended questions are more efficient to administer and score than open-ended questions. More can be asked and answered in a given period of time. Closed-ended questions are particularly useful for addressing sensitive or stressful topics about which respondents may be reluctant to talk at length. Income is an example of a variable that may best be measured using preestablished categories, rather than an open-ended question. On the other hand, use of closed-ended questions may result in information loss. A respondent who is not limited by a closed-ended question might provide additional, valuable information.

The open-ended question is easier to construct; however, responses are more difficult to record and analyze reliably. Responses to open-ended questions are often long and complex, therefore cannot be recorded accurately without an audio recorder. The procedures of content analysis are generally employed in order to code and score open-ended responses, which can be communicated quantitatively or qualitatively. In qualitative research, elaborate strategies and special software may be employed to help identify themes in the data, and to validate the meaning of the information with the respondent (see Chapter 8). Considerations of interrater reliability are crucial in recording, coding, and interpreting responses to open-ended questions.

The open-ended question "sets the stage" for the respondent's answer, but provides only
Chapter 14 Interviews

293

respondents. The decision is based on the objectives for the investigation, the question it is designed to answer, or the variables and hypotheses that have been identified to be measured. As described in Chapter 2, it is helpful to construct a blueprint, table of specifications or, at the very least, a content outline listing all of the types or categories of information needed.

Step 2: Develop the Questions or Items

After the content is specified, the next step is to draft the actual questions to be asked and the potential responses, if any are to be provided. This is not an easy task. It involves translating the purposes into questions that will yield the needed information, and designing “lead-ins,” or explanatory statements, that will motivate the respondent to provide the information requested. The wording of each question must allow the meaning to be clear to the respondent and sufficiently precise to convey what is expected without biasing the content of the response. Several guidelines are suggested below:

1. Be sure that the wording accurately conveys the meaning intended. If meaning is potentially problematic, ask others the question and have them interpret what they think it means.
2. Keep sentences, phrases, and questions short, because some people have difficulty understanding and remembering complex ideas.
3. Use simple terms that can be understood by the least educated respondent. If technical terms are necessary, clearly define each one before asking the question in which it is included, and list possible synonyms.
4. Limit each question to only one idea; avoid questions with multiple parts.
5. Avoid words with multiple or ambiguous meanings.
6. Avoid terms that are derogatory, emotionally laden, or that might trigger biased responses.
7. Do not ask questions in ways that suggest an answer.

PROCEDURE FOR DEVELOPING THE INTERVIEW SCHEDULE

The suggested procedure for developing an interview schedule is described below. A brief overview of each step is provided. More detailed information about designing and conducting interviews can be obtained from one of many excellent resources, for example, Gubrium and Holstein (2002), Denzin and Lincoln (2008), Seidman (2006), and Silverman (2005).

Step 1: Determine the Information to Be Sought

The first step in designing an interview is to determine what information is needed from respondents. The decision is based on the objectives for the investigation, the question it is designed to answer, or the variables and hypotheses that have been identified to be measured. As described in Chapter 2, it is helpful to construct a blueprint, table of specifications or, at the very least, a content outline listing all of the types or categories of information needed.

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4. Limit each question to only one idea; avoid questions with multiple parts.
5. Avoid words with multiple or ambiguous meanings.
6. Avoid terms that are derogatory, emotionally laden, or that might trigger biased responses.
7. Do not ask questions in ways that suggest an answer.
8. Avoid personal or delicate content that the respondent may be reluctant to answer. If such content must be addressed, word the questions as delicately as possible and consider placing them near the end of the interview.

9. If a closed-ended format is used, clearly define the entire set of responses. This may be done verbally as part of the question. However, if the list of possible responses is long or complex, the responses should be written on a card or booklet and shown to the respondent.

10. Try to minimize the effect of social desirability by avoiding questions that lead respondents to express sentiments that imply approval of things generally considered good or behaviors that are expected by society. (See Chapter 26 for a more thorough discussion of social desirability.)

11. Use filter questions to be sure that respondents are not being asked to provide answers about topics with which they are unfamiliar.

12. Identify probes that can be used to elicit additional information or clarification.

13. Lead-in information is provided at the beginning of the interview and additional, reorienting information is sometimes periodically included throughout the interview to set the stage for the next questions and help provide a context in which the respondent is to interpret them. Such information is helpful when the interview shifts from one topic to another. In a structured interview, the script is provided for the interviewer to read identically to each respondent. In unstructured interviews, the interviewer may be permitted to design lead-in or transitional statements that are individualized for each respondent.

As an example, during an interview to assess a new mother’s social support network, a statement such as the following might be used to help reorient the mother’s thinking:

For the past few minutes you have been telling me about the help and support you think you might be able to receive from your family, friends, and coworkers if you needed it. Now I would like you to think instead about the help you have actually received during the past month, from one specific person, your spouse/partner.

This statement alerts the respondent to two changes in orientation: (1) from hypothetically available support to that which has actually been received, and (2) from the support network as a whole to a focus on one support provider.

**Step 3: Determine the Sequence of the Questions**

Once the questions have been designed, an appropriate sequence is determined. The main criterion for determining the sequence is that questions or items be arranged in a logical and realistic fashion so that they make sense to the respondent. For example, if the interview is designed to elicit information about a sequence of steps in a process that the respondent completed, the questions should be arranged so that events occurring earliest in the sequence are asked about before those coming later. The order that is generally suggested is to begin with questions that are likely to capture the interest of the respondent and increase motivation to cooperate. Less interesting questions and those that may be difficult to answer should come later in the interview. Sensitive or personal questions are generally asked near the end of the interview. Traditionally, sociodemographic information is requested near the end of the interview.

In order to make the interview more logical and less confusing, it is desirable to cluster questions concerning a particular topic. Within clusters, open-ended questions should precede closed-ended questions, and general questions should precede more specific ones. The reason for this ordering is to avoid earlier questions suggesting responses to those that follow, thus minimizing bias in the response. There are exceptions to the general-to-specific ordering. For example, some scales require questions to be randomly ordered; also, specific questions can be positioned in the interview to help trigger a respondent’s recollection of past events.
Step 4: Draft the Interview Schedule

The interview schedule contains both the questions to be asked and any introductory statement, explicit instructions for the interviewer and respondent, and a closing statement. Introductory information is directed toward providing the basis for informed consent. It is usually presented in writing, but may also be covered verbally from a script. It should address the purpose of the interview, what will be done with the information obtained and who will have access to it, risks and benefits to the respondent and others (if any), explicit statements that participation is voluntary and that the respondent can refuse to answer any question or terminate the interview at any time, an estimate of the time involved, and an orientation to the interviewing and recording procedure. (See Chapter 24 for more detailed information about informed consent and ethical considerations in measurement.) It is appropriate to end the interview by expressing appreciation for the respondent’s time, help, and cooperation. In some cases, the investigator offers to share the findings with the respondent when the study is complete.

Instructions to the respondent should be explicit. New instructions are required whenever there is a change in format or topic. Instructions to the interviewer must also be detailed and precise. These should include such matters as whether questions may be repeated or reworded, lists of probes, and instructions about how to record or code the response. A particularly important aspect of instructions in health-related interviews, especially in research interviews, is whether the interviewer is permitted to provide any assistance or health-related information or advice to the respondent either during or after the interview. Health care providers often find it difficult to not intervene with respondents who have obvious problems.

Step 5: Pilot-Test the Interview

Pilot-testing an interview actually involves several activities. First it is advisable to subject the questions on the interview schedule to review by measurement experts and experts in the content area. Measurement experts can often spot ambiguous or unclear wording or questions that are unlikely to yield the desired response. Content experts, who may include nurse clinicians and researchers, scholars in other disciplines, and advisory groups of patients, are able to evaluate the clarity of wording, appropriateness of the question to the content area and potential respondents, and completeness and appropriateness of the response alternatives. It also may be helpful to have individuals who are not familiar with the content of the interview review the questions for clarity of meaning and use of readily understandable terms. (Computer programs are available to assist with assessing the comprehension level of the questions.) Such individuals may also suggest additional responses to consider.

A second pilot-testing activity is to trial the interview with individuals with characteristics and experiences like those for whom the interview is designed. The pilot-test provides the opportunity to detect problems with the wording of the instructions or questions, determine the time involved, and assess the reliability and validity of the instrument. An opportunity should be provided to “debrief” the pilot-test subjects in order to elicit their opinions of the interview. Because the nature of the setting in which the interview is conducted influences the kind and amount of information that the respondent reveals, it is advisable to conduct the pilot study in a setting similar to that in which the interview ultimately will be carried out. Such an approach also allows assessment of barriers and facilitators that might be inherent in the setting.

Step 6: Train Interviewers

Subjects’ reluctance to answer questions and variations among interviewers in how they conduct the interview are two additional sources of response error. Adequate training and supervision of interviewers can be a major factor in reducing these two sources of error and cannot be overemphasized. Selection of interviewers is also important, particularly in unstructured interviews where the interviewer represents one aspect of the instrument. Selection of appropriate interviewers must take into account the nature of the anticipated respondents and the
Part IV Instrumentation and Data Collection Methods

Reporting and scoring the information. Acceptable levels of interrater and intrarater reliability must be established before training can be considered complete.

Adequate training is imperative from a measurement perspective, because the interviewer controls much of the information obtained. Interviewer bias can be a substantial threat to reliability and validity, as can factors in the interviewer-respondent interaction that might inadvertently discourage the respondent from answering completely and truthfully. Problems may occur because of inter- or intrainterviewer differences in the way questions are asked, responses are elicited and recorded, respondents perceive interviewers and questions, interviewers perceive respondents, and in the interview settings. Conversely, an interviewer’s ability to listen effectively, maintain an objective stance, and establish a sense of trust can be instrumental in eliciting valid responses.

With a highly structured interview schedule in which much control is built into the instrument itself, the interviewer must ensure that the schedule is administered and responses recorded consistently across all respondents in order to achieve reliable and valid results. Even with structured interviews, reliability and validity are dependent not just on the instrument, but also on the human beings involved in the interview interaction. With unstructured interviews the interviewer holds considerable discretionary power. Therefore, thorough understanding of the purposes of the interview and considerable communication skill are essential. Regardless of the degree of structuring, personal characteristics and behaviors of the interviewer (e.g., gestures, posture, facial expression, verbal intonation, and voice quality) can influence responses.

If the study is to take place over a period of weeks, it is not sufficient to train interviewers only before the study begins. Periodic updates of the training are needed, particularly if and when interrater reliability begins to decline. Periodic assessment of inter- and intrarater reliability, with retraining and updating sessions as warranted, are essential ingredients in a comprehensive interviewer training program. Reliability may be checked by having one other person accompany the interviewer and record the complexity of the interview situation. Research has shown that the gender, age, race, social class, intelligence, experiential background, appearance, level of expertise or authority (i.e., lay vs. professional health care provider), and voice of the interviewer influence respondents’ willingness to participate in the interview and the nature of the information received from them; however, the results are mixed, depending on the particular population being studied (Denzin & Lincoln, 2008; Kavale & Brinkmann, 2009). In general, the more congruent the characteristics and experiences of interviewer and respondent, the more likely is the respondent to cooperate, and the more valid are the responses obtained.

Interviewers must be carefully trained. The training period may vary in length from a few hours to several weeks, depending on the complexity and degree of structure of the interview and the prior experience of the interviewer. Highly structured interviews may require training periods lasting from one hour to a full day. For unstructured interviews, longer periods of training are usually necessary, particularly if the interviewer must code or interpret the data. Training includes not only instruction and practice in administering the questions and recording and coding the responses, but also consideration of verbal and nonverbal communication skills, appropriate appearance and dress, control of distracting environmental elements, and techniques for securing cooperation and for motivating respondents. Although some general guidelines pertaining to virtually all interview situations should be included in interviewer training (see Fielding, 2003), a large portion of the training is specific to the requirements of the particular study and interview.

When research interviewers are clinicians, it is also advisable to include a discussion of the differences between clinical and research interviews. When sensitive questions are to be addressed or the population is vulnerable, special consideration of ethics, human rights, and ways to handle difficult situations should be included in the training. For research interviews, it is advisable to familiarize the interviewers with the research project; however, one should be careful not to share information that might bias the interviewers or compromise their objectivity in reporting and scoring the information. Acceptable levels of interrater and intrarater reliability must be established before training can be considered complete.
and code responses or by recording the interview for another individual to code. In telephone interviews, interrater reliability is checked by having another individual listen to the interview and code the information simultaneously. Reliability coefficients are then computed using the two sets of scores.

**Step 7: Administer and Code the Interview**

The final step in the interview process is to administer the interview and record, code, and score responses. In addition to the interpersonal factors noted above, several elements in the interview situation itself may influence the reliability and validity of responses. The timing, duration, and scheduling of the interview in relation to other demands and events may influence the information obtained. A respondent who feels rushed to complete the interview quickly because of time pressures, or one who is preoccupied with personal issues, may be unwilling or unable to supply accurate and complete information. Interviews that are too long may create respondent burden, particularly for respondents who are ill, emotionally distraught, or feeling very time-pressured, thereby compromising the validity of their responses. Interviewing children requires special, age-dependent, techniques (see Irwin & Johnson, 2005). Particularly when the interview addresses sensitive information, intense emotional experiences, or a traumatic event, its timing relative to the event in question affects the respondent’s willingness and ability to share information or express feelings. During the initial phases of such experiences—for example, the recent death of a family member or close friend—respondents may be unable to discuss their thoughts and feelings.

The setting for the interview is also important. Considerations include convenience for the respondents, degree of privacy available, possible distractions or interruptions, and the potential influence of the setting on the content of the response. For example, a respondent might reply differently to questions about sexual behavior with and without the spouse present. Respondents would be likely to answer differently about their hospital experience if interviewed in the hospital rather than at home, in part because of the cuing effect of the environment. Some environments, such as busy clinics that provide little privacy, have been found to obstruct the free flow of information in patient–health provider interaction, so one can assume that they would similarly impede the flow of information for all types of interviews.

The means used to record responses also influence reliability and validity. Reliability is generally higher for closed-ended than for open-ended questions, because responses are recorded on a precoded format. Open-ended questions require that the interviewer take notes or use a voice recorder. In general, the more complex the information, the more rapid the information flow, and the greater the likelihood of unanticipated responses, then the more preferable is the use of a recording device, despite the increased time and cost involved in transcription. Subjects may find the use of a voice recorder to be distracting, particularly in the early stages of the interview, or may prefer that their responses not be taped. The interviewer must secure permission for tapping in advance, being sure to communicate to the respondent what will be done with the recording. In order to increase reliability and validity, open-ended interview data should be transcribed and coded as soon as possible after the interview. The transcript should be checked and, if necessary, clarified or corrected by the interviewer. Coding can be done either by the interviewer or another individual.

**RELIABILITY AND VALIDITY**

As with all measurement instruments, reliability and validity are crucial considerations in the interview. Reliability assessment includes consideration of inter- and intrarater reliability (determined at the time of pilot-testing the interview schedule, during interviewer training, and periodically throughout use of the interview with respondents), and reliability of the instrument itself. The latter assessment generally is carried out for structured interviews using the procedures of test/retest reliability, wherein the same respondent is interviewed more than once using the same schedule and
results are compared. This is a time-consuming procedure that makes considerable demands on the respondent; therefore, it is generally carried out only during the pilot phase of instrument development. It is advisable to compute test/retest reliability periodically on a small sample of interviews during the administration phase as well. Parallel forms reliability assessment may also be employed for structured interviews; split-half reliability is generally not appropriate. However, if a structured instrument is administered via interview, then it is possible to assess the split-half reliability of that portion of the interview. Given the intent of the unstructured interview to focus with few imposed constraints on the perceptions and priorities of the respondent and given inconsistency in the questions asked, traditional reliability assessment is virtually precluded.

Validity of interview information is a complex issue that entails consideration of the interview itself as well as the issue of self-reported information. Sources of invalidity in the interview include (1) lack of commonly comprehended meanings; (2) differences in situations and settings; (3) reactive effects of the interview itself, wherein respondents modify their responses simply because they are being interviewed; and (4) respondents’ modifying their responses to fit their perceptions of social requirements or the interviewer’s preferences. It is possible to minimize some of these sources of invalidity with careful instrument design, attention to the wording of questions, using the input of experts, and thorough interviewer training.

Interviews most often elicit self-reported data, that is, information reported by the respondent about himself or herself. Self-reports of events or even the subject’s own opinions are subject to error. Most common sources of error in self-reported data include the tendency to respond in a socially approved manner, the tendency to acquiesce or agree with a statement without careful consideration, varying ability to engage in self-focused attention and accurate self-appraisal, and variable recall. Depending on the availability of alternative sources of the information, it may be possible to check the validity of information reported by respondents with external data sources, as described below. However, much self-reported factual information is not easy to validate. In most instances, it must simply be assumed that the respondent is telling the truth; however, this assumption may be problematic when recall is difficult, sensitive issues are involved, or the response may cast an unfavorable light on the respondent. Often the factual accuracy of the information provided by a subject is irrelevant because the purpose of the interview is to ascertain the individual’s perceptions.

There are several ways in which the validity of self-report information can be assessed. For example, within the context of the interview itself, the interviewer can observe whether the respondent is disturbed by certain questions or hesitates to answer. Such observations should be noted, so they can be taken into account in interpreting the information. Inconsistencies in response can also be noted, carefully called to the respondent’s attention, and clarified in order to increase validity. Likewise, in many cases inconsistencies between self-reports and behavior can also be noted by the interviewer. For example, an elderly respondent may verbally report no difficulty in moving around the house, yet can be observed holding onto furniture for balance. A diabetic patient may claim to self-administer insulin daily, yet be unable to locate the medication or a syringe when asked to do so.

Validity can also be assessed by gathering information external to the interview situation to check the accuracy of responses. Family members can be asked to validate respondents’ self-reports, recognizing that the family members themselves may have inaccurate or incomplete information. Medical records can be consulted to validate reports of factual information about a hospital visit or immunizations received. Other measures of the same behavior or characteristic (e.g., clinical laboratory results or electronic devices such as pedometers) can be employed in conjunction with the interview as a means for assessing concurrent validity.

Qualitative researchers point out that the procedures used to assess the reliability, validity, and rigor of quantitative data collection instruments are not adequate for evaluating qualitative approaches. Different concepts and criteria must be applied. In many different types of qualitative
research, the key data are the respondent’s perceptions and definitions of the situation; therefore, only the respondent is truly able to validate the data and the way they have been analyzed and interpreted. Approaches to assessing the reliability and validity of interviews and interview data in qualitative studies are discussed in greater detail in Chapter 8.

REFERENCES


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The questionnaire is a form or document containing questions or other types of items to which the subject supplies a written response. Unlike the interview, the questionnaire is self-administered by the respondent. Because it does not require verbal interchange, a questionnaire can be administered electronically, mailed, or simply handed to a respondent. It is more impersonal than an interview, so anonymity can be assured. Questionnaires are always structured, in that the questions or items and their order are predetermined and fixed. Although they are structured, questionnaires can be quite versatile. Either closed-ended or open-ended questions can be included, as can a variety of types of scales including checklists, visual analog scales, semantic differentials, Likert- and Guttman-type scales, and sociometric measures. Because of the growing use of e-mail in research and the ease and efficiency of delivering questionnaires electronically, the questionnaire’s popularity as the preferred mode of data collection has grown tremendously in recent years.

The questionnaire is a relatively direct method of obtaining information. Commonly used to gather self-report data, it is used to gather respondent reports of factual information, opinions, intentions, standards, beliefs, and attitudes, and to assess the level of knowledge about a given topic. No personal interaction is required for its use; therefore, the questionnaire is often the method of choice for large-scale surveys of community-based or geographically dispersed samples. Questionnaires are often used to elicit information and opinions about sensitive or controversial topics. Because there is usually no interpersonal contact to allow clarification or prompting, the questionnaire may be less useful than the interview for eliciting information about complex processes or remote events. It is, of course, useless for individuals who are unable to read or write.

Because it is structured, the questionnaire is useful in situations in which a high degree of consistency is required for description or comparison. The printed format of the questionnaire makes it ideal for scales such as the visual analog scale that are visual representations, or for those that require the respondent to rank or compare numerous items or to select responses from a long or complex array of response alternatives. Examples of uses of questionnaires in nursing include research studies of the knowledge, attitudes, and behaviors of patients, families, and nurses; patient opinion surveys; health history and health risk appraisals; student and peer evaluation of courses and programs in schools of nursing; surveys to assess the health problems and resource needs of groups and communities; and postdischarge surveys of patient satisfaction with care received during a hospitalization.

With the growing popularity of electronic distribution, software to assist with questionnaire design has mushroomed in recent years, and numerous options exist (Top Ten Reviews, 2009). To name just a few: Survey Monkey™ (http://www.surveymonkey.com), Question Pro™ (http://www.questionpro.com), Key Survey™ (http://keysurvey.com), Qualtrics™ (http://www.qualtrics.com), and Checkbox™ (http://checkbox.com). While many of the software applications have been designed for marketing and political surveys, they are also widely used in academia and health care to assess student opinions and attitudes and patient or customer satisfaction, respectively. Although the software can greatly facilitate formatting of the questionnaire, as well as greatly speeding data analysis and results reporting, the considerations and careful thought that must go into determining
the content, wording, and sequence of the questions are identical to those for the more traditional printed formats.

A detailed discussion of the capabilities, advantages, and disadvantages of the many survey software packages that are currently available is beyond the scope of this chapter. Suffice it to say that the products are becoming increasingly sophisticated, offering design templates that can be customized, libraries of possible questions, data export to statistical software such as SPSS, data analysis, and creation of reports, including visual representation. Some of the software products are open-source and others, more numerous, are closed-source. Each of the programs has a distinctive array of features and many offers free trials, so it is wise to examine a number of different products and comparative product reviews, try several different packages, and talk with colleagues who have used them before making a choice. Major considerations are cost, ease of use, ability to import questions from existing word processing software and to export data to statistical software, security of the data, and availability of e-mail and other technical support (see Kaczmirek, 2004). Security is of prime importance when protected data, such as health information, are involved. Another consideration is whether the software can be stored on an institution’s or agency’s servers, as opposed to being hosted by a third-party company. The software is similar for both hosting models; however, support services offered in a given institution or department, ability to secure the information by means of encryption, privacy, and policy should be considered.

PROCEDURE FOR DEVELOPING THE QUESTIONNAIRE

The procedure for developing the questionnaire is very similar to that for developing the interview (see Chapter 14), and many of the considerations for each step are identical. Therefore, the only elements of the procedure that will be detailed here are those that are specific to the questionnaire. For detailed information about constructing questionnaires and for the various types of items that can be included in them, the reader is referred to Lavrakas (2008), Fowler (2009), and Bickman and Rog (2009).

**Step 1: Determine the Information to Be Sought**

The procedure for this step involves the same considerations as the interview, that is, specifying objectives, developing a blueprint or table of specifications, and weighting the importance of each content area to determine the number of questions needed, and the level of specificity desired.

**Step 2: Develop the Questions or Items**

In developing questions or items to be included in a questionnaire, it is important to consider clarity of meaning, the language used, the ability of the respondent to comprehend and answer the questions, the potential for biasing responses, and the best ways to elicit sensitive or personal information. The guidelines suggested for writing interview questions apply equally to questionnaire items, and are even more important because there is no individual present to help the respondent understand what is being asked or to clarify misperceptions. It is even more crucial in questionnaires than in interviews to word each item clearly, avoid ambiguous and technical terms, define terms with which the respondent may be unfamiliar, avoid double-barreled questions (those that ask for a single answer to more than one question), keep sentences short, avoid negative wording, and provide explicit instructions about how the responses are to be recorded. The questions must be scrutinized to assure that they are relevant to the potential respondents, are not biased or misleading, and do not include potentially objectionable wording. Because of one’s own and often unrecognized cultural and disciplinary biases, it may be very difficult to identify questions that are problematic or culturally insensitive. Therefore, it is wise to use the assistance of others, preferably persons with experiential backgrounds and characteristics similar to the potential respondents, to identify such problems at a very early stage of questionnaire development. Special considerations for
developing questions to collect sensitive information are addressed in Chapter 22.

Closed-ended questions often require that the set of response alternatives be clearly specified. Like interviews that use closed-ended questions, the array of potential responses should be represented as completely as possible, responses should be constructed so as to be mutually exclusive, and there should be a rationale for the order in which responses are listed. Although responses can be longer with a questionnaire than with an interview, brevity is desirable. In the instructions or in the body of a question, it is necessary to specify the number of responses that may be chosen (e.g., choose one answer, check all that apply) and the way in which the respondent is to indicate the chosen responses (e.g., circle the response, check the response, fill in the space on the response sheet, or in the case of computer-administered questionnaires, click on the desired response or touch the screen next to the desired response).

For open-ended questions, it may be helpful to include a list of suggested topics, examples, or subquestions in order to cue the respondent about the kind of information expected or the aspects of the question to consider in responding to the item. Although there are some exceptions, open-ended questions that demand a complicated, detailed, or long response are less frequently included on questionnaires than in interviews, primarily because subjects find it difficult or cumbersome to provide great detail in writing. If such detailed information is to be elicited, a successful approach is to break down the more general question into a series of more specific questions, each with a narrower scope and easy to answer in a sentence or two. Unless the topic is highly salient and the respondent highly motivated, it is difficult to elicit richly descriptive data from a questionnaire. The respondent will to some extent be cued about the expected length of a response by the amount of space provided. This may be more difficult to ascertain on computerized questionnaires.

With a questionnaire the interpersonal skills of an interviewer are not available to motivate or encourage response. Therefore, the questions themselves must be clear and compelling, and worded to facilitate a correct interpretation and willing response. A number of techniques can be used to personalize questionnaire items; for example, using conversational sentence structure, using first- and second-person pronouns, and italicizing or underlining words for emphasis. Because it is not possible to correct, clarify, or question a respondent’s answers, introductory phrases or sentences help provide the needed context for the question.

Because the questionnaire is presented electronically, printed, or typed, the format for questions and sets of possible responses is an important consideration. Clarity, ease of reading, and ease of following instructions are key criteria. In printed versions, response alternatives are typically separated from the question and are usually aligned vertically. In electronic versions, questions and response alternatives are generally presented on the same screen, so the number of response possibilities may have to be limited. Filter questions assess the respondent’s level of familiarity or experience with a phenomenon and come before the other questions about it. (For example: Have you been hospitalized within the past year?) They can also direct the respondent to different portions of the questionnaire based on the response selected. (For example: If yes, go to question #10; if no, skip to question #18.) Filters are often difficult for respondents to handle without confusion unless the instructions about how to proceed are very clear and supplemented with visual aids, such as arrows. Formatting for electronic distribution facilitates the use of filters, because the survey designer builds in the appropriate routing.

The format, appearance, or sequence of responses may inadvertently confuse, bias, or unintentionally cue the respondent. For example, splitting the list of possible response alternatives onto two pages may artificially truncate the options the respondent considers before answering. It is not unusual for a respondent to misunderstand or misinterpret a question or to fail to read it carefully. A major source of response bias is carelessness due to fatigue or lack of motivation. Suggestions to reduce carelessness include keeping the number of questions to a minimum, keeping the questions relatively short, keeping the questionnaire interesting by putting less interesting items at the end and mixing different types of scales
and questions. Another source of problems is social desirability, or the tendency for respondents to give the most socially acceptable answer. A possible solution is to include on the questionnaire some items to measure social desirability, then correlate the responses on these items with other variables. Significant correlations suggest that respondents have a tendency to base their responses on social desirability. Another alternative is to make it clear throughout that there are no right or wrong answers and provide anonymity. A third problem is acquiescence, or the tendency to agree with positively worded items. To help alleviate this problem, positively and negatively worded items about the same issue can be combined on the questionnaire.

Blount, Evans, Birch, Warren, and Norton (2002) assessed the relative merits of several self-report instruments by asking lay and professional experts to assess their acceptability to users. The problems identified included inappropriate length, vague language and meaning, use of slang, and making cultural assumptions in the way items are worded. The recommendation was to go beyond psychometric evaluation of measures to include evaluation of their acceptability to potential respondents. They also noted that exposure to an instrument can be upsetting to some respondents, and urged sensitivity to possible problems as items are developed. Housen and colleagues (2008) suggested that input be sought from individuals with the same characteristics as intended users at an early stage of item development. They used cognitive interviewing techniques to solicit information about the way nursing home residents would answer proposed items, then modified problematic questions based on that input. Detailed discussions about the design of survey instruments are provided by Sue and Ritter (2007) and Dillman, Smyth and Christian (2009), and specifically about the design of health surveys by Aday and Cornelius (2006) and Shi (2008).

Step 3: Determine the Sequence of the Questions or Items

Guidelines for sequencing questionnaire items are somewhat different from those for the interview. In a self-administered questionnaire, it is best to begin with the most interesting topic and questions in order to capture the attention of the respondent, remembering that the sequence in which questions are asked can influence the responses (e.g., Taylor et al., 2002).

Step 4: Subject the Questionnaire to Review

As with the interview, the opinions of measurement and lay and professional content experts, as well as persons unfamiliar with the content, should be sought in order to assess the clarity, readability, completeness, and acceptability of questions and response alternatives. It is generally desirable to compile a preliminary draft of the questionnaire for review, so that it can be examined as a whole and the format evaluated. Trial administrations of questionnaires that are formatted for electronic delivery are particularly important to assure that the program runs smoothly. Revisions are made on the basis of input received.

Step 5: Draft the Questionnaire and Cover Letter

Once input from reviewers has been incorporated, the questionnaire is compiled in the form that will be used for respondents. It may be helpful to solicit advice and/or assistance from an expert in graphic design, especially for instruments that are to be administered electronically. As noted in the introduction to this chapter, a number of survey design software programs exist to facilitate the creation of Web-based surveys, by providing templates that can be customized by means of many options. Explicit instructions about how the questionnaire is to be self-administered and how responses are to be recorded should be included on the instrument itself. Therefore, prior decisions must be made about how the data are to be gathered and handled. For example, if the instrument is to be used with a large sample with access to computers, then electronic distribution is most likely the method of choice. If the proposed sample does not have computer access and the questionnaire must be mailed, use of optical scanning
sheets may be preferable to having the responses to closed-ended questions recorded on the questionnaire itself. Whatever the distribution method, the format for the questionnaire should be clear, legible, and easy to navigate, in order to avoid respondent frustration. Once assembled, it is advisable to submit the questionnaire to an editor who is familiar with questionnaire design for review.

A cover letter must be drafted if the questionnaire is to be distributed by mail or electronic mail. The cover letter introduces to the respondent the purpose of the questionnaire and its intended uses. Information is also included about such human subject protection issues as the risks and benefits to the respondent and others, provisions for confidentiality and anonymity, the right to refuse to participate or to answer some questions, and the steps that will be taken to assure the security of personal information (see discussion of research ethics in Chapter 24). The letter should also provide an estimate of the time required for completion, and explicit instructions about what the respondent is to do with the questionnaire when it has been completed. Because the cover letter replaces the personal contact, it must be worded carefully and in a manner that is likely to motivate the respondent to reply. If the questionnaire is to be handed to the respondent rather than mailed, a script is prepared for an introductory verbal statement containing the same kind of information as a cover letter. It is advisable to repeat some of this information—particularly that concerning the human subjects’ protections and about what to do with the completed instrument—in print on the questionnaire.

Whether to distribute questionnaires electronically, mail them, or distribute them by personal contact is based primarily on the nature of the intended respondent population and sample(s). Electronic distribution is very cost-effective and efficient, particularly for a large or geographically dispersed sample, provided the population being sampled has computers and Internet connectivity and is computer literate. This may be an invalid assumption for certain populations, such as the elderly and those living in some inner-city and rural areas. The response rates for e-mailed surveys have varied when compared with those delivered by “snail mail,” with lower rates being attributable to concerns about computer security and receipt of “spam” (Greenlaw & Brown-Welty, 2009; Kaplowitz, Hadlock, & Levine, 2004). For large or geographically dispersed samples that cannot be assumed to have the requisite computer resources for electronic distribution, mail distribution may be the only practical approach, despite the problems of low response rate and high postage cost. If the respondents can be reached easily by personal contact, it is generally preferable to mail distribution, because of higher response rates. Personal distribution by the investigator or other cooperating individuals is feasible for many health-related applications of the questionnaire, for example, those that involve patients or staff in local hospitals, clinics, or private practices, or intact community or student groups. On the other hand, personal distribution may be perceived by potential respondents to compromise the anonymity of their responses.

Mailing costs must be weighed against the costs incurred in personal distribution, that is, expenditures of time and possibly money for travel. When sensitive topics are being addressed and anonymity is desirable, computer or mail distribution or an approach that combines personal distribution with a mailed or computer return is generally preferable, because anonymity can be guaranteed. On the other hand, for some sensitive or personal topics, personal distribution (with mail or computer return) may be preferable, because it permits rapport to be established with the respondent before or as the questionnaire is distributed. Personal distribution may allow a debriefing session after data collection is complete. Comprehensive discussions of mailed and computer surveys and techniques for maximizing their reliability, validity, and response rates can be found in Dillman (2007), Dillman et al. (2009), Edwards and colleagues (2009), O’Toole, Sinclair, and Leder (2008), and Curtis and Redmond (2009).

**Step 6: Pretest the Questionnaire**

The questionnaire is pretested with a small sample of individuals who are similar to those for whom the instrument is designed, in order to assess clarity, adequacy for the research to be
conducted, and freedom from problems and bias. The pretest may be conducted by mail; however, it is generally preferable to distribute the questionnaire to the pretest sample in person, then to follow the administration with an interview in which the respondents are asked to indicate their reactions to the questions and format, identify any portions of the questionnaire with which they had difficulty, and suggest improvements. The personal approach to pretesting also allows validation of the estimated time needed to complete the questionnaire. Item analyses, and reliability and validity assessments, are computed following the pretest and necessary revisions are made. If the revisions are extensive, it is best to conduct a second pretest.

Step 7: Administer and Score the Questionnaire

Once a final version of the questionnaire has been prepared, decisions must be made about the administration procedure. One of the key features of the questionnaire is its standardization, which allows the assumption that all respondents are presented with identical stimuli. As noted in the discussion of interviews in Chapter 14, a given stimulus (word or question) may not have the same meaning to different individuals, so the assumption is tenuous at best.

If the information from the questionnaire is to be used for comparison across respondents, it is essential that the conditions of administration be as standard as possible. In the case of a personally distributed questionnaire, it would be important to maintain as much consistency as possible in the individuals distributing the questionnaire, the types of settings in which it is distributed and completed, and the way in which the questionnaire is introduced and cooperation secured. For example, if nursing administrators in each of several hospitals were to distribute a questionnaire to staff nurses, it would be important to select administrators who were in identical positions and to instruct each one to read the predefined introductory statement in the same way to all potential respondents in similar types of settings. If one group was told to complete the questionnaires onsite during a staff meeting and another was asked to complete them at home, the different conditions of administration could potentially influence the results and render the two sets of data incomparable.

Mailed questionnaires should be packaged identically and sent to similar settings (e.g., either work address or home address, but not a combination of the two) in order to standardize administration conditions as much as possible. With a mailed questionnaire, the investigator has no control over the specific conditions under which the respondent chooses to self-administer the instrument. Considerable variation can occur in the degree of input or help that is sought from others, the order in which the questions are answered, the setting in which the instrument is answered, and the amount of distraction in the environment. Thus, complete standardization is impossible to achieve. The same may be true for computer-administered questionnaires, particularly those that are sent via the Internet to respondents’ homes or workplaces. Mail and Internet surveys are discussed in detail by Dillman (2007), Dillman et al. (2009), and Sue and Ritter (2007).

A problem that continues to plague researchers who use questionnaires is nonresponse. Three types of nonresponse have been identified: noncoverage, a sampling problem in which some sampling units (e.g., individuals) are omitted from the sampling frame; unit nonresponse, in which some sampling units yield no data because of noncontact or refusal to participate; and item nonresponse, when the sampling unit participates but fails to answer some of the questions or answers them in a way that makes the data unusable (Elliot, 1991). Barrribal and White (1999) have developed an explanatory model of data loss in surveys to display the relationships among these three types of nonresponse and factors that influence their occurrence.

Noncoverage may be a particularly difficult problem in population-based research using electronically distributed questionnaires, because computer and Internet access are not universal. Unfortunately, and particularly when questionnaires are mailed, unit nonresponse is common. It is not unusual to encounter response rates as low as 25%. The result is not only a diminished sample size, but also a set of responses that may be atypical of the sample as a whole, since
nonresponse is not a random process. Several techniques can improve response rates with mailed or e-mailed questionnaires. These include (1) supplying a self-addressed and stamped return envelope, (2) following up the original administration with one or two e-mailed, mailed, or telephone reminders (including another copy of the questionnaire), and (3) offering incentives or rewards (e.g., small amounts of money or inexpensive gifts) either in advance or upon receipt of the completed questionnaire. Strategies already mentioned, such as carefully wording the cover letter to establish rapport and providing a clear and attractive questionnaire, also enhance response rates. A number of experiments have been conducted to determine the effects on response rates of specific variables such as paper color, type of envelope and stamp, type of letterhead, typed versus written address, incentives, and timing and type of follow-up on response rates. The findings are inconclusive. However, some commonsense principles are advisable; for example, response is encouraged by a questionnaire that is appealing in appearance, interesting in content, easy to understand, and not overly demanding in time or difficulty. Detailed discussions of minimizing and handling nonresponse in surveys are provided by Dillman (2007), Groves (2002), Edwards and colleagues (2009), and Curtis and Redmond (2009).

Response rates are predictably problematic with mailed questionnaires. It is helpful to make provision at the time of administration for estimating the nonresponse bias that may exist because of systematic differences between those who respond and those who do not. For example, a record should be kept of the date when each questionnaire is returned, because late respondents have tended to be similar to nonrespondents. Early and late responses can be compared to detect bias. If data are available about some characteristics of the entire sample to whom questionnaires were sent, then the characteristics of those who returned questionnaires can be compared with those of nonrespondents to determine differences, and with the sample as a whole to determine representativeness. Once the degree of potential bias is assessed, it can be taken into account in interpreting the information obtained.

The coding and scoring procedures for questionnaires with closed-ended questions are straightforward but do require prior decisions about how to handle such common complicating occurrences as item nonresponse, responses that are unclear or unreadable, or obvious misinterpretation of instructions (e.g., checking multiple responses instead of one for each question). The important point is that all questionnaires should be treated identically, with guidelines identified in advance. Coding and scoring open-ended questions are more complex and time-consuming, requiring application of content-analysis techniques to the responses (see content analysis discussion in Chapter 10). One of the clear advantages of many of the survey software programs is that they include the capability of analyzing the data and generating verbal, tabular, and graphic reports of the results.

Once the data have been obtained from the questionnaire, reliability and validity are assessed using the approaches detailed in Chapters 5 and 6. Some of the cross-checking procedures described for the interview can also be employed to assess the validity of factual information provided on the questionnaire. Examples include checking responses against external sources of information such as hospital or clinic records, and including consistency checks within the questionnaire itself, whereby the same information is requested in more than one way.

**ADVANTAGES AND DISADVANTAGES**

The questionnaire has several advantages as a measurement instrument. Major advantages are its cost efficiency and convenience, particularly when the sample is large and/or geographically dispersed and time and funds are limited. The questionnaire is more time efficient and convenient than the interview, not only for the investigator, but also for the respondent, who is often able to plan the self-administration time, pace, and setting independently. Certainly the time and cost savings for the investigator are considerable when the questionnaire comprises exclusively closed-ended questions that can be scored by a scanning device or administered via computer, including
touch screens. Computer administration permits immediate scoring and tabulation of results (see Sue & Ritter, 2007). Another advantage is that its impersonal and standardized format assures that all respondents are exposed to uniform stimuli. Such a feature increases reliability, facilitates comparison across respondents, and removes interviewer bias as a threat to validity. The questionnaire also allows complete anonymity to be preserved, a feature that is believed to increase the validity of response, especially to sensitive issues and personal questions.

The disadvantages of the questionnaire include low response rates, high rates of missing data, inability to rectify respondents’ misunderstandings, inability to adapt questions and their wording to respondents’ individual needs and styles, inability to probe complex issues in depth, and, for mailed questionnaires, inability to control the conditions of administration. Problems related to clarity of meaning may not be identified until after data are collected; however, this disadvantage can be largely eliminated through careful pretesting. The questionnaire can be used only by literate respondents, a factor that limits its use for many populations of interest in nursing practice and research.

REFERENCES


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The Delphi technique is a survey method designed to structure group opinion and discussion (Goodman, 1987), generate group consensus (Isaac & Michael, 1995), and quantify the judgments of experts (Aron & Pogach, 2008), assess priorities (Tolson and colleagues, 2005), or make long-range forecasts (Linstone & Turoff, 1975; Kennedy, 2004), and develop measurement instruments (Brehaut et al., 2008; Guangyi, Chongsuvivatwong, Geater, Ming, & Yun, 2009). In addition, Linstone and Turoff (1975) suggest the following variety of applications for the Delphi technique:

1. Gathering current and historical data not accurately known or available
2. Examining the significance of historical events
3. Evaluating possible budget allocations
4. Exploring planning options
5. Planning program and/or curriculum development
6. Collating the structure of a model
7. Delineating the pros and cons associated with potential policy options
8. Developing causal relationships in complex economic or social phenomena
9. Distinguishing and clarifying real and perceived human motivations
10. Exposing priorities of personal values and/or social goals (p. 4)

In nursing and health research, the Delphi technique has been employed for more than three decades. Early on the technique was applied primarily to determine the direction and priorities for future research. For example, in an early effort to determine the direction of future nursing research, primary clinical areas in need of research were identified using a Delphi survey conducted by the Western Interstate Commission for Higher Education (WICHE) (1974). The resulting priorities were instrumental in guiding the design of clinical nursing research (Brockopp & Hastings-Tolsma, 2003).

More recently, the emphasis has expanded to use of the Delphi technique for the analysis of policy issues, formulation of health policies, assessment of health-related outcomes and determination of their relevance as a basis for practice and as a basis for developing measurement instruments. For example, Brehaut and colleagues (2008) employed a rigorous Delphi methodology to develop a checklist used in a mixed-method study to determine if decision aids help people make decisions about participating in clinical trials. Aron and Pogach (2008) employed the Delphi method to inform performance measurement development based on quality indicators for diabetes mellitus in the ambulatory setting, and researchers at the Evidence-Based Practice Center, University of Alberta, Canada (Agency for Healthcare Research and Quality [AHRQ], 2007) employed a Delphi method to develop a set of parameters to describe meditation practices included in studies to ascertain health-related outcomes, study relevance, and methodological quality.

**CONDUCT OF THE DELPHI TECHNIQUE**

In its conventional form, the Delphi technique, also referred to as the Delphi exercise, is used in the following way:

1. A panel of experts on the topic of interest is identified. Selection of this panel of experts proceeds with care and concern that a variety of personalities, interests, perceptions,
predictions, or beliefs among all the experts on the panel. It should be noted that when an interactive computer is employed, the procedure is often referred to as a Delphi conference. By programming a computer to administer and compile panel results, it is often possible to eliminate the delay and, hence, reduce the cost accrued in summarizing each round of the Delphi.

Thus, the Delphi technique has four characteristics that distinguish it from other group decision-making processes: anonymity, interaction with feedback, statistical group responses, and expert input (Goodman, 1987). Linstone and Turoff (1975) suggest the following as circumstances in which the Delphi is most appropriately employed:

- The problem to be addressed does not lend itself to precise analytical techniques but can benefit from subjective judgment on a collective basis.
- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.
- Input is needed from more individuals than can effectively interact in a face-to-face exchange.
- Time and cost make frequent group meeting infeasible.
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.
- The heterogeneity of the participants must be preserved to assure validity of the results, that is, avoidance of domination by quantity or by strength of personality (“bandwagon effect”). (p. 4)

### ADVANTAGES AND POTENTIAL LIMITATIONS OF THE DELPHI TECHNIQUE

The Delphi technique is appealing because of its adaptability to a variety of data collection
settings. Experts are usually those individuals who are most involved in a variety of undertakings, are busy, and are located in varied and scattered geographical locations. Hence, this approach affords an opportunity to gain input from experts without the difficulties inherent in gaining personal access to such a population. Similarly, experts need not adjust their busy schedules to attend a meeting, be subject to influence by other experts, or relinquish their anonymity—all factors tending to further minimize biases in the resulting data. Anonymity is viewed as advantageous by some who believe that it encourages opinions that are not influenced by peer pressure or other extrinsic factors (Goodman, 1987); others, including Sackman (1975), believe that anonymity leads to a lack of accountability. He notes that in the majority of Delphi studies, where individuals are recruited because of their expertise, less accountable responses may be minimized.

Another advantage of the method stems from the fact that it provides for condensing the opinions of many and varied experts on a topic into a few precise and clearly defined statements. Critics of the Delphi method assert that results represent the opinions of experts and may or may not be consistent with reality. Similarly, Linstone (1975) notes that there are uses of the Delphi technique for which it is obvious that experts do not exist, such as quality-of-life studies where, he states, one would want to ensure representation of all relevant social and cultural groups. Attention to variance in the selection of the panel members as well as precision and care to avoid overgeneralization in reporting of findings can do much to minimize these concerns.

Opinions regarding use of the Delphi technique have been varied. Some (Chaney, 1987; Delbecq, 1975; Janis, 1978) characterize the Delphi as fast, inexpensive, understandable, and versatile, while others believe a major disadvantage of the technique relates to the need for multiple data collections, analyses, and processing that is to a large extent dependent upon a speedy response by busy experts. Prior to using the Delphi technique, it is wise to ascertain if the benefits to be gained from the effort outweigh the actual cost.

Several authors have noted potential pitfalls to be avoided when using the Delphi technique. These include but are not limited to:

1. Overstructuring the Delphi by the investigator, thus disallowing the respondents an opportunity to contribute other perspectives related to the problem
2. Excessive vagueness of the Delphi, reducing the information produced by respondents
3. Using inadequate techniques for summarizing and presenting group responses
4. Ignoring and not exploring disagreements so that discouraged dissenters drop out and an artificial consensus results
5. Underestimating the demands on respondents to participate and failing to properly compensate them for their time if the Delphi is not an integral aspect of their job function
6. Overgeneralizing results
7. Taking inadequate care to obtain a large, representative sample of experts (Linstone & Turoff, 1975, p. 6; Linstone, 1975, pp. 573–586; Sackman, 1975, pp. 5–27)

In some cases, modifications of the Delphi technique, if undertaken with an eye to preserving the basic integrity of the method, may be more desirable than the specific steps of the conventional procedure outlined. For example, Turoff (1975) points out that the Delphi as originally designed was intended to deal with technical topics and to obtain consensus among homogeneous groups of experts. When employed for delineating the pros and cons associated with potential policy options, the Delphi instead seeks to generate the strongest possible opposing views on the potential resolutions of a major policy issue. He asserts that a policy issue is one for which there are no experts, only informed advocates and referees. Hence, in this case, the expert is redefined as an advocate for concerned interest groups within the society or organization involved with the issue.

Furthermore, the policy Delphi rests on the premise that the decision maker is not interested in having a group generate his or her decision, but rather, in having an informed group present
all the options and supporting evidence for his or her consideration; that is, the policy Delphi is a tool for the analysis of policy issues and not a tool for making a decision, it is a decision-analysis tool versus a decision-making tool. Hence, generating consensus is not the prime objective, and in some cases, the design of the Delphi may be altered to inhibit consensus information (pp. 84–101). Those interested in an example of how the Delphi technique has been employed in the area of health policy formulation will find an article by Moscovice (1978) useful.

**APPLICATION OF THE DELPHI TECHNIQUE IN NURSING AND RESEARCH**

Varied ways in which the Delphi technique has been applied in nursing and health research are further exemplified in the following published works. Lindeman (1975) reported in *Nursing Research* the results of a Delphi survey of priorities in clinical nursing research obtained from a panel of 433 nurses and nonnurse experts. Potential panel members were sought through correspondence to nursing organizations, military officials, allied health organizations, funding agencies and foundations, personal contact, and review of published rosters and membership lists. Expert was operationally defined as a person knowledgeable about clinical practice as well as one who had an appreciation for research. The Delphi procedure in this study consisted of four survey rounds:

- **Round I:** Identification of burning questions about the practice of nursing
- **Round II:** Response to a 150-item questionnaire answering the following questions:
  a. Is this an area in which nursing should assume primary research responsibility?
  b. How important is research on this topic for the profession of nursing?
  c. What is the likelihood of change in patient welfare because of research on the topic?
- **Round III:** Response to the same questionnaire with statistical summary of Round II responses
- **Round IV:** Response to the same questionnaire with statistical summary of Round III response and minority report. (p. 436)

The scale underlying responses to the 150-item questionnaire ranged from 1 to 7 with the higher number referring to the greater value or impact of the question. Statistical summaries provided during rounds III and IV included for all three questions and for each item: the individual panel member’s response; the median for the total panel; the response range; and the interquartile range. In round III respondents were asked to comment on statements for which they answered outside the interquartile range and then round IV included a 79-page minority report of all the comments of respondents who were outside the interquartile range in round III of the study. The first round of the study began in March 1974, and the final input was completed by September 1974. The report of this study provides numerous examples of questionnaire items and procedures that would be worthwhile reading for those interested in employing the Delphi method.

Another example of the use of the Delphi technique in nursing appeared in a 1981 issue of the *Journal of Nursing Administration*. In this instance, Ventura and Walegora-Serafin reported on the results of a Delphi survey of 347 nursing administrators, clinical nursing staff, and nursing researchers in Veterans Administration (VA) hospitals nationwide in order to identify priorities for nursing research specifically related to the care of the veteran. Potential participants in this study were identified by letters sent to the chiefs of nursing service in 170 VA medical centers and independent clinics. The Delphi procedure included three rounds. During round I each nurse willing to participate submitted three questions related to the nursing care of the veteran believed to warrant study. A group of three nurses then classified the questions into general topic areas and developed 73 statements related to the care of the veteran patient. In rounds II and III nurse participants reviewed and rated each of the 73 statements using a scale of 1 to 7 in terms of the question: “What would be the magnitude of the impact on the care of the veteran patient if increased knowledge was available in this
A rating of 1 indicated the least impact and 7 the greatest impact. In addition, during round III, respondents reviewed feedback consisting of their own individual rating and the group median for each of the 73 statements from round III (p. 31).

Akins (2003) employed a Delphi technique in developing a process-centered tool for evaluating patient safety performance and guiding strategic improvement in patient safety systems in health care institutions. The tool consists of critical processes and performance measures identified within the context of the 2003 Malcolm Baldrige National Quality Award (MBNQA) Health Care Criteria for Performance Excellence. A series of questionnaires was used to collect data from 23 health care quality improvement experts representing 18 states. The Delphi employed three rounds.

Round 1 employed a questionnaire based on review of the literature and MBNQA criteria for excellence in health care. Experts were asked to rank the critical processes and performance measures on a Likert-type scale ranging from 1 (unimportant) to 4 (very important), to add any critical process or performance measure they believed should be included in the questionnaire, and to edit all processes and measures as they deemed appropriate.

Round 2 employed a questionnaire that included all critical processes and performance measures in the original questionnaire as well as three additional processes and 12 measures provided by the experts during the first round. The group rank mean for each process and measure from the first round was included as well as the individual participant rank for each variable. Experts were asked to review the group scores and reevaluate their individual responses given during round 1. Changes of ranks were allowed in the process of building consensus.

Round 3 included processes and measures for which consensus was not reached during the second round, along with all critical processes and performance measures suggested by experts during the first iteration.

At the conclusion of round 3, consensus was reached about the current and future importance of patient safety critical processes and performance measures. On the basis of the Delphi findings, a patient safety applicator tool for an institution-wide systems approach to introducing, maintaining, and improving health care patient safety systems was created. The criteria for inclusion of processes and performances in the tool were based on the group mean rank and the standard deviation of the importance of the items in the Delphi surveys.

In a report of a Web Conference sponsored by AHRQ (2003) on the topic of information/communication technology and monitoring and surveillance systems in bioterrorism preparedness, the use of a Delphi technique in developing an automated decision support system to assist the clinician in detecting anthrax or smallpox was discussed. Specifically, steps to be taken include (1) assembling signs and symptoms of anthrax and/or smallpox; (2) creating a Delphi panel comprising experts who would assist the clinician in outlining those signs and symptoms and in what order they appear, and (3) constructing with the assistance of informaticians or computer engineers a differential diagnosis along with probabilities around signs and symptoms.

The Agency for Healthcare Research and Quality (AHRQ) (2008) developed a consensus-driven quality assessment instrument for evaluation of hospital-based domestic violence programs. Jeffery H. Coben, MD, AHRQ Domestic Violence Senior Scholar in Residence, based the tool on the views of national experts who took part in an AHRQ-funded Delphi process. The tool can be used to assess the quality of a hospital's performance in implementing a domestic violence program and to create program goals, assess performance over time, and compare one program to another. Results of this measure can be linked to outcomes to determine what parts of the program create the best outcomes for victims of domestic violence. The tool measures nine different categories of performance: (1) policies and procedures, (2) physical environment, (3) cultural environment, (4) training of providers, (5) screening and safety assessment, (6) documentation, (7) intervention services, (8) evaluation activities, and (9) collaboration (p. 8). A panel of 18 experts on domestic violence, including researchers, program planners, and advocates, evaluated and agreed on 37 performance measures in these nine categories that can be used to evaluate hospital-based domestic violence programs.
programs. Each performance measure within a category is assigned a score and the scores are added to obtain a total score for the category. The raw scores are then weighted and the weighted scores added to obtain a total score, with 100 being the best possible score. Field testing of the instrument was conducted to determine its feasibility and interrater reliability. Reliability testing was conducted at four different hospital sites, using two different pairs of coders. One pair were experienced and familiar with the tool and the other pair were inexperienced and received minimal training. Resulting Cronbach’s alpha coefficient values ranged from 0.97 to 0.99 from the experienced coders and 0.96 to 0.99 for the inexperienced coders.

Guangyi and colleagues (2009) applied the Delphi technique to identify screening questions for chronic low back pain from traditional Chinese experts’ opinions. Their goal was to obtain a standard list of traditional Chinese medicine (TCM) symptoms and signs for screening low back pain from a group of experts and to assess agreement and consistency among their opinions on the items of a questionnaire.

The study design involved 3 rounds of a modified Delphi technique, carried out by 13 experts in orthopedics, massage, and acupuncture working in four hospitals affiliated with a traditional Chinese medicine university in China. Using a Likert scale ranging from 1 (not important) to 5 (very important), experts rated 12 pain characteristics, 11 associated factors, and 25 physical and tongue diagnostic expressions identified in 8 textbooks as important factors in TCM diagnosis of low back pain. After 3 rounds, 13 characteristics were eliminated from the list resulting in the following final numbers: 8 characteristics, 11 associated factors, and 16 physical and tongue diagnostic expressions. Further, 7 items based on Western medicine were added by the experts.

The value of the intraclass correlation coefficient (ICC) employed to assess agreement among the experts at the end of round 3 was 0.2. ANOVA of items appearing in all 3 rounds revealed significant effects of expert and group symptoms and signs ($p < 0.001$) and no significant differences were found among scores of the same expert in the 3 rounds ($p = 0.97$). Mean score of physical and tongue expressions was significantly ($p < 0.001$) lower than that of all other groups of signs and symptoms. Based on these findings, the researchers concluded that modern TCM experts have deemphasized the items on physical and tongue expressions and instead have adopted those from Western medicine. Further, intraexpert agreement across items was low, indicating that each expert tended to stay with his or her original opinions.

Readers interested in learning more about the use of the Delphi technique in nursing research are referred to the work of Keeney, Hasson, and McKenna (2006) who present a cogent discussion of lessons learned and issues encountered using the Delphi technique in their nursing research efforts. Additional examples of application of the Delphi technique can be found in the following sources. Hall and Slembrouck (2009) employed a Delphi procedure in a study of professional categorization, risk management, and interagency communication in public inquiries into disastrous outcomes. Breault and colleagues (2008), in a mixed-method multistage study to determine if patient decision aids help people make good decisions about participating in clinical trials, used a rigorous Delphi methodology to develop a checklist employed in the assessment of a stratified random sample of 50 consent documents from recently completed clinical trials. Gabb (2006) employed a Delphi method in a multidisciplinary child protection research study. Larson (1984, 1986) used a Delphi survey of practicing nurses on caring behaviors and a study of patient’s perceptions of nurse caring behaviors as a preliminary step in identifying nurse caring behaviors that served as the basis for the subsequent development of the Caring Assessment Report Evaluation Q Sort that is still widely employed in nursing research and practice (Watson, 2003). Melnyk (1990), interested in the reasons why people do or do not seek health care, employed a Delphi technique to operationalize the concept of barriers. Kim, Oh, Kim, and Yoo (2002) employed a Delphi procedure to determine priorities for nursing research in Korea. Tolson and colleagues (2005) used a Delphi technique in which members of a panel ($n = 33$) were asked to identify the most important current policies relating to the provision of high-quality nursing care...
in long-term care environments in Scotland. During the second round of the study, a survey was mailed to nurses ($n = 2000 +$) to explore their awareness of, access to, and use of policies identified in the first round. Readers interested in more examples of the use of the Delphi in nursing and health research can find them by searching “Delphi” on the Agency for Healthcare Research and Quality (AHRQ) Web site: http://search.ahrq.gov/.

**SUMMARY**

The Delphi technique is a survey method useful in generating group consensus and quantifying judgments of experts for a variety of purposes. In nursing and health research, the Delphi has been applied for a variety of reasons, including but not limited to, the analysis of policy issues, formulation of health policies, assessment of health-related outcomes and determination of their relevance as a basis for practice. Four characteristics that distinguish the Delphi technique from other group decision-making processes are anonymity, interaction with feedback, statistical group responses, and expert input. Advantages regarding use of the Delphi include that it is fast, inexpensive, understandable, and versatile, while disadvantages relate to the need for multiple data collections, analyses, and processing that to a large extent is dependent on speedy responses from busy experts. Applications of the Delphi technique in nursing and health research have been varied and have served several important purposes. Prior to employing the Delphi technique, it is wise to ascertain if the benefits to be gained from the effort outweigh the actual cost.

**REFERENCES**


Visual Analog Scales

Visual analog scales (VAS) are typically used to measure the intensity, strength, or magnitude of individuals’ sensations and subjective feelings and, less often, the relative strength of their attitudes and opinions about specific stimuli and the frequency of engaging in specified behaviors, such as adherence to a therapeutic regimen (e.g., Amico et al., 2006; Ivanova et al., 2008). VAS are among the most popular measurement devices in nursing research, in large part because they are easily administered in a variety of environments, even atop mountains (Wagner, Tatsugawa, Parker, & Young, 2007). It is a very common approach to measuring the intensity of symptoms. Visual analog scales employ a drawn, printed, or computer-generated straight line of a specified length, with verbal anchors at each end, to represent a subjective state or stimulus, such as pain (Adachi, Shimoda, & Usui, 2003; Chantler, Mitchell, & Fuller, 2009; Raven et al., 2008; Tittle, McMillan, & Hagan, 2003; Winkelman, Norman, Maloney, & Kless, 2008); dyspnea (Dorman, Byrne, & Edwards, 2007; Gift & Narsavage, 1998; Goyal, Logie, Nadar, Lip, & Macfadyen, 2009); fatigue (Khanna et al., 2008; Montgomery et al., 2009); nausea (Lasheen, Walsh, Hauser, Gutgsell, & Karafa, 2009; Sah et al., 2009; Ward et al., 2002); and health-related quality of life (Grandy & Fox, 2008; Pickard et al., 2009). An alternative is a mechanical VAS using a plastic mechanical 0–10-cm slide ruler (Prushansky, Handelzalts, & Pevzner, 2007). VAS may be included as a component of a more complex instrument; for example, the EQ-5D, a measure of health-related quality of life, combines a questionnaire with a VAS (see Whynes & the TOMBOLA Group, 2008).

Although VAS lines can range from 50–200 mm, typically, a 100-mm line with right-angle stops and anchor phrases at each end is used. It can be drawn either horizontally or vertically; however, the horizontal format is most common. The anchors usually depict extreme states, ranging from absence of the sensation (e.g., “no pain”) to maximum intensity (e.g., “worst pain imaginable”). The line can be drawn without any numbers or calibrations, or numbers from 0 to 10 can be placed at equal intervals below it. The latter variation is sometimes called a numerical rating scale, but also is referred to as a VAS in the literature (e.g., Khanna et al., 2008). The VAS has been used in computer-assisted data collection as well as in paper-and-pencil studies (e.g., Amico et al., 2006; Ramachandran, Lundy, & Coons, 2008).

The subject is instructed to place a mark on the line to self-report the intensity or quality of his or her perception of the sensation or other quality being experienced. The scale is scored by measuring the distance, usually in millimeters, from the low end of the scale to a specified place on the subject’s mark, often the extreme bottom or left margin of the mark. The data are usually treated as being at least interval level. There is controversy about the level of measurement, however. Although some researchers argue that VAS are ratio level, there is little evidence to suggest that, for example, a score of 40 on a VAS measuring pain represents half the intensity of pain rated as 80 or that ability to judge ratios is the same at all points along the VAS line (Wewers & Lowe, 1990). In the case of the computer-assisted use of the VAS by Amico and colleagues (2006), respondents were instructed that they could mark either anchor or “on any 10% increment in between” (p. 456). This nontraditional approach more closely resembles a numerical rating scale (NRS) than the traditional VAS because responses are limited by the number of incremental categories delineated.

Visual analog scores tend to correlate positively with scores on 10-point NRS or the more easily administered verbal numerical rating scales.
Part IV Instrumentation and Data Collection Methods

subjects may require repeated instruction. For some populations, such as children and cognitively impaired adults, a more easily understood visual scale, such as a pain thermometer, which is actually a special case of the VAS (Wewers & Lowe, 1990), can be substituted for the traditional line (Taylor & Herr, 2003). In general, however, people do not have a great deal of difficulty using the VAS format, and it has been used successfully even in high-stress, high-volume clinical settings, such as emergency departments.

The VAS in its traditional form is presented on paper to the subject. It can be handed to the respondent on a clipboard or incorporated as a page on a mailed questionnaire. The data collector may have to mark the scale for subjects who have motor difficulties or are otherwise unable to hold or use a pencil. The subject indicates when to stop, and the data collector marks the line accordingly. Recent developments in technology permitting the use of handheld computers or PDAs for data collection have opened up new possibilities for administering the VAS (e.g., Amico et al., 2006). For example, Ramachandran and colleagues (2008) compared paper-based and computer touch-screen-based versions of the EQ-5D quality of life instrument and found that they yielded equivalent results.

Visual analog scales are scored by measuring the distance of the respondent’s mark from the end of the scale in millimeters. Generally the low end is used as the zero point on the scale. To ensure consistency of scoring, rules are established before scoring begins to address such issues as the exact point on the line to be designated zero (e.g., outside or inside the vertical end marker), which border of the respondent’s mark will be used, and how the mark will be scored if it falls between calibrations on the ruler. If more than one ruler is being used, they should be compared to ensure that they are identical so that systematic bias can be avoided. Such issues will become less problematic with the shift to computerized administration and scoring.

RELIABILITY AND VALIDITY

Reliability of visual analog scales is most frequently assessed using the test-retest method,
and correlations between the two administrations have been moderate to strong (e.g., Wagner et al., 2007); however, Wewers and Lowe (1990) have pointed out that this method of reliability assessment is unacceptable because the phenomena that are rated with VAS tend to be highly dynamic, and are likely to change from day to day or even moment to moment. A low coefficient of reliability that could result from applying test-retest reliability assessment to a dynamic attribute may accurately be measuring change in the actual stimulus, rather than any problem with the scale itself. Good and colleagues (2001) argue that test-retest reliability can be used when the sensation is believed to be quite stable (e.g., chronic pain) or when a short retest interval is used (e.g., 15 min). On the other hand, Prushansky and colleagues (2007), based on a study of chronic pain in whiplash patients, recommend that VAS scores be used to monitor change in chronic pain only if the initial score is above 4, because reliability was unacceptable at lower levels. A second problem relates to subjects’ recalling their rating on the original test and allowing that to influence the retest rating. The ultimate outcome in such confounding situations is questionable reliability. Internal consistency reliability cannot be assessed on one-item measures. Interrater reliability needs to be assessed if scoring is being done by more than one person.

Reliability of the method itself has been assessed in a number of studies. Issues examined have included reproducibility of previous ratings at various points along the line (more accurate at the extremes than in the middle ranges), the length and position of the line, the position of the subject (may be problematic for patients in bed), the visual and motor ability of the subject, and the influence of making previous ratings available to the subject (Wewers & Lowe, 1990).

The validity of visual analog scales has been assessed using several methods. The most common approach is to correlate visual analog scale scores with other measures of the phenomenon. Acceptable levels of concurrent or convergent validity have been substantiated for both affective states and sensations (Bijur et al., 2003; Good et al., 2001; Winkelman et al., 2008). A contrasted groups approach was used by Good and colleagues (2001) to assess both the construct and discriminant validity of sensation and distress VAS for pain. Discriminant validity using the contrasted groups approach has also been established for some VAS measuring mood and quality of life (Padilla et al., 1983); however, Lowe and Holm (1988, reported in Wewers & Lowe, 1990) found only limited support for discriminant validity when using a multitrait-multimethod approach to assess the convergent and discriminant validity of the VAS as a measure of pain and anxiety in laboring women.

**ADVANTAGES, DISADVANTAGES, AND USES**

Visual analog scales’ major advantages are their ease of use, acceptability to respondents, sensitivity to subtle fluctuations in levels of the stimulus, and reliability and validity coefficients that are often similar to more time-consuming and complex measures. Because they can be administered rapidly, visual analog scales are often preferable to measures that make greater time and effort demands on ill or busy respondents.

Visual analog scales use uncomplicated language and are easily understood by most subjects; however, some populations, such as the elderly, children, and those with cognitive limitations, may find the VAS too abstract. With some modification in the scale, children may be able to use the VAS successfully (see Hamunen, Maunuksela, & Olkkola, 2008). On the other hand, people who are visually oriented may find it easier to express the magnitude or intensity of a subjective state on a VAS than on more verbally oriented scales. The former may also be easier than numerical scales for people who have difficulty comprehending the meaning and placement of numbers. Compared with measures that require subjects to rate the intensity of their moods, feelings, or sensations on a categorical scale or checklist, visual analog scales do not constrain subjects to a limited number of possible responses, but allow them to place their response at any point on the continuum. This feature allows visual analog scales to be more sensitive to subtle changes
than categorical scales, because potentially finer distinctions can be made. Therefore, they are useful for measuring change over time in the same individual.

Disadvantages of visual analog scales include their unidimensionality, problems related to inaccurate reproduction and scoring, and difficulties associated with administering them in print. Most symptoms are conceptualized to have several measurable dimensions. Severity or intensity (the dimension that is most often measured by a VAS) is only one of the measurable dimensions (see Gift, 2009; Lenz & Pugh, 2008; Lenz, Pugh, Milligan, Gift, & Suppe, 1997). Verbally presented numerical rating scales, while less sensitive, may be easier than the VAS to administer in clinical settings, and tend to be more commonly used there. VAS can be used to track changes in the magnitude of a sensation or mood over time; however, the impact of testing effects may compromise validity, particularly if the interval between measurements is short. Another disadvantage is that they should not be used to analyze differences across subjects and populations, because it is impossible to assume that a given stimulus has the same meaning to everyone to whom the instrument is administered (Kane, Bershandsky, Rockwood, Saleh, & Islam, 2004). Kane and colleagues have developed a standardization approach that should facilitate the interpretation of VAS pain scores across individuals, interventions, and populations.

The VAS is a useful measurement approach. Its relative ease of administration and interpretation and the ability to track changes in symptoms and other characteristics over time have made it a favorite of clinicians and researchers. Computerized applications have removed many of the objections to its use in practice.

REFERENCES


Chapter 17 Visual Analog Scales 323


Magnitude estimation scaling (MES) is a technique used to measure and compare the perceived magnitude of stimuli. Originally developed in the field of psychophysics to measure the intensity of physical stimuli, such as sound (Stevens, 1975), other applications have gone beyond the original applications in two ways. In addition to measuring strength or intensity of stimuli, MES has been used to measure their clarity, intelligibility, complexity, difficulty, or perceived importance. Also, the stimuli that have been rated have gone beyond physical stimuli, such as light or recorded sounds, to include physiological states, such as breathlessness (Meek, Sennott-Miller, & Ferketich, 1992) or dyspnea (Nield, Kim, & Patel, 1989), or stimuli with social meaning, such as tasks (Sullivan-Marx & Maislin, 2000), nursing diagnoses (Grant, Kinney, & Guzzetta, 1990; Kinney & Guzzetta, 1989), or goals (Sennott-Miller, 1994).

The most common approach to MES is that subjects rate the magnitude of a stimulus relative to one of standard strength. For example, subjects might be asked to rate the magnitude of several different pain-inducing stimuli (e.g., electric shocks that vary in intensity) by comparing each to a standard, that is, a shock of mid-range intensity that is provided at the outset of the measurement. Most commonly, the standard stimulus is given a value (usually an easily understood number such as 10 or 100) by the investigator; however, in some cases the rater is asked to assign his or her own value to the first stimulus presented or to choose from a list the stimulus that he or she believes to be of medium or average strength. The rater is then presented with several randomly ordered stimuli and asked to assign a number to each that reflects his or her perception of its strength or importance in proportion to the standard. For example, if the stimulus is a recording of an infant’s cries and the loudness value of the standard is 10, then a cry perceived to be twice as loud would be given a value of 20, and one-half as loud would be given a value of 5. The ratings of each stimulus, therefore, are relative to the value of the standard stimulus. Generally, there are no restrictions placed on the range of numbers raters can use, except that they are instructed to assign higher numbers to stronger stimuli. Because the task of assigning proportional values to their perceptions may be difficult for some subjects, a training session with a trial exercise ordinarily precedes carrying out the ratings for data collection purposes. For detailed information the reader is referred to Duncan (1984), Gescheider (1988), Lodge (1981), Sennott-Miller, Murdaugh, and Hinshaw (1988), and Wills and Moore (1994).

In the classical psychophysical experiments, physical stimuli of varying magnitudes were administered and subjects were instructed to estimate their relative magnitudes. Physical stimuli, such as audiotaped samples of speech or other sounds, or even food samples that differ in a quality such as saltiness are currently being used in fields such as discrimination psychology, perception psychology, and psychoacoustics (e.g., Bettagere & Fucci, 1999; Ellis, 1999; Ellis & Pakulski, 2003; Fucci, McColl, & Petrosino, 1998; Fucci, Petrosino, McColl, Wyatt, & Wilcox, 1977). MES is a technique commonly used in speech and hearing research (Beltyukova, Stone, & Ellis, 2008; Ellis, 1999; Ellis & Pakulski, 2003; Whitehill, Lee, & Chun, 2002). In behavioral science and nursing research, narrative or verbal stimuli that represent psychological or social phenomena tend to be used. For example, Sullivan-Marx and Maislin (2000) asked RNs to rate the work value (time and intensity of work...
required to carry out the procedures) of various CPT codes relative to a standard procedure. Sennott-Miller (1994) asked women to rate specific cancer prevention activities in terms of the perceived difficulty of adopting the behavior and the likelihood that they would adopt or maintain the behavior in the year ahead. In most of the above research, the focus was on ascertaining differences between the stimuli, rather than between the individuals rating them. It is also possible to use MES to compare the subjective states or comparative judgments of individuals or groups.

Typically stimuli are the variables that are rated and compared. Scores are usually analyzed for specific stimuli across subjects, with a mean, median, or geometric mean of subjects' ratings computed for each stimulus. (For example, infant cries of varying intensity can be the stimuli which subjects are asked to evaluate and for which frequency distributions are computed.) Although Lodge (1981) argued that the geometric mean (the antilog of the mean of the logs of the subjects' numerical responses) is the most appropriate measure of central tendency to use with magnitude estimation data, arithmetic means are more commonly used in nursing and in current speech and hearing research. Magnitude estimation scaling generally yield curvilinear data that, when plotted logarithmically, yield linear relationships that can be analyzed using least-squares statistical procedures. Although one of the claimed benefits of magnitude estimation scaling is that it results in ratio-level data, there is disagreement about whether this is really the case (Lodge, 1981; Wills & Moore, 1994).

USES, ADVANTAGES, AND DISADVANTAGES

Magnitude estimation scaling has been used to study psychophysical questions related to sensations, and to study psychological and social phenomena. Some examples of uses in the psychosocial realm include comparative ratings of task difficulty, language ambiguity, social status, occupational prestige, the seriousness of criminal offenses, strength of opinion, and goal difficulty and attainability. A decision about whether to use MES is usually based on its advantages and disadvantages relative to the simpler and more common approach of categorical scaling. In the latter, the rater assigns each stimulus to a predetermined category that reflects its perceived value; Likert scales are examples. Some controversy exists about which type of scale is preferable, because when compared with the same stimuli and subjects, the relationship is often found to be curvilinear, rather than linear. When compared to categorical scaling, MES has the advantage of forcing the rater to make proportional comparisons rather than simply rank ordering the stimuli, therefore (at least theoretically) allowing finer distinctions and greater sensitivity. In nursing research categorical scaling is used more frequently than MES. Several comparisons of MES with equal-appearing interval scaling have been carried out with mixed results, a thorough discussion of which can be found in Wills and Moore (1994). In more recent speech and hearing research, categorical scales have been determined to be less appropriate than MES for rating some speech qualities, such as intelligibility, stuttering severity, and hypernasality, whereas either equal-appearing interval categorical scales or MES is appropriate for measuring the speech dimensions of "defectiveness of articulation" and foreign accent (see Whitehill et al., 2002).

Other proposed—but disputed—advantages of MES are that they yield ratio scales (Lodge, 1981), can detect small variations in perceptions, have high reliability, and can be used to specify the form of functional relationships and to determine the rate and impact of change (see Lodge, 1981; Wills & Moore, 1994).

Magnitude estimation scaling is not an easy technique for raters to use, because it requires abstract and complex thinking. Therefore, it may be inappropriate for several types of subjects whose perceptions are of interest in nursing research: those who are ill or in pain, experiencing stress, have difficulty understanding instructions, or are of below-average intelligence. It is inappropriate for use with most children. Even when used with subjects who seem able to carry out the complex thinking involved, it is imperative to provide training and practice exercises, and to provide instructions that are clear and complete.
In general, these limitations have resulted in a decline in interest in magnitude estimation scaling in nursing research.

RELIABILITY AND VALIDITY

Reliability assessment in MES is generally accomplished by means of the test-retest reliability procedure. Both interrater and intrarater reliability have been computed, with coefficients between 0.51 and 0.99 reported. For example, Whitehill et al. (2002) used as stimuli recorded samples of five predetermined sentences read by 20 speakers who had had primary cleft palate procedures. The listener sample was 20 undergraduate college students who passed an audiological screening test. Two of the speaker samples were repeated, so were scored twice by the listeners to examine intrarater reliability. Pearson product–moment correlations ranged from 0.67 to 0.95. Interrater reliability was calculated using Cronbach’s alpha, and ranged from 0.90 to 0.98. A recent example of a study in which both item (stimulus) and test-retest rater reliability were assessed was an investigation of naïve listeners’ judgments about the intelligibility of the speech of children with severe hearing impairment (Beltyukova et al., 2008). The stimuli for the study were 8 digitally recorded speech samples of hearing-impaired children telling a story. They were presented in random order to 55 study participants, all students in a communications class. Data were collected twice from each participant to assess test-retest reliability.

Validity is an important consideration in evaluating magnitude estimate scales. Particularly critical is that in order to be a valid measure of an individual’s perceptions, the rater has to understand and be able to carry out the scoring instructions. The majority of validity assessments in psychophysics have been carried out by comparing MES ratings with direct physical measurement of the stimulus (e.g., decibel level of a sound). Given the sophisticated instrumentation now being used in audiology research and practice, MES is being used less and less. Where gold standards exist for rating stimuli (e.g., word identification for scoring speech intelligibility) (Beltyukova et al., 2008), validity is assessed by comparing obtained MES ratings with the standard. The validity approaches in measures of social phenomena often involve comparing MES ratings with category ratings or interval scaling of the same stimuli. As noted above, the relationships discerned in most studies have tended to be curvilinear, rather than linear. Magnitude estimation scaling has limited applicability in nursing research and has little utility for practice. It should be considered when comparative matching of the strength of selected sensations, tasks, or opinions is required, provided the subjects are capable of handling the complexity of the measurement procedure. However, alternative, easier-to-use measures should be considered as well.

REFERENCES


Good tests don’t just happen! It takes hard work to create a good test. Any test is only as good as the items (questions) on the test. Multiple-choice items have been criticized on the grounds that they tend to test only at the knowledge or recall level. Unfortunately, this criticism is more reflective of the item writer than the item format. Multiple-choice items can test at the application level if they are carefully constructed. In fact, they are the most widely used type of item on certification examinations that test at the application level. Item writing has been described as “a rather demanding exercise in creative writing” (Thorndike, 1982) and as more art than science. “Just as there can be no set of formulas for producing a good story or a good painting, so there can be no set of rules that guarantees the production of good test items” (Wesman, 1971). Writing good items requires a combination of “soundness of values, precision of language, imagination, knowledge of subject matter and familiarity with examinees” (Wesman, 1971). No matter how hard writers try to produce quality items, an estimated 40% do not work as the writer intended (Haladyna, 2004).

A taxonomy of more than 31 item-writing principles has been developed based on an analysis of 27 educational measurement textbooks and 27 empirical research papers (Haladyna, Downing, & Rodriguez, 2002). However, the validity of many of the rules has not been studied. When these 31 principles were used to evaluate 40 continuing education items in 20 consecutive issues of a major journal, a total of 203 item flaws in the 40 items were identified. Each item had at least three item flaws, with a mean of 5 flaws. Given the use of multiple-choice items in the classroom, on licensure and certification exams, and for continuing education purposes, it is useful to review some guidelines for writing them.

As noted in Chapter 4, multiple-choice items consist of a stem followed by choices known as responses, options, or alternatives. One option is correct or best and the others are referred to as distractors or foils. Their role is to appear plausible to the less knowledgeable examinee, while the more knowledgeable examinee recognizes them as incorrect. Some general guidelines can be offered for constructing both the stem and the set of options:

1. Base the item on sound, significant ideas. Avoid testing trivial material and using “trick” items.
2. The item must have a clear correct or best answer. Do not ask for opinion.
3. Phrase items so that content rather than form determines the answer. For example, if the item contains double negatives or complicated sentences, then it most likely assesses test-taking skills and reading ability.
4. The vocabulary and difficulty of the item should reflect the group being tested. Items testing measurement concepts as part of an undergraduate research course, for example, would not use the same vocabulary as items testing measurement concepts in a doctoral level course.
5. Items must be independent of one another so that the answer to one does not depend on giving the correct answer to another. Sets of items about a case scenario can be an effective way of testing as long as the items themselves are independent.

**WRITING THE STEM**

**Stem Guideline 1**

The stem should include all the information the examinee needs to select the correct option. The stem is the most important part of an item because it poses the problem and serves as the stimulus for the response. In a quality item the stem will include all the information the examinee needs to select the correct or best option. One quick check on the clarity and completeness of a stem is to cover the options and try to anticipate the answer. If one has to read the options to determine what is being asked, then the stem is either not clearly written or it is incomplete. Examinees should not have to read the options to figure out what is being asked.

Either a completion format or a question format can be used for the stem. Be aware, however, that the completion format can increase test anxiety if the examinee has to try each option with the stem to determine the correct or best option. If the completion format is used, place the blank near the end of the stem. Also, the completion format can result in an ambiguous stem. For these reasons, the question format is preferred. Compare these two stems and decide which more clearly states the problem:

<table>
<thead>
<tr>
<th>Completion Format</th>
<th>Question Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>The consistency of responses is reflected in the ____ of the test.</td>
<td>Which measurement property reflects the consistency of responses?</td>
</tr>
<tr>
<td>A. generalizability</td>
<td>A. generalizability</td>
</tr>
<tr>
<td>B. believability</td>
<td>B. believability</td>
</tr>
<tr>
<td>C. reliability</td>
<td>C. reliability</td>
</tr>
<tr>
<td>D. validity</td>
<td>D. validity</td>
</tr>
</tbody>
</table>

**Stem Guideline 2**

Word the stem positively. Avoid stems such as “Which of the following is NOT true?” or “All of the following are true EXCEPT.” In one study of 200 students, the reliability was lower for items that were negatively worded, and the scores were artificially high when compared with questions requiring a true/false response (Harasym, Doran, Brant, & Lorscheider, 1993). It is easy to see why this is true. Consider this example:

All of the following are measures of reliability EXCEPT:

A. coefficient alpha
B. coefficient of stability
C. omega coefficient
D. coefficient of determination

An examinee might recognize the exception or the false option (in this case, option C) and yet not know that the coefficient of determination is a measure of reliability.

There may be times when it is appropriate and even necessary to use an “except” item. For example, it might be important to test whether a student knows that an intervention or a drug should not be used with a patient with a specific condition. As a general rule, however, one should use “except” items and other negative wording in the stem sparingly in order not to confuse examinees. If the stem includes words like “not” or “except,” they should be in **boldface** or **underlined** or **CAPITALIZED**.

**Stem Guideline 3**

Include as much information as possible in the stem and as little as possible in the options. More difficult items tend to have longer stems and shorter, more discriminating options. For example, if you want to test the definition of measurement error, do not use “What is measurement error?” as the stem. Rather, give the definition in the stem and present several similar terms as options. This guideline also means that if words need to be repeated in each option, they can be moved out of the options and put in the stem. In the following example, the word “validity” has been incorporated in the stem rather than repeated in each option:
What type of validity is assessed when the scores from two measures of the same variable are correlated?
A. concurrent
B. construct
C. content
D. predictive

**Stem Guideline 4**

Avoid “window dressing” or unnecessary wording. There may be times when it is important to include extraneous information in order to test the examinee’s ability to sort out what is important. For example, a stem may include more lab values than necessary so that the examinee is required to know which values are important in deciding what action to take next. Also keep in mind that an item stem is not the place to try to teach something. As a rule, including unnecessary information in the stem merely increases the reading time and it can be deleted without affecting clarity of the stem. For example:

There are several types of objective items that can be written for a classroom test to assess student learning. Each type has strengths and weaknesses that must be considered by the item writer. Which of the following is a type of objective item?
A. case study
B. essay
C. multiple choice

This item could easily be rewritten without the extraneous information, as follows:

Which of the following is a type of objective item for classroom tests?
A. case study
B. essay
C. multiple choice

**WRITING THE OPTIONS**

It goes without saying that one of the options should clearly be correct or best, and options should be grammatically correct and consistent with the stem. Items can be made more difficult by having options that are similar. Two other guidelines for writing the options are very important: distractors should be plausible and options should not provide clues for test-wise examinees.

**Option Guideline 1**

Use as many distractors as plausible. Multiple-choice items generally contain anywhere from 3–5 options from which the examinee selects the correct or best option. A good distractor (incorrect option) is one that is selected by less knowledgeable examinees, so it is important that distractors be plausible. Some recommend using 4 or 5 options while others recommend using as many distractors as plausible. Empirical evidence suggests there is no difference in the discrimination or item difficulty of comparable 3- and 5-option items (Owen & Froman, 1987). Having more options per item does tend to increase the reliability of a test, but only if the distractors are plausible. Unfortunately, in most cases, it is difficult for writers to develop four plausible distractors. In fact, a meta-analysis of more than 80 years of research supports the idea that 3 options are optimal (Rodriguez, 2005).

Haladyna and Downing (1993) examined items on three standardized multiple-choice tests and found that about two-thirds had only one or two effective distractors, leading them to recommend that 2- or 3-option items be used rather than 4- or 5-option items. For some items, only three options are possible. For example:

How does increasing the number of items on a test tend to change the reliability of a test?
A. decreases it
B. has no effect
C. increases it

Other researchers have examined the effect of eliminating nonfunctioning distractors (Cizek, Robinson, & O’Day, 1998). They found that when nonfunctioning distractors were removed from items, the reliability of the test increased, test-taking time decreased, and validity of the score interpretation increased. Given that the
plausibility of distractors is more important than the number of distractors, there is no advantage to having the same number of options for each item (Frary, 1995).

**Option Guideline 2**

*Construct options that are uniform in content, length, and grammatical structure.* Often item-writers try to ensure that no one will argue with the correct or best answer so more information or technical detail is added to that option. However, differences in content, length, and structure can often serve as a clue for the wise test-taker.

**Option Guideline 3**

*Avoid using “all of the above” or “none of the above” as an option.* Item-writers sometimes use these options when they cannot think of another plausible option. However, there are difficulties with each of these as an option. Consider the following item:

What is the capital of Missouri?

A. Rolla  
B. Columbia  
C. Kansas City  
D. None of the above

Test-takers may answer the item correctly by knowing that the first three choices are not the capital, but there is no indication of whether they know what is the capital. Also, the item asks examinees to select the correct response to the question and yet the options fail to provide the correct response. Generally, there is no advantage to using “none of the above” as an option. There is one exception, though: if the item requires computation, then “none of the above” can serve as a plausible option.

A similar problem exists with items that include the option “all of the above,” as in the following item:

Which of the following indices reflect reliability?  
A. alpha coefficient  
B. coefficient of stability  
C. generalizability coefficient  
D. all of the above

Test-takers who recognize that two of the first three options are correct will probably select “all of the above,” which is the correct response. Do they really know that all three are coefficients of reliability? In both instances—where “none of the above” and “all of the above” are options—the score for an individual would be artificially inflated.

**Option Guideline 4**

*Do not include specific determiners or absolute qualifiers in the options.* Sometimes an item writer will include terms like “all,” “none,” “always,” “never,” and so forth to make the option clearly incorrect. Test-wise students often can use the absolute as a clue that the option is incorrect when they are not certain of the correct answer.

**Option Guideline 5**

*Avoid overlapping options.* Such items may have more than one correct option and could even have all correct options. Consider this example:

An acceptable level of reliability for research purposes is:  
A. > 0.60  
B. > 0.70  
C. > 0.80  
D. > 0.85

In this instance, option A is correct given that it is the most inclusive option. Overlapping options also can occur if the options contain a range of values such as 0.10–0.20 and 0.20–0.30.

In summary, prior to using the multiple-choice items you have constructed, review them against the guidelines. Check the grammar, punctuation, spelling, and sentence structure. (Interestingly, incorrect options tend to have more grammar and spelling errors than the correct option since more attention is paid to the correct option.) Have you avoided cluing in the stem and/or options? Is there unnecessary wording? Are items independent of one another—that is, does answering one item
correctly depend on having answered another correctly? Using a case scenario with several items can be an effective testing strategy, but only if the items are independent of one another. Finally, remember that item writing is more art than science. The best way to learn to write quality items is to follow the old adage: practice, practice, practice!

REFERENCES


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Researchers and clinicians are interested in capturing a comprehensive view of the health and health alterations of their study participants and patients. Health, as defined by the World Health Organization, comprises three domains: medical or physiological, social, and psychological (Cieza, Bickenbach, & Chatterji, 2008). Researchers and clinicians are interested in measuring the physiological, social, and psychological well-being of their subjects and patients in order to determine the effectiveness of nursing interventions (Figure 20.1).

While clinicians are at the forefront using physiological measures to evaluate the condition and monitor the progress of their patients, nurse researchers have not readily incorporated physiological outcome variables in their research. The National Institute of Nursing Research (NINR) conducted a portfolio analysis of the 141 funded nursing research grants in 1988 and reported that of the total grants only 25% included the measurement of physiological variables (Cowan, Heinrich, Sigmon, & Hinshaw, 1993; Sigmon, 1993). NINR held a Biological Task Force meeting in 1990 and invited nurse researchers, nurse physiologists, pharmacologists, and exercise physiologists to develop strategies to enhance the use of cutting-edge physiologic measurements and techniques in nursing research (Sigmon, 1993). In 1991, Cowan developed a 10-year plan to enhance the educational opportunities and research training of nurse researchers to learn biomedical instrumentation and measurement techniques to capture physiological data. Recommendations included increasing the content about physiological measurement techniques in doctoral programs in nursing (Cowan et al., 1993). In addition, a Molecular Biology Nursing Research Task Force Meeting was held in 1992 to recommend strategies to facilitate the incorporation of genetics into nursing clinical practice and research (Sigmon, 1993). Thus, in the 1990s, there was a significant attempt to identify potentially useful biological measurement methods and develop strategies to increase the use of biological measures in nursing research. Genetics is an excellent example of this endeavor.

The Human Genome Project was completed in May 2006. This work provided a map of the entire human genome sequence that was published in a special issue of Nature (Zody et al., 2006) and is available at the Human Genome Project Web site: http://www.ornl.gov/sci/techresources/Human_Genome/project/about.shtml. As a result of this work, the clinical application of genetic technology is becoming a reality. Nurse researchers are now including genotyping and cellular genetic expression in their programs of research (Jarrett et al., 2007). In 2001, the National Coalition for Health Professional Education in Genetics (NCHPEG) issued a set of competencies that mandated new directions for nursing education and research (Jenkins, Blitzer, & Boehm, 2001) and Dr. Patricia Grady,
Director of the National Institute of Nursing Research, established the Summer Genetics Institute (SGI) to train selected nurse researchers, doctoral students, and advanced practice nurses in the techniques necessary to perform genomic research (Grady, 2003). Since 2000, the University of Iowa has offered postdoctoral training in genetics funded by the National Institute of Nursing Research (NINR) (Williams, 2002) and the Cincinnati Children’s Hospital now offers an online Genetics Education Program for nurses (http://www.cincinnatichildrens.org/ed/clinical/gpnf/default.htm). The International Society of Nurses in Genetics provides support and direction to educational resources for nurse clinicians and researchers with an interest in genetics. Thus, even though clinicians and researchers often are required to learn new measurement techniques to meet the future challenges applied to the clinical and research arena, there is an ever-increasing number of resources to support this learning.

More recently, Rudy and Grady (2005) examined the research contributions of biologically focused nurse researchers funded by NINR \((n = 31)\). Nearly half of these investigators had received postdoctoral training and a majority of this training was in areas that included physiology and neuroscience. The research of these investigators focused on understanding of biological systems and biological responses to illness and nursing interventions. Rudy and Grady (2005) concluded that a small, but developing group of nurse researchers are performing important biological research that contributed to the development of our understanding of multiple phenomena. In 2006, Grady reported that biobehavioral research that used biological measures to evaluate health and illness had become one of the primary foci of research supported by NINR. Thus, the use of biological measures has increased significantly over the past 2 decades.

This chapter provides an introduction to the principles of physiological measurement using biomedical instrumentation. An overview of biomedical instrumentation will be presented, as bio-instruments are the tools used to measure physiological variables. The major classes of physiological measurement including biophysical and biochemical will be addressed. Techniques to measure electrical activity, pressures, gases, lung volumes, temperature, metabolism, cellular products, and nucleic acids including DNA and RNA will be presented.

**BIOMEDICAL INSTRUMENTATION**

Biomedical instruments are electrical devices that measure physiological variables. Researchers and clinicians can make visual (cyanosis, edema, or breathing pattern) or auditory (heart
obtained by placing a surface recording electrode on the chest or scalp, respectively.

When conducting research, the method of measuring physiological variables (invasive vs. noninvasive) should be seriously considered. Biomedical human subjects committees who review grant proposals are responsible for evaluating the subject’s (human or animal) risks relative to the measurement technique. For example, there are known risks associated with invasive physiological monitoring of arterial pressure, including significant blood loss or extravasation, blood clotting, reduced blood flow to the distal extremity, and infection. Noninvasive, indirect, automated oscillating blood pressure monitoring may be used to determine blood pressure indirectly in place of a direct measure. The blood pressure cuff cycles every 2–3 min to monitor blood pressure intermittently. A number of investigators have described the issues that must be considered when selecting direct versus indirect measurement of blood pressure relative to the reliability and validity of the information obtained (Clark, Leih-Lai, Sarnaik, & Mattoo, 2002; McGhee & Bridges, 2002). In choosing between the two techniques, one must consider the importance of direct versus an indirect measure, continuous versus intermittent measurement, and the overall accuracy of the measure, as well as the risk to the subject. Consequently, the researcher must be cognizant of the risks associated with each alternative measurement method and is required to carefully consider these and justify the selection of measurement method in grant proposals to address the risk/benefit ratio.

In Vitro

In vitro biomedical instrumentation requires the application of the measuring device outside of the subject. Neurohormones including norepinephrine, epinephrine, cortisol or their breakdown products can be measured in blood, urine, or saliva using radioimmunoassay techniques. The samples are obtained from the subject, preserved, and later analyzed outside of the subject using a biomedical instrument. While there is less risk to the subject using an in vitro biomedical instrument, consideration should be given as to whether a direct measure of the neurohormone...
is needed from a blood specimen, as opposed to a breakdown product measured in urine or saliva. For example, in smoking cessation studies, carbon monoxide, a byproduct of cigarette smoke, can be measured directly in blood by using an in vitro biomedical instrument called gas chromatography or co-oximetry and indirectly in exhaled air by using an ecolyzer. While the risks associated with venipuncture are minimal when performed properly according to guidelines, the total amount of blood removed as in neonates may be a significant issue for investigators. In addition, research subjects are often more likely to participate if the sampling technique is less invasive.

Care must be taken to prevent contamination when obtaining a sample to be measured using an in vitro biomedical instrument. Contamination could alter the results of the measurement. The sample may be obtained in a specimen container with preservative. Each type of sample (e.g., blood or amniotic fluid) may require different types of preservatives. Once the sample has been obtained, cell and fluid separation may be necessary and can be performed using centrifugation. A centrifuge spins the sample at high rates of speed and causes the heavier cells to fall to the bottom of the container and the fluid or supernatant to rise to the top. The cells or the supernatant may be stored separately in measured aliquots by removing the supernatant using a pipette. The samples may then be refrigerated or flash frozen for later analysis.

**CLASSIFICATION OF PHYSIOLOGICAL VARIABLES MEASURED BY BIOMEDICAL INSTRUMENTATION**

There are numerous physiological variables that can be measured using biomedical instrumentation. The clinician or advanced practice nurse in the clinical setting including hospitals, outpatient clinics, community, nursing home facilities, or home settings frequently monitors physiological variables to assess the health status of patients. Patients with diabetes may use home blood glucose monitoring each day to guide insulin administration. These data may be stored in the memory of the glucose monitor and downloaded into a home computer and printed at home for the patient or downloaded during the outpatient clinic visit. The advanced practice nurse may evaluate a hemoglobin A1c blood test to determine overall blood glucose control during the past 3 months. These data can also be used for clinical monitoring of the patient or for research purposes to determine the effectiveness of a nursing intervention to enhance glycemic control (Hornsten, Stenlund, Lundman, & Sandstrom, 2008).

Telehealth initiatives supported by the National Institute of Nursing Research have expanded home patient monitoring using biomedical instruments (Assimacopoulos et al., 2008). Biomedical instruments can send real-time videos of wounds, transmit vital signs from sensors sewn in a shirt, measure intrathoracic hemodynamic values, or send lung spirometry values via the telephone to monitor patients with chronic heart failure and chronic lung disease, and these data have been demonstrated in numerous studies to have a positive effect on patient outcomes (Dellifraine & Dansky, 2008).

Physiological variables can be classified generally by body system (cardiovascular, respiratory, reproductive, etc.) or more specifically by type of biophysical or biochemical parameter being measured. Table 20.1 lists the classification of physiological variables by the biophysical or biochemical parameter being measured. When physiological variables are classified by this method, the type of biomedical instrument used to measure the variable naturally follows. For example, pressures measured in arteries, veins, lungs, esophagus, bladder, and uterus can all be made using biophysical strain gauge transducers. Gases from the lungs and blood can be measured by the same category of biochemical biomedical instruments.

**BIOMEDICAL INSTRUMENTATION MEASUREMENT SCHEMA**

Figure 20.2 presents the components of the organism-instrument schema.
### TABLE 20.1 Categories of Physiological Variables Detected by Biomedical Instruments

<table>
<thead>
<tr>
<th>Categories</th>
<th>Variables</th>
</tr>
</thead>
</table>
| Electrical Potentials | • Heart: electrocardiogram (ECG)  
• Brain: electroencephalogram (EEG)  
• Muscle: electromyogram (EMG) |
| Pressure            | • Arteries: systolic and diastolic pressure and mean arterial pressure (MAP)  
• Veins: central venous pressure (CVP)  
• Lungs: intra-airway ($P_{aw}$) and intrapleural pressure  
• Esophagus: esophageal pressure ($E_{os}$)  
• Bladder: degree of distention determined by pressure in the bladder  
• Uterus: uterine activity determined by monitoring pressure in the uterus  
• Brain: intracranial pressure (ICP) |
| Mechanical Waves    | • Heart: heart sounds  
• Ears: sound waves |
| Gases               | • Blood: arterial concentrations of oxygen ($P_{aO_2}$), carbon dioxide ($P_{aCO_2}$), and carbon monoxide (CO)  
• Lungs: oxygen, carbon dioxide, nitrogen, and carbon monoxide |
| Temperature         | • Core  
• Surface  
• Ear |
| Cellular            | • Hormones  
• Cellular proteins and enzymes  
• Cytokines |
| Nucleic Acids       | • DNA  
• RNA |

**FIGURE 20.2** Components of the organism-instrument system.
Subject

The majority of nursing research studies are conducted in human subjects who have been selected based upon specific clinical and demographic characteristics. Some research questions cannot be measured in human subjects due to the level of risk to the subject or due to the type of biomedical instrument that must be applied or inserted. For ethical reasons, the research may need to be conducted in an animal model (Page, 2004). The investigator needs to choose the most appropriate animal model that most closely reflects the characteristics of a human subject. There are a number of established animal models that can be used by nurse researchers. Collaboration with a veterinarian or a medical researcher can assist the nurse researcher in choosing the most appropriate model so that the findings generated by the research can be applicable in humans.

Stimulus

The experimental stimulus may arise naturally or may be administered as a nursing care procedure or intervention. In nursing care studies, the stimulus may result naturally from the clinical environment as noise or light (Akansel & Kaymakci, 2008). The circadian rhythm of a patient may be significantly altered by hospitalization, particularly in the intensive care unit in both neonates and adults. Monitoring the stimulus—noise in decibels and light in watts—and the physiological outcome variables—neurohormone levels, sleep using electroencephalography, and movement using wrist actigraphy—can provide valuable insight into the physiological effect of hospitalization. Numerous nursing research studies apply an intervention that has been developed by nurse researchers rather than measure the response to natural stimuli. For example, Hsieh et al. (2008) tested the effects of a supervised exercise program, the intervention, on cardiopulmonary function and perceived fatigue in cancer survivors who were undergoing various clinical treatments.

The stimulus or nursing intervention can be manipulated by altering the intensity, duration, or frequency. Endotracheal suctioning, a common nursing care procedure, can be altered by increasing or decreasing the intensity (mmHg of mercury of vacuum), the duration of exposure (5–10 s), and the frequency of performance (every 4 hr), and by using different techniques (open vs. closed).

SENSING EQUIPMENT

A biomedical instrument is an electrical device that responds to changes in electrical output. Ohm’s law expresses the relationship between voltage, current, and resistance.

\[ \text{Voltage} = \text{Current} \times \text{Resistance} \]

The majority of biomedical instruments measure changes in voltage. However, the physiological variables that are to be measured include electrical potentials, pressures, mechanical waves, gases, and temperature. Therefore, a transducer is required to sense the change in the physiological variable and convert one form of energy, such as pressure, into an electrical output in volts that is proportional to the phenomenon of interest. There are many different types of transducers including an electrode to measure electrical activity in the heart, a displacement transducer to measure pressure, a Doppler used to measure mechanical sound waves in a blood vessel, a pulse oximeter to measure oxygen saturation, and a thermistor to measure temperature.

A displacement transducer to measure pressure will be discussed to illustrate the principle of a transducer. The most common pressure transducer is a Statham displacement transducer. The transducer is located external to the subject or patient. The transducer is connected to a polyethylene catheter placed in either an artery or a vein. The catheter is typically attached to pressurized tubing filled with fluid, which is then connected to a fluid-filled dome that covers the surface of the sensing diaphragm of the Statham transducer (Figure 20.3).

With pulsatile blood flow in the blood vessel, the sensing diaphragm is displaced alternately inward and outward at a distance that is proportional to the degree of pressure change within the vessel. The sensing diaphragm is connected by a wire to a bonded or semiconductor strain gauge. Stretching of the wire causes a change in the electrical resistance of the wire. In this biomedical instrument, the current remains constant. Hence,
the change in the electrical resistance of the wire results in a change in voltage that is detected by the biomedical instrument according to Ohm’s law: Voltage = Current × Resistance.

Temperature can be measured with the use of a thermistor. A thermistor is a thin wire whose resistance changes as the temperature changes. In a cold environment, the resistance in the wire increases; while in a warm environment, the resistance decreases. A thermistor can measure temperature changes in the blood in the pulmonary artery using a pulmonary artery catheter, on the skin surface, or in a body cavity (rectum, bladder, or uterus).

Not all biomedical instruments measure changes in voltage. For example, a Clark-type, polarographic oxygen electrode uses a chemical reaction (reduction) to measure the partial pressure of oxygen. Blood oxygen diffuses through a semipermeable membrane and equilibrates in a solution of potassium chloride. The solution is exposed to a polarizing voltage of 600–800 m volts that is held constant. The subsequent reaction produces a current flow at the cathode surface of the electrode. The current change in milliamps is detected by the bio-instrument. The current change is proportional to the partial pressure of oxygen in the electrolyte solution. The biomedical instrument then displays the current charge numerically on the front panel as the partial pressure of oxygen (PaO₂).

When using a transducer, a number of confounding variables must be addressed in order to assure the validity, accuracy, and reliability of the data obtained. For example, blood pressure must be measured consistently against a standard reference plane, which is the right atrium of the heart. This reference site is determined with the subject in the supine position. The right atrium is fixed at a point at the fourth intercostal space along the midaxillary line. The pressure transducer’s balancing port is positioned using a laser level, so that it is horizontal to the subject’s right atrium (Rice, Fernandez, Jarog, & Jensen, 2000) (Figure 20.4). Meticulous leveling of the transducer is important, because for each inch (2.5 cm) of difference between the balancing port and the right atrium, the blood pressure varies by ± 2 mmHg.
All transducers must be zeroed and calibrated. It is essential that the voltage or current be set to zero at baseline before any measurement is made. For a displacement transducer used for vascular pressure measures, the balancing port of the dome is opened to the atmosphere to expose the sensing diaphragm to the atmospheric pressure and the voltage is set to zero on the biomedical instrument. The displacement transducer is then calibrated by applying a known pressure, in either millimeters of mercury (mmHg) or in centimeters of water (cm H$_2$O). Centimeters of water pressure are used when greater sensitivity is required and is typically used with low pressures like those in the venous system. The known values are applied in equally spaced intervals, for example, 50, 100, 150, and 200 mmHg, to determine that the output voltage is linear and proportional to the applied pressure. An oxygen electrode is zeroed by exposing the Clark-type, polarographic electrode to a solution with no oxygen and then by exposing it to known oxygen solutions with a low and high concentration of oxygen. The calibration is then repeated automatically every 30 min to 1 hr throughout the day, as this type of electrode experiences electrical drift.

**SIGNAL CONDITIONING EQUIPMENT**

The output signal from the transducer is usually in millivolts or millamps. An electrical amplifier is required to increase the output to volts or amps to drive the display unit (oscilloscope, graphic recorder, or computer). The majority of display units require a 5 to 10 volt output. The amount of voltage or current required can be obtained from the instrument manual. The amplification of the signal is referred to as “increasing the gain.” Occasionally, the electrical signal will include noise or artifact. Electrical noise may be the result of 60-cycle Hz from the environment as the result of alternating current (AC). Electrical noise can be eliminated by grounding or reduced by using an electrical filter. Artifact may also arise from muscle movement, as with an electrocardiographic (ECG) signal. Artifact can be separated, diluted, or omitted by adjusting the electrical filter or sensitivity control on the biomedical instrument.

**DISPLAY EQUIPMENT**

Display equipment converts the electrical signals into visual (cathode ray oscilloscope, graphic recorder, or computer) or auditory output (Doppler or a beeping sound), so that the human senses can perceive the information.

**Cathode Ray Oscilloscope**

An oscilloscope is a voltmeter that measures voltage versus time. An oscilloscope has the advantage in that the beam of electrons generated from the cathode (electron emitter) has very little inertia and is therefore capable of rapid motion. Some physiological phenomena occur so rapidly (an action potential in a neuron or myocyte) that it can only be displayed on an oscilloscope screen. The beam of electrons interacts with the phosphor screen to produce a physiological waveform (Figure 20.5). An oscilloscope interfaced with a computer allows for the physiological waveform to be stored or entered as a numerical value into an Excel spreadsheet. In the clinical setting, these data can be recalled for further review or analysis. In addition, the data can be trended over hours, days, or weeks. The data can also be displayed as histograms. This clinical information can serve as a rich source of data, for example, to examine the circadian rhythm of cardiac alterations in the critical care setting.

**Graphic Recorders**

The graphic recorders used in the clinical setting to display physiological data are often curvilinear recorders. A curvilinear recorder has a significant limitation when used for research purposes. The display system of a curvilinear recorder uses an inking system in which the pen moves in an arc and produces a display on curvilinear recording paper. It is not possible to obtain an exact value of the physiological parameter being measured using a curvilinear recorder. In contrast, a rectilinear recorder uses an inking pen that moves in a linear mode (vertical) and produces an exact value. When the graphic recorder is calibrated against a known value, for example, mmHg, exact values can be obtained (Stone & Frazier, 1999).
Chapter 20  Measurement of Physiological Variables Using Biomedical Instrumentation

343

electrical potentials, pressures, lung volumes, and temperatures. Specialized software already programmed or programmable software is available to acquire and store the data automatically into an Excel spreadsheet or to a SPSS output file. The software packages allow operator visualization of the data and the hand selection of specific areas of the data for further analysis.

The characteristics of biomedical instruments are listed in Table 20.2. The specific characteristics of the biomedical instrument can be provided by the manufacturer. It is important when purchasing a biomedical instrument that the characteristics of the instrument match the physiological variable of interest. For example, does the instrument measure in the range of interest 0–250 mmHg and is it sensitive enough to accurately determine small changes in the variable? The characteristics of the measurements are listed in Table 20.3 and address the issues of validity, accuracy, precision, and reliability.

The major classes of physiological measurement including biophysical and biochemical will be discussed in the order as presented in Table 20.1. While a comprehensive discussion of all of the available measurement techniques is beyond the scope of this chapter, the topics to be addressed were chosen based upon

Graphic recorders may use a traditional inking pen that is water-based or embed the ink into specialized paper. A water-based ink may be subject to smearing or when in contact with water can be removed from the paper. An alternative method is the use of a thermal array recorder that uses a heat stylus pen. The heated pen as it moves along a waxed recording paper produces a black tracing. It should be noted that the tracing produced using a thermal pen and waxed paper can fade over time.

Data can be stored permanently on a magnetic tape or flash drives. A Holter monitor records 24-hr electrocardiographic (ECG) data and stores it on a cassette tape or in newer models on a digital flash memory device. The tape or flash device is then removed from the Holter monitor and is inserted into an interface box. The data are then uploaded onto the hard drive of a computer. Specialized software is used to analyze the data heart rate, rhythm, and heart rate variability.

The majority of physiological data can now be acquired and displayed using a computer. National Instruments and the Gould Corporation have developed integrated systems that include the preamplifiers, signal conditioning equipment, and the computer for the display of data. The preamplifiers are specific for each type or category of data including

C = cathode (electron emitter)
G = control grid (beam intensity)
A = electron accelerating anode
F = focusing electrode
X = X direction deflecting plates
Y = Y direction deflecting plates
S = phosphor coated screen

FIGURE 20.5  Cathode ray oscilloscope.
TABLE 20.2 Characteristics of Biomedical Instrumentation

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range of an instrument: the complete set of values</td>
<td>Scale to measure weight from 0–100 g</td>
</tr>
<tr>
<td>that an instrument can measure</td>
<td>Heart rate monitor: 1 to 250 beats per minute</td>
</tr>
<tr>
<td></td>
<td>Thermometer from 0 to 60°C</td>
</tr>
<tr>
<td>The frequency response of an instrument: indicates</td>
<td>Measuring the action potential of a neuron requires equipment with a fast</td>
</tr>
<tr>
<td>the capability of the instrument to respond equally</td>
<td>response time, as the total time for an action potential is in milliseconds.</td>
</tr>
<tr>
<td>well to rapid and slow components</td>
<td>This type of physiological phenomenon requires a cathode ray oscilloscope</td>
</tr>
<tr>
<td></td>
<td>for the measurement. The response time of the instrument is rapid because</td>
</tr>
<tr>
<td></td>
<td>there is no inertia in the beam of electrons. A graphic recorder cannot</td>
</tr>
<tr>
<td></td>
<td>be used to measure a neural action potential because the frequency</td>
</tr>
<tr>
<td></td>
<td>response is too slow. The inertia of the pen as it moves across the graph</td>
</tr>
<tr>
<td></td>
<td>paper results in a slow response time.</td>
</tr>
<tr>
<td>Sensitivity of an instrument: the degree of change</td>
<td>One instrument might weigh material within one-tenth of a gram (0.1 g),</td>
</tr>
<tr>
<td>in the physiological variable that the instrument</td>
<td>whereas another instrument might weigh the same material within</td>
</tr>
<tr>
<td>can detect</td>
<td>one-hundredth of a gram (0.01 g), with the latter instrument being the</td>
</tr>
<tr>
<td></td>
<td>more sensitive.</td>
</tr>
<tr>
<td>Specificity of an instrument: the capability of the</td>
<td>The blood gas analyzer is specific for the measurement of oxygen</td>
</tr>
<tr>
<td>instrument to measure the desired variable of</td>
<td>and carbon dioxide in a blood sample. This same equipment is not able</td>
</tr>
<tr>
<td>interest</td>
<td>to measure oxygen and carbon dioxide in an exhaled breath.</td>
</tr>
<tr>
<td>Stability of an instrument: the ability to maintain</td>
<td>Over time, biomedical instruments frequently lose calibration, called</td>
</tr>
<tr>
<td>a calibration over a given time interval</td>
<td>“drift.” It is important that a biomedical instrument maintain calibration</td>
</tr>
<tr>
<td></td>
<td>because the reliability of the data is dependent on an accurate measure.</td>
</tr>
<tr>
<td></td>
<td>The instruction manual normally specifies the stability of the instrument</td>
</tr>
<tr>
<td></td>
<td>over time. The manual also indicates how often the manufacturer</td>
</tr>
<tr>
<td></td>
<td>recommends recalibration. Because loss of calibration, or “drift,” is</td>
</tr>
<tr>
<td></td>
<td>common among biomedical instruments, it is important to evaluate the</td>
</tr>
<tr>
<td></td>
<td>calibration before, during, and after an experiment to ensure the</td>
</tr>
<tr>
<td></td>
<td>reliability of the data.</td>
</tr>
<tr>
<td>Linearity of the instrument: the extent to which an</td>
<td>For every one degree of actual change in a subject’s temperature, there</td>
</tr>
<tr>
<td>input change is directly proportional to an output</td>
<td>is a one-degree change recorded on the thermometer.</td>
</tr>
<tr>
<td>change</td>
<td>The higher the signal-to-noise-ratio, the less the artifact.</td>
</tr>
<tr>
<td>Signal-to-noise ratio of an instrument: indicates</td>
<td></td>
</tr>
<tr>
<td>the relationship between the amount of signal</td>
<td></td>
</tr>
<tr>
<td>strength and the amount of noise or artifact</td>
<td></td>
</tr>
</tbody>
</table>

general applicability to both clinicians and researchers.

**MEASUREMENT OF ELECTRICAL POTENTIALS**

Electrophysical measurements provide data about the voltage changes that occur during depolarization and repolarization of tissues like those in the heart and nervous system. These voltage changes are transmitted to the surface of the body and detected through electrodes that contain a conductive solution (Figure 20.6).

The electrocardiogram (ECG) is the most common type of electrophysical measurement. Appropriate ECG electrode placement is essential to detect accurate electrocardiographic changes.
Heart rate is modulated by the autonomic nervous system through its effect on the pacemaker of the heart, the sinoatrial node. The electrocardiogram may be analyzed to provide information about the balance between sympathetic and parasympathetic influences upon heart rate by examining the sequential distances between R waves (Figure 20.9).

This analysis, heart rate variability, may be performed in the time domain or the frequency domain. Time domain analyses provide a number of measures that identify the mean time between heartbeats in milliseconds, the standard deviation of this time, and other derived measures based on these statistics. Frequency domain analysis employs power spectral analysis to decompose the electrical signal into the sum of sine waves with different amplitudes and frequencies; so, this technique breaks down the cardiac signal into its frequency components and quantifies them based on their intensity or power. This
FIGURE 20.7 Standard electrode placement for a 12-lead electrocardiogram. Electrode position for the V leads include V1, at the fourth intercostal space right sternal border; V2, at the fourth intercostal space left sternal border; V3, halfway between V1 and V4; V4, at the fifth intercostal space left midclavicular line; V5, at the fifth intercostal space anterior axillary line; V6, at the fifth intercostal space midaxillary line.

method permits differentiation of sympathetic and parasympathetic activity (Figure 20.10).

Investigations of heart rate variability have identified that increased sympathetic tone and reduced heart variability is associated with mortality in a number of disease states (Kruger et al., 2002; Laitio, Jalonen, Kuusela, & Scheinin, 2007; Mowery et al., 2008; Ong et al., 2008; Schmidt, et al., 2005; Stein, Schmieg, El-Fouly, Domitrovich, & Buchman, 2001). Further analyses of standard electrocardiogram may provide additional important information.

Continuous ST-segment monitoring provides a reliable assessment of myocardial ischemia in patients with acute coronary syndromes. While a 12-lead electrocardiogram is the standard technique to assess alterations in the ST-segment, it only provides a single, one-time snapshot of the myocardium. Continuous ST-segment monitoring provides the opportunity to monitor myocardial physiology during periods of normal function and during ischemia. The ECG is often more sensitive than patient symptoms for the detection of ischemia. Eighty to ninety percent of ischemic events detected by ECG are not associated with clinical symptoms (Crater et al., 2000; Yan et al., 2007). Alterations in the ST-segment, either elevation or depression, are independent predictors of myocardial infarction or cardiac death. The recommended ST-segment analysis point is 60 ms (0.06 s) beyond the J point (Drew et al., 2005) (Figure 20.11). It is recommended that alarms to alert the clinician or researcher should be programmed to activate with 1–2 mm deviation above or below the baseline indicating ischemia. Continuous ST-segment monitoring can be used to detect ischemia in subjects with acute coronary syndromes in emergency departments, during cardiac catheterization, in the intensive care unit, or in the
telemetry unit (Leeper, 2003a). Continuous ST-segment monitoring has been used to monitor the effectiveness of fibrinolytics, during the monitoring of acute closure of coronary vessels following angioplasty, postmyocardial infarction, weaning (Frazier et al., 2006a; Jolly et al., 2007; Terkelsen, Norgaard, Lassen, & Andersen, 2005), although a more recent investigation identified significant knowledge gaps in clinicians’ understanding about ST-segment monitoring that should be addressed to promote optimal patient outcomes (Stephens, Anderson, Carey, & Pelter, 2007).

Signal averaged electrocardiography (SAECG) is a technique that permits analysis of small segments of a standard ECG waveform like the T wave and provides a more detailed evaluation of the temporal differences of the electrocardiographic waves (Zabel et al., 2000). Small segments of electrocardiographic data are amplified and then filtered. These signals are then averaged by computer algorithm. Late potentials, low amplitude signals, have been found using this technique. These low amplitude signals have been found to be associated with serious cardiac rhythm disturbances and sudden cardiac death in a number of investigations (Grube et al., 2008; Haghjoo et al., 2007; Schoenenberger et al., 2008).

Electrical potentials generated by neurons provide information about central nervous system function. The frequency and amplitude of electrical potentials is captured by skin electrodes that contain conductive solution. These potentials are filtered and amplified and may be digitized, printed, and analyzed. The electroencephalogram (EEG) provides information about cerebral metabolism and neurotransmitter
function. This is a common measure in studies of sleep (Carlson, Neelon, Carlson, Hartman, & Dogra, 2007; Parthasarathy & Tobin, 2002; Resnick et al., 2003). EEG data may be collected to examine cerebral responses to illness or injury (Boutin, Lassonde, Robert, Vanassing, & Ellemberg, 2008; Wallace, Wagner, Wagner, & McDeavitt, 2001) or to evaluate the response to drugs like sedatives or anesthetic agents (DeWitt, 2008; Hernández-Gancedo, Pestaña, Pérez-Chrzanowska, Martínez-Casanova, & Criado, 2007; Rhoney & Parker, 2001).

EEG technology is the basis for the Bispectral Index, one technology that is used clinically to monitor arousal and depth of sedation in the operating room and critical care units (Arbour, 2000; DeWitt, 2008; Lefoll-Masson et al., 2007). This EEG-based measure assigns a numeric value from 0 (absent electrical activity) to 100 (normal awake state) based on computer analysis of one

FIGURE 20.10 Power spectral analysis of heart rate variability. The upper figure illustrates a subject with increased sympathetic tone as represented by the large peak in the very low frequency range less than 0.04 Hz. The lower figure illustrates a normal subject with normal heart rate variability with both sympathetic and parasympathetic tone seen across the range of frequencies.
methods of measurement actually evaluate two different phenomena. Indirect measures evaluate pressure using blood flow, while direct measures are based on the directly measured pulse pressure (McGhee & Bridges, 2002).

A key to accurate indirect arterial blood pressure measurement is the use of the correct size cuff and an evidence-based standardized protocol for measurement of blood pressure (Pickering et al., 2005). The optimal ratio of the width of the bladder of the blood pressure cuff to the circumference of the arm is 0.4, in that the bladder width is 40% of arm circumference. Figure 20.12a illustrates that when the cuff is correctly positioned at the midpoint of the upper arm and wrapped around the arm, the end of the cuff should fall in the range marked D. When the bladder is too wide or greater than 40% of arm circumference, then the cuff will be to the left of D and underestimate the pressure. When the bladder is too narrow or less than 40% of arm circumference, the cuff will be to the right of D, overestimating pressure.

There are a number of confounding variables that may occur during measurement and may result in error. These include neglecting to wrap the cuff snugly enough (one finger under the cuff), neglecting to express the air out of the cuff bladder before application of the cuff, the presence of a kinked air hose, or use of a nonstandard position of the arm (not at heart channel of EEG and electromyographic evaluation of the muscles of the forehead.

**MEASUREMENT OF PRESURES, FLOW, AND HEMODYNAMICS**

The measurement of arterial blood pressure may be obtained either indirectly using a blood pressure cuff or directly by the placement of a polyethylene catheter in an artery. The oscillographic (cuff) indirect method of measuring arterial blood pressure is based upon flow-induced oscillations in the arterial wall, as compared to the direct method that measures pressure directly in the vessel. As previously discussed, Ohm’s law also expresses the relationship between pressure, flow and resistance: Pressure = Flow $\times$ Resistance. A positive relationship exists between pressure and flow when resistance is constant. However, when evaluating arterial pressure, it must be appreciated that resistance in the vascular bed does not remain constant and is influenced by perfusion requirements, autonomic nervous system tone, and vasoactive substances including medications. Hence, there may be significant differences in indirect versus direct arterial pressure measurements based upon physiological changes in the vascular bed. More important, these two
Part IV Instrumentation and Data Collection Methods

When blood flow stops, an end pressure occurs in the vessel and will cause the systolic arterial blood pressure reading to be falsely high by 2–10 mmHg. If the pressures appear to be dampened, then a fast-flush technique should be performed to assess the dynamic response characteristics of the system (McGhee & Bridges, 2002).

When choosing which method is preferable, either indirect or direct arterial cannulation, consideration must be given to the invasive nature of arterial cannulation. The risks associated with the procedure include blood loss, extravasation, hematoma formation, occlusion of the vessel with potential for loss of the extremity, and infection.

A frequently employed hemodynamic monitoring technology to assess pressures and cardiac status is the pulmonary artery catheter (PAC), although there is considerable controversy about the effectiveness and safety of this measurement technique (Frazier & Skinner, 2008). The PAC is a multilumen, balloon-tipped, flow-directed

level), and inadequate time between measures (Turner et al., 2008). Anatomical and physiological variables in the individual can also influence accuracy of measures. These include talking during the measures, arm motion, seizure activity, shivering, an obstruction in the vessel limiting flow, or alterations in heart rhythm.

Direct arterial blood pressure monitoring is accomplished by the insertion of a polyethylene catheter directly into an artery that is then attached by pressurized tubing to the fluid-filled dome of a Statham displacement transducer. The transducer must be zeroed and calibrated against a column of mercury. Referencing the transducer to the right atrium at the phlebotatic axis as discussed earlier in the chapter must be completed before making pressure measurements. The pressure transducer senses the pressure pulse generated by the contraction of the left ventricle. Vasodilation or vasoconstriction of the vascular bed will alter the arterial blood pressure measurement resulting in lower or higher measures, respectively. When blood flow stops, an end pressure occurs in the vessel and will cause the systolic arterial blood pressure reading to be falsely high by 2–10 mmHg. If the pressures appear to be dampened, then a fast-flush technique should be performed to assess the dynamic response characteristics of the system (McGhee & Bridges, 2002).

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Chapter 20 Measurement of Physiological Variables Using Biomedical Instrumentation

351

blood temperature. With the injection of 10 ml of either room temperature or iced injectate at end-expiration, a thermodilution cardiac output curve can be obtained. The cardiac output computer integrates the area under the thermodilution curve to calculate cardiac output.

More recently, modified pulmonary artery catheters have become available for continuous measurement of cardiac output and right ventricular end-diastolic volume (RVEDV) as an indicator of cardiac preload. These catheters contain a thermal filament 10 cm in length located approximately 14 cm to 25 cm from the tip of the PAC. The thermal filament emits pulses of energy to produce minute changes in temperature of the blood. A relaxation waveform is generated based on a repeating on/off input signal. Data are collected throughout the respiratory cycle with this method of measurement (Figure 20.13).

![Input Signal](image1)

![Temperature Signal](image2)

![Relaxation Waveform](image3)

**FIGURE 20.13** Right ventricular volumetric measurements. The filament emits pulses of thermal energy as the signal. The relaxation waveform is generated to resemble the thermodilution washout decay curve with the standard pulmonary artery catheter. The waveform is based on repeating on/off input signal and is generated by accumulating the temperature change for each off and on segment of the input signal.
Impedance measures were found to be comparable with thermodilution measures in patients with advanced decompensated heart failure ($r = 0.89$, bias 0.08 L/min, precision 1.38 L/min), and a newer generation of biomedical equipment that uses whole body bioimpedance described the equivalence of measures made with impedance in a wide range of patients with cardiac conditions ($r = 0.89$, bias 0.0009 L/min, precision 0.68 L/min) (Albert, Hail, Li, & Young, 2004; Cotter et al., 2004). In patients with heart failure, Zo has been found to correlate closely with chest radiographic findings and be predictive of clinical decompensation (Packer et al., 2006). Impedance cardiography is useful for outpatient management of patients with congestive heart failure and to determine the effectiveness of diuretics, angiotension-converting enzyme inhibitors, and beta blockers (Lasater & Von Rueden, 2003).

A minimally invasive method of monitoring hemodynamics is Doppler cardiography. Continuous real-time Doppler-based hemodynamic assessment can be obtained by an esophageal Doppler catheter inserted to a depth of approximately 35–40 cm from the teeth. The tip of the esophageal catheter rests near T5-T6 where the esophagus is parallel to the descending aorta. Esophageal Doppler monitoring produces a two-dimensional physiologic waveform of the velocity of pulsatile blood flow in the descending aorta over time. The waveform allows for the derivation of cardiac output, stroke volume, and a qualitative indicator of preload, afterload, and contractility. When compared to invasive PAC intermittent thermodilution, the correlation coefficients range from $r = 0.86–0.93$ (Lasater & Von Rueden, 2003). A unique component of impedance cardiography is the measurement of thoracic fluid (Zo) including interstitial, intravascular, or intra-alveolar fluid, all of which reduces impedance to electrical current flow. Increased fluid and electrolytes in the fluid decreases the impedance to current flow.
FIGURE 20.14 Waveform obtained from the Doppler esophageal probe. PV = peak velocity; FTc = flow time corrected; SD = stroke distance.

FIGURE 20.15 Esophageal Doppler waveforms illustrating preload, afterload, and myocardial contractility or inotropy.

of hypovolemia. Afterload is indicated by the width and the amplitude of the waveform. A narrow waveform with decreased amplitude is indicative of an increase in afterload. A wide waveform and increased amplitude is seen with afterload reduction. The peak velocity is a marker of contractility and can be visualized by the amplitude of the waveform (Turner, 2003). This technology is available in the emergency department, operating room, postanesthesia care, and in the critical care areas. Esophageal Doppler monitoring has been used
intraoperatively to enhance fluid optimization (Mathews & Singh, 2008). Use of this technique is contraindicated in coarctation of the aorta, pathology of the esophagus, or coagulopathies (Prentice & Sona, 2006). Implantable hemodynamic and volume-monitoring devices are currently being evaluated with patients who have chronic heart failure; however, the efficacy of this type of monitoring for the reduction of heart failure events has not been clearly demonstrated in early studies (Bourge et al., 2008; Rich, Freudenberger, Ohman-Strickland, Cho, & Kipen, 2008; Zile et al., 2008).

**MEASUREMENT OF GASES**

Determination of the partial pressures of gases like oxygen and carbon dioxide can be obtained by analysis of blood concentrations of individual gases and evaluation of transcutaneous measurements of oxygen and carbon dioxide, pulse oximetry, capnography, and regional carbon dioxide evaluation. Gas measurements are commonly used as a variable in studies that investigate cardiopulmonary status during illness or following injury (Cancio et al., 2006) and during interventions like endotracheal suctioning and ventilator weaning (Banasik & Emerson, 2001; Cordero, Sananes, & Ayers, 2001; Mohr, Rutherford, Cairns, & Boysen, 2001; Oh & Seo, 2003; Sud, Sud, Friedrich, & Adhikari, 2008). Gas concentrations are also frequently evaluated in studies of shock (Müller et al., 2008; Wang, Wei, & Chen, 2007; Yu, Chapital, Ho, Wang, & Takanishi, 2007).

**Arterial Blood Gases**

Arterial blood gas sampling and evaluation allows calculation of total gas content in the blood and, in combination with cardiac output data, evaluation of gas delivery (Blonshine, Foss, Mottram, Ruppel, & Wanger, 2001). Most commonly, blood oxygen concentration, the partial pressure of oxygen (PO\textsubscript{2}), is measured by a Clark-type, polarographic electrode, which uses a chemical reaction (reduction) to measure oxygen partial pressure. The oxygen electrode contains a membrane through which oxygen from the blood sample diffuses and equilibrates in a potassium chloride solution. This solution is exposed to a polarizing voltage of 600–800 mV and the subsequent reaction produces a current flow at the cathode surface of the electrode. This current is linearly proportional to the partial pressure of oxygen in the electrolyte solution (Figure 20.16).

The partial pressure of carbon dioxide (PCO\textsubscript{2}) is typically measured by a Stow-Severinghaus-type electrode, which contains two separate chambers separated by a semipermeable membrane. One chamber of this electrode is for the blood sample. The second chamber contains a pH electrode surrounded by a buffer solution of sodium chloride and bicarbonate. The carbon dioxide from the blood sample freely diffuses through the membrane and into the buffer.
Oxygen saturation

Oxygen saturation, the proportion of hemoglobin sites bound with oxygen molecules, is measured from an arterial blood sample ($SaO_2$), from pulse oximetry ($SpO_2$) or from an indwelling catheter placed in the pulmonary artery ($SvO_2$) or the central venous circulation ($ScVO_2$). With each of these measures, hemoglobin molecules are exposed to red and infrared light by a light-emitting diode. Hemoglobin bound to oxygen, oxyhemoglobin, absorbs more infrared light and hemoglobin without oxygen molecules, deoxyhemoglobin, absorbs more red light. Once the light passes through the hemoglobin molecules, a light-receiving sensor determines the proportion of red and infrared light received and calculates the proportion of oxyhemoglobin in the sample.

Blood samples are exposed to up to five wavelengths of light in the laboratory setting using a co-oximeter. The use of a co-oximeter also allows accurate measurement of dysfunctional hemoglobin like methemoglobin (heme iron oxidized to the ferric state) and carboxyhemoglobin (hemoglobin bound to carbon monoxide).

Pulse oximetry uses a sensor containing the light-emitting and light-receiving diodes placed on a finger, toe, foot, hand, earlobe, or bridge
of nose (Casati et al., 2007). The light-emitting portion of the sensor is placed on one side of an area with a pulsating arterial bed and the light-receiving diode is placed so that it will receive the light once it has traversed the pulsatile bed. Typically, pulse oximetry uses two wavelengths of light and provides a measure of the proportion of available hemoglobin that is oxygenated. Dysfunctional hemoglobins are not detected by pulse oximetry.

Oxygen saturation of pulmonary artery or central venous oxygen saturation (SvO₂, ScVO₂, respectively) is performed with a specialized fiberoptic pulmonary artery catheter (Marx & Reinhart, 2006). The catheter contains one optic fiber to emit the red and infrared lights and a second to detect the light that reflects from the hemoglobin molecules. The saturation is determined by the absorption of red and infrared light by the exposed hemoglobin molecules. These measures are used to evaluate tissue oxygenation in critically ill patients (Goodrich, 2006).

Capnography, the measurement of carbon dioxide concentration in exhaled gas, may be an invasive or noninvasive measure. Exhaled gas may be sampled via an invasive artificial airway like an endotracheal tube or noninvasively from nasal prongs. Gas may be sampled either by mainstream or sidestream technique. With mainstream sampling, the measurement sensor is placed at the proximal tip of the artificial airway and exposed to the gas as it is expired from the respiratory tract. With sidestream sampling, exhaled gas is collected from the proximal end of an artificial airway or nasal prongs and diverted through a sampling tube to the analyzer located in the monitor. Regardless of sampling technique, either infrared spectography or mass spectography is used to analyze the gas sample and measure carbon dioxide concentration.

Infrared spectography is the most common method of analysis for capnography (Cheifetz & Myers, 2007). Carbon dioxide selectively absorbs infrared light in the 4.3 micrometers wavelength. Exhaled gas is exposed to infrared light and the selective absorbance of this wavelength of light is proportional to the concentration of carbon dioxide in the gas. With mass spectography, the gas sample is aspirated into a high vacuum chamber. The gas is exposed to an electron beam that fragments the gas. Following fragmentation, the ions contained in the gas are accelerated by an electric field into a chamber with a magnetic field located at right angles to the stream of ionized gas. Here molecules are separated based on their mass to charge ratio and the concentration of gas components like carbon dioxide is determined.

### Regional Carbon Dioxide Measurement

Evaluation of carbon dioxide concentration in localized tissue affords a measure of tissue blood flow (Marik, 2006). Carbon dioxide accumulates during periods of reduced tissue blood flow. Thus, an increase in tissue carbon dioxide may be used to evaluate the adequacy of perfusion in selected tissue beds. The measurement of gastric carbon dioxide (gastric tonometry) and sublingual carbon dioxide are two techniques currently in use in research and clinical practice.

Gastric tonometry provides a close estimate of gut carbon dioxide concentration (Fisher, Kerr, Hoffman, Steiner, & Baranek, 2005; Gomersall et al., 2000; Huang, Tsai, Lin, Tsao, & Hsu, 2001). This technique requires placement of a modified nasogastric tube that contains a gas permeable balloon on the distal end of the catheter. To measure gastric carbon dioxide, the balloon is filled with air that remains in place for 10 min period. During this dwell time, carbon dioxide diffuses freely into the balloon and equilibrates with the local tissue carbon dioxide levels. At the end of 10 min, the balloon air is withdrawn and carbon dioxide concentration is commonly measured by infrared spectroscopy as previously described. Bicarbonate ion concentration may be used in conjunction with the gastric carbon dioxide value to calculate the intramucosal pH (pHi). There is an integral negative relationship between the gastric carbon dioxide and intramucosal pH; as carbon dioxide increases, pHi decreases. The calculation of the gap between arterial and gastric carbon dioxide may provide more relevant data about tissue perfusion. There should be little difference (< 10 mmHg) between gastric and arterial carbon dioxide [P(g-a)CO₂]. However, as perfusion
is reduced, this difference will increase in size to poor perfusion.

Sublingual capnometry provides a measure of carbon dioxide concentration for proximal esophageal tissue in the sublingual area (Creteur, De Backer, Sakr, Koch, & Vincent, 2006; Marik, 2006). Prior investigations demonstrated that increased sublingual carbon dioxide occurred in conjunction with increases in esophageal and gastric carbon dioxide (Baron et al., 2007; Creteur, 2006). With this technique, a disposable microelectrode sensor is placed in the sublingual space for 5 min or less. This sensor is connected to a fiberoptic cable that conveys information from the sensor to an analyzer. When the sensor is placed in the sublingual space, carbon dioxide freely diffuses through the sensor and into the fiberoptic cable. This cable is coated with a fluorescent dye that is permeable to and reacts with carbon dioxide. The dye emits light in proportion to the concentration of carbon dioxide present and this light is used to calculate the concentration of carbon dioxide present. Sublingual carbon dioxide is well correlated with gastric carbon dioxide \( r = 0.86 \) and has been found to have a 100% positive predictive value for shock (Pellis et al., 2005).

**MEASUREMENT OF PULMONARY VOLUMES AND GAS FLOW**

Measurement of pulmonary volumes and gas flows provides specific information about lung function. Pulmonary volumes and capacities and gas flow rates are commonly used to assess the degree of objective or restrictive lung disease prior to study or in response to some intervention (Carter et al., 2002; Ferreira et al., 2003; Hsieh et al., 2008; Weekes, Emery, & Elia, 2008).

Static pulmonary gas volumes are not influenced by gas flow. These volumes are most commonly measured by a spirometer and include tidal volume, inspiratory and expiratory reserve volumes, inspiratory capacity, and vital capacity. A spirometer will provide a direct measure of ventilated gas volume that may be presented as a graphic display of volume over time called a spirogram (Figure 20.18).

**FIGURE 20.18 Spirogram of lung volumes.**
A spirometer may be classified as a volume-displacement or flow-sensing spirometer. With a volume-displacement spirometer, exhalation of a volume of gas most commonly displaces a bell in a water tank an equivalent volume.

With other volume-displacement spirometers, exhalation of gas moves a piston or a bellows and that movement is transformed into the equivalent volume of gas. Flow-sensing spirometers primarily measure gas flow and use this value to calculate simultaneous volume by integration of the flow signal. Flow sensors measure the rate of gas flow by detection and analysis of a pressure drop across a resistance pneumotach, detection of cooling of a heated wire (anemometer), or by calculation using the rotation of a turbine blade. This type of spirometer has the ability to integrate the flow and volume data simultaneously and produce a flow volume loop that provides additional data about pulmonary status. Although spirometry provides important information about many lung volumes and gas flows, measurement of other volumes like functional residual capacity, total lung capacity, and residual volume require other techniques.

Functional residual capacity, residual volume, and total lung capacity must be measured indirectly. These gas volumes are most commonly measured by the use of a helium dilution technique or body plethysmography. With the helium technique, the subject breathes a known volume of gas that contains a small, known concentration of helium for 3 to 5 min. At the direction of the investigator, the subject exhales gas down to residual volume (exhale as much as possible) and the investigator measures the concentration of helium in the volume of gas. The concentration of helium in the known volume of gas is used to calculate the residual volume. The subject is requested to perform a vital capacity maneuver (maximal inspiration following a maximal expiration) and the calculated residual volume is added to the vital capacity to provide the total lung capacity. Clearly, the individual must be able to fully cooperate and participate for this technique to provide useful data.

Body plethysmography uses Boyle’s law to calculate total lung volume. The individual is placed in a sealed chamber and requested to breathe through a mouthpiece. During this ventilation, a shutter obstructs the mouthpiece and the individual attempts to ventilate against the closed gas pathway. Contraction of the diaphragm reduces intrathoracic pressure and with an increase in chest size, the volume and pressure in the sealed chamber are altered. The differences in pressure and volume in the sealed chamber are used to calculate total lung volume. This method also provides a measure of airway resistance to gas flow.

**MEASUREMENT OF TEMPERATURE**

The body temperature of an individual is the result of a dynamic balance between heat production and heat loss. Body temperature measurements may be made from a number of sites: oral, axillary, rectal, skin, pulmonary artery, and bladder. Body temperature is often used as a variable in studies of neonates (Knobel & Holditch-Davis, 2007).

Body temperature may be evaluated by a thermistor, infrared detector, or less commonly, a liquid in glass thermometer. Thermistors are located at the distal end of a probe. This type of device is found in the distal tip of a pulmonary artery catheter or in an electronic thermometer. The electrical resistance in the thermistor is altered in proportion to body temperature. This change in electrical resistance is converted to temperature and displayed. Infrared thermometers evaluate body temperature by detection of infrared emission from the tympanic membrane, skin, or axilla. Infrared thermometers measure body temperature by quantifying radiant body heat loss in the form of infrared heat rays. Liquid in glass thermometers consist of a solution (usually alcohol) in a bulb connected with a glass column marked with the appropriate measurement scale. When the bulb area is exposed to body temperature, the solution heats, expands, and moves into the column. Once the solution equilibrates with body temperature, the solution expansion ceases and body temperature is
MEASUREMENT OF METABOLISM

Metabolism refers to the total energy expended by all chemical reactions in the body. The measurement of energy expenditure permits an investigator to evaluate individual metabolic responses to illness and injury and to determine metabolic response to interventions like weaning from mechanical ventilation or inclusion of specific nutrients in feedings (Boullata, Williams, Cottrell, Hudson, & Compher, 2007; Faisy et al., 2008; Hoher, Zimmermann-Teixeira, Hertz, da S. Moreira, 2008; Petros & Engelmann, 2001; Savard et al., 2008). Estimates of caloric requirements and energy expenditure have been approximated for decades by the use of established equations like the Harris-Benedict equation. However, this equation was based on normal, healthy young individuals in the early 20th century and has been found to overestimate actual energy expenditure by as much as 15% (Frankenfield, Coleman, Alam, & Cooney, 2008). Faisy et al. (2008) recently offered a newer equation for calculation of resting energy expenditure for critically ill adults that includes an individual indicator of metabolism and may be a more valid estimate of energy expenditure.

Metabolism may be quantified by calorimetry, a technique that measures the energy released from the individual’s total chemical reactions (Haugen, Chan, & Li, 2007). Heat production from chemical combustion is a constant and is proportional to the rate of chemical reaction. Thus, a measure of the heat produced by an individual may be used to quantify metabolism. Direct calorimetry, the most valid measure of energy expenditure, involves direct measurement of an individual’s heat dissipation. To make metabolic measures using direct calorimetry, an individual is placed in a closed metabolic chamber for a minimum of 24 hr and instructed to perform certain activities, in addition to eating regular meals and sleeping. The heat released from the individual’s body during these activities provides data about the individual’s energy expenditure and is used to calculate energy expenditure. This technique requires specialized facilities and is expensive and time-consuming.

Metabolic measures are more typically made using indirect calorimetry (Haugen et al., 2007). This technique is based on the fact that the chemical combustion of 1 calorie requires precisely 208.06 ml of oxygen. Thus, oxygen consumption is directly associated with energy expenditure. Oxygen consumption (VO\(_2\)), carbon dioxide production (VCO\(_2\)), and minute ventilation (V\(_E\)) are used in the calculation of resting energy expenditure (REE) or the amount of calories required for a specified period of time by an individual. Indirect calorimetry may be performed in the laboratory setting or in a clinical site using equipment that is either separate from or integrated into a mechanical ventilator or a bedside monitor (Haugen et al., 2007; Headley, 2003). The individual is interfaced with the calorimetry equipment either through a mouthpiece, face-mask, canopy, or specialized attachment to an endotracheal tube. These devices permit precise evaluation of the volumes of inspired and expired gases. The concentration of oxygen and carbon dioxide is determined typically by spectroscopy as previously described. Oxygen consumption is calculated as the difference between inspired and expired oxygen concentration, while carbon dioxide production is determined by subtracting the inspired concentration of carbon dioxide from the expired concentration. Both values are multiplied by the minute ventilation and then entered into a Weir equation for the calculation of resting energy expenditure.

MEASUREMENT OF CELLULAR PRODUCTS

The level of cellular synthesis of proteins like cytokines, hormones, and neurohormones often provide important data for investigations (Frazier et al., 2008; Fukuda et al., 2008; Furukawa et al., 2003; Janson, Earnest, Wong, & Blanc, 2008; Jessup, Horne, Yarandi, & Quindry, 2003). These products may be measured using a variety of techniques that include chromatography, electrophoresis, immunohistochemical staining, and enzyme-linked immunosorbent assay (ELISA).
Chromatography is a process that separates the components of a sample and permits identification and quantification of a selected substance. There are many different forms of chromatography including liquid, gas, gas-liquid, and ion-exchange. Within each sample to be separated, each component has different chemical, electrical, and physical properties. The sample is exposed to a bed or column. The substrate in the bed or column, called the stationary phase, is specifically selected based on its ability to attract the substance to be quantified. As the sample is passed over the bed or through the column, the substance to be measured is attracted to the specific components of the substrate and this attraction permits quantification. In gas chromatography, a carrier gas is used to transport the sample. The sample is passed over the separating column and the rate at which the sample passes through the column is detected by a heat-sensing device called a kathometer. Each component of the sample separates out at differing rates and amounts, producing a series of waveforms for each component and the area under the waveform reflects the amount of the component in the sample.

Electrophoresis is a technique that uses an electrical field to separate proteins within a sample. A substrate or gel is inoculated with the sample. An electrical field is then established and proteins are attracted to either the positive or negative end of the field. The attraction of the molecules is dependent upon the charge and the molecular weight of the molecule. Thus, some proteins will be attracted to the positive end of the field, the anode, and others to the negative end of the field, or the cathode. The degree of attraction will also influence the result by its effect on the speed of movement of the proteins. This technique allows identification of multiple proteins within a sample.

Immunohistochemical staining may be used to identify cytokines and requires careful selection of a specific antibody for the cytokine of interest. The sample may be incubated with the antibody for a specified time period, and then stained with a chromogenic solution. The stain is attracted to the antibody that is bound to the cytokine and produces a color change that affords the investigator the ability to observe and quantify using a microscope. Antibodies may also be coupled to molecules of fluorescent dye and introduced into a tissue sample. The antibody dye molecules bind with the protein of interest. Inspection of fluorescent molecules under a microscope provides a means to identify the protein.

Radioimmunoassays (RIAs) use a competitive binding technique. The protein of interest is labeled with radioactivity. These radioactive molecules are added to a sample that contains specific antibodies to the protein along with a known quantity of the same protein that has not been radio-labeled. These proteins competitively bind with antibodies and the amount of free protein and protein bound to antibody is determined. A number of determinations are made with different amounts of radio-labeled and free protein are plotted to form a standard curve. Then the sample with the unknown concentration of protein is mixed with radio-labeled antigen and antibody. The unknown proteins in the sample competitively bind with the antibodies and the results are compared with the standard curve previously prepared to determine the concentration of the protein.

Enzyme-linked immunoabsorbent assays (ELISAs) are immunodiagnostic assays that use an immune reaction to measure specific proteins. A solid support medium is coated with an antibody that is specific for an antigenic site on the protein of interest. These antibodies bind with the protein. In a sandwich type assay, a detector antibody is then added. The detector antibody binds to the previously formed antigen-antibody complex. Once this “sandwich” is formed, the addition of a substrate that activates a specific enzyme will generate a signal proportional to the concentration of the antigen/protein of interest. ELISA is the easiest, most accurate, and most sensitive method for the quantification of cytokine protein levels. The sandwich type assay technique is typically used and monoclonal or polyclonal anticytokine antibodies that are conjugated to one of a number of available enzymes are a part of the analysis. The assays must also take into account the species specificity of the cytokine being analyzed, for example, human versus mouse.
MEASUREMENT OF NUCLEIC ACIDS

The human genome contains large amounts of deoxyribonucleic acid (DNA) that contains the code for controlling all aspects of embryogenesis, development, growth, metabolism, and reproduction. There are about 50,000 genes encoded in the DNA that make up the chromosomes in the nucleus of the cell. The double-stranded DNA serves as the code or the template for the production (transcription) of the single-stranded messenger RNA or ribonucleic acid. Messenger RNA contains the instructions for the production of proteins (translation) in the cell cytoplasm at the ribosome of the endoplasmic reticulum. Advances in the understanding of molecular genetics have facilitated the development of revolutionary new technologies that have permitted the analysis of normal and abnormal genes and the detection and diagnosis of genetic diseases.

Molecular geneticists had to overcome two fundamental obstacles in order to study the molecular basis of hereditary disease. The first challenge was to produce a sufficient quantity of either DNA or RNA to permit analysis. Hence, molecular cloning techniques were developed. The second challenge was to purify the sequence of interest from all other segments of DNA or RNA. Polymerase chain reaction (PCR) can selectively amplify a single molecule of DNA or RNA several billion-fold in a few hours (Rox, Müller, & Pötzch, 2009).

Molecular Cloning

The process of molecular cloning is the transfer of a DNA sequence into the single cell of a microorganism, so that it grows in culture it reproduces the DNA. A significant advance in molecular biology occurred in the 1970s with the discovery of bacterial restriction endonucleases or restriction enzymes. These bacterial enzymes are capable of recognizing specific double-stranded sequences in the DNA and cleaving the DNA at specific recognition sites. For example, Escherichia coli RY 13 or EcoRI recognizes the specific six base-pair sequence 5′-GAATTC-3′ in the double-stranded DNA molecule. The enzyme cleaves the DNA by placing a nick on each strand between the G and the adjacent A. More than 1,000 restriction enzymes have been identified (Figure 20.19).

A vector is a DNA molecule that can auto-replicate in a host cell as bacteria or yeast, so that the DNA can be isolated in its pure form. Generation of the desired number of identical copies (clones) of a particular DNA sequence by a bacterial or other cell is called recombinant DNA technology. Plasmids are circular double-stranded DNA molecules that replicate extrachromosomally in bacteria or yeast. Another commonly used vector is a bacteriophage lambda, which is a bacterial virus with a relatively large

![Diagram of Molecular Cloning and PCR]

FIGURE 20.19 Molecular cloning and the polymerase chain reaction (PCR).
double-stranded DNA molecule. The *E.coli* cell is infected with the lambda virus and the human DNA sequence, so that cloning of DNA pieces can be accomplished. Other vectors include the cosmid and bacterial artificial chromosomes (BACs) and the yeast artificial chromosome (YAC) that can carry large (100–300 kb) inserts of human DNA. The purpose of molecular cloning is to isolate a particular gene or DNA sequence to allow further study. A set of clones of bacteria or yeast that contains a vector into which fragments of DNA have been inserted is called a library. Following cloning to produce a sufficient quantity of the DNA sequence of interest, the next step is to analyze the DNA fragment.

**Southern Blotting**

The Southern blotting technique is the standard method for analyzing the structure of the DNA cleaved by the restriction enzymes. DNA is first isolated from a human cell, usually a lymphocyte obtained from a blood sample via venipuncture. DNA cannot be extracted from a mature red blood cell as they are nonnucleated cells. Samples can also be taken from cultured skin fibroblasts, amniotic fluid, or chorionic villus cells of the placenta for prenatal screening. The cloned DNA fragments are then separated on the basis of size by agarose gel electrophoresis. The small DNA fragments move through an electric field and are separated based on size and charge. The separated DNA segments are then stained with a fluorescent DNA dye such as ethidium bromide, causing the DNA fragments to appear as a smear of fluorescing material. The Southern blotting technique allows one to find and examine the one or two DNA fragments of interest. The now single-stranded DNA fragments are transferred from the gel to a nylon filter paper by blotting, hence the name Southern blotting. A radioactively labeled piece of cloned DNA is used to identify the DNA fragments of interest. The radioactively labeled probe and the filter are incubated to allow DNA base pairing. After washing to remove the unbound probe, the filter is exposed to X-ray film to reveal the position of the one or more fragments to which the probe hybridized (Figure 20.20).

The best probe to use for detection of a particular single base mutation is a synthetic oligonucleotide because it is shorter in length and is more sensitive to one single base-pair mismatches. An allele-specific oligonucleotide or ASO can be used to detect deletions or insertions of a single base.

**Northern Blotting**

RNA analysis is performed by the counterpart of Southern blotting called Northern blotting. DNA restriction enzymes cannot be used for RNA. RNA transcripts can be identified and are then separated by gel electrophoresis, followed by transferring to nylon filters (blotting). The filter is then incubated with a denatured, radio-labeled probe. After washing, the filter is exposed to X-ray to permit visualization.

**Polymerase Chain Reaction**

The polymerase chain reaction (PCR) can selectively amplify a single molecule of DNA or RNA in a few hours. PCR is an enzymatic amplification of a fragment of DNA. Repeated cycles of heat denaturation, hybridization of the primers, and enzymatic DNA synthesis result in exponential amplification. PCR can also be applied to the analysis of small samples of RNA in a procedure called reverse transcriptase PCR. A single strand of DNA is synthesized from the mRNA by reverse transcriptase. The PCR primers are then added along with the DNA polymerase.

PCR is an extremely sensitive technique. It allows for the detection and analysis of specific gene sequences without cloning or Southern or Northern blotting. Analysis can be performed from a single cell from a hair root, from sperm obtained from a vaginal sample from a rape victim, or from a drop of dried blood at a crime scene.

**In Situ Hybridization**

Probes can be hybridized to DNA contained within chromosomes and immobilized on a microscope slide called in situ hybridization. The cells must be in metaphase when the chromo-
separated out by size and banding characteristics using fluorescence-activated chromosome sorting. Each chromosome is represented by a probe with its own spectra of wavelengths of fluorescence. A computer assigns each chromosome a specific color that is used to identify the chromosome.

**Western Blotting**

Genes direct protein synthesis by the coding of mRNA from DNA. The analysis of both normal...
and abnormal gene function requires an examination of the protein encoded by the normal or mutant gene of interest. Western blotting is used to obtain information on the size and the amount of mutant protein in cell extracts from patients with genetic diseases. Proteins isolated from cell extracts are separated by a polyacrylamide gel electrophoresis and then transferred to a membrane. The membrane is then incubated with antibodies that recognize the protein to be analyzed. This antigen-antibody reaction can then be detected by a second antibody against the first, tagged with a detectable fluorescent, histochemical, or radioactive substance. Figure 20.21 is an example of a Western blot to detect the muscle protein dystrophin in patients with X-linked muscular dystrophy.

With the rapid advances in the development of technologies to clone and separate DNA and RNA, it is important that nurses keep abreast of these latest technologies in the measurement of nucleic acids and incorporate them in their programs of research. Nurses may become familiar with these technologies through a Web-based educational program (University of Cincinnati), participate in the Summer Genetics Institute (SGI), or through doctoral or postdoctoral work. Nurses are encouraged to work collaboratively with cytogeneticists to incorporate these technologies into nursing research.

**SUMMARY**

Physiological measures are an integral component of patient evaluation and provide critical data for nursing research. Clinicians and researchers should be knowledgeable about how to select appropriate physiological measures, how to operate the equipment used to measure these variables, and the procedure for obtaining valid, precise measures.

**REFERENCES**


Rox, J. M., Müller, J., & Pötzch, B. (2009). PCR-based amplification of platelet mRNA sequences obtained from small-scale platelet


Evaluation of Measurement Precision, Accuracy, and Error in Biophysical Data for Clinical Research and Practice

Nancy A. Ryan-Wenger

Data from laboratory tests and biomedical devices serve as proxy measures of biophysical constructs. Effective decision making in clinical practice and research requires biophysical data with maximum precision (similar to reliability), maximum accuracy (similar to validity), and minimal error. This chapter focuses on metrology, “the science of measurement and its application” (Bureau International des Poids et Mesures, 2008, p. vii). Underlying measurement theories and standard terminology are described in this chapter, followed by explanations of precision, accuracy, and error in biophysical measurements. Methods to analyze, interpret, report, and illustrate precision, accuracy, and error are described, including exemplars from the nursing literature.

MEASUREMENT THEORY

Whether observed measurements are psychosocial or biophysical, classical test theory (CTT) is the underlying theory for most evaluations of reliability and validity, precision and accuracy. CTT is based on the principle that an observed score (O) is equal to the true score (T) plus error, as shown below (Spearman, 1904).

\[ O = T + \text{error} \]

Error diminishes the extent to which observed scores are adequate proxies for a construct of interest. Errors in measurement are categorized as random and systematic. Random error is unpredictable and uncontrollable because of the randomness of nature, so that some random error is normal in biophysical measurements. An underlying principle of CTT is that with repeated measurements, and a large sample, the sum of all random errors equals zero, so that the total effect of random error on observed scores is negligible. In the context of biophysical measures, systematic error is called bias, such that observed scores underestimate or overestimate true scores. The unit of measurement is the metric used to quantify a variable, such as millimeters, grams, or a simple frequency count, and is a key factor in the evaluation of precision (similar to reliability), accuracy (similar to validity), and error scores. Measurements may be compromised by characteristics of persons (subjects, raters), specimens, measurement devices, measurement protocol, or the environment of testing (see examples in Table 21.1). Potential sources of systematic error should be identified a priori and prevented, controlled, and/or measured as part of the research design. It is important to note that error in precision and error in accuracy are cumulative and the extent of error must be considered in its totality (Westgard, 2007).
TABLE 21.1 Sources of Error in Precision and Accuracy and Methods to Control or Minimize Error

<table>
<thead>
<tr>
<th>Source of Error</th>
<th>Potential Causes of Error</th>
<th>Methods to Control, Minimize, or Measure Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persons</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raters, Observers, Lab and Study Personnel</td>
<td>Poor measurement technique</td>
<td>• Develop detailed, precise measurement instructions</td>
</tr>
<tr>
<td></td>
<td>Unmotivated</td>
<td>• Prior to beginning a study, and periodically during the study:</td>
</tr>
<tr>
<td></td>
<td>Overwhelmed</td>
<td>o Train study personnel in data collection protocol</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Conduct interrater and intrarater analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Incentives for accuracy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Workload adjustments</td>
</tr>
<tr>
<td>Subjects</td>
<td>Behaviors that mask the true results of a test</td>
<td>• Provide clear preparation instructions to subjects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Secondary validation tests</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Incentives</td>
</tr>
<tr>
<td>Specimens</td>
<td>Inadequate amount</td>
<td>• Prior to beginning a study, and periodically during the study:</td>
</tr>
<tr>
<td></td>
<td>Inadequate labeling</td>
<td>o Train study personnel in specimen management protocol</td>
</tr>
<tr>
<td></td>
<td>Contaminated</td>
<td>o Conduct intertest and intratest quality checks</td>
</tr>
<tr>
<td></td>
<td>Improper handling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improper storage</td>
<td></td>
</tr>
<tr>
<td>Device/Measurement Apparatus</td>
<td>Uncalibrated</td>
<td>• Purchase equipment maintenance contracts</td>
</tr>
<tr>
<td></td>
<td>Calibration drift</td>
<td>• Calibrate equipment prior to beginning a study, and periodically during the study</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Conduct preventive maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Conduct quality control checks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Have back-up devices available</td>
</tr>
<tr>
<td>Data</td>
<td>Illegible data</td>
<td>• Plan for data entry that is legible, auditable</td>
</tr>
<tr>
<td></td>
<td>Data transcription errors</td>
<td>• Maintain detailed procedure logs that include:</td>
</tr>
<tr>
<td></td>
<td>Missing data</td>
<td>o Dates and times</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Problems that arise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Solutions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Decision points</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Errors</td>
</tr>
</tbody>
</table>

STANDARDS FOR MEASUREMENT TERMINOLOGY

The terms “precision” and “accuracy” are used interchangeably in common parlance, and in dictionary definitions, but in the context of measurement, they are quite distinct, which is why standard terminology for measurement characteristics is essential to communication among practitioners and scientists (Westgard, 2007). Yet, many authors of published research studies involving biophysical measurements inappropriately apply the terms and methods of quantifying precision, accuracy, and error. This problem is perpetuated by inadequate training in measurement theories and methods, and by investigators who tend to model new studies after previously published studies (Altman & Bland, 1983).

Standards for most biophysical measurement terms are established by national and international organizations, four of which are described here. The International Vocabulary of Metrology commonly known as VIM, is a document produced by representatives from eight organizations known as the Joint Committee for Guides in Metrology (JCGM, 2009). The International Organization for Standardization (ISO, 2009) is a nongovernmental network of national standards representatives from 159 countries. ISO standards are developed through international
consensus among experts in the technology concerned. The European Committee for Standardization, known as CEN, develops standards by consensus from “manufacturers, consumers, and regulators of a particular material, product, process, or service” (2009). The Clinical and Laboratory Standards Institute (CLSI) publishes a database of accepted laboratory science and health care terminology called the Harmonized Terminology Database. Standard definitions of terms cited in this chapter are listed in Table 21.2, using the accepted hierarchy of reference standards for measurement: VIM definitions are preferred, followed by ISO, CEN, CLSI, and other authoritative terminology documents (CLSI, 2009).

### PRECISION AND ACCURACY

The standard definition of precision according to VIM is shown in Table 21.2. Basically, precision is the extent to which repeated biophysical measurements from the same subject, the same specimen, or across raters are in agreement, that is, consistent. High levels of agreement lead to confidence that the measurement process will provide consistent results. Precision is similar, but not identical, to the concept of reliability in multi-item instruments. Like reliability, precision is not a characteristic of a measurement device, but of the device as it is applied by investigators or research participants. Precision is a function of the level of sensitivity of a device. Sensitivity is

<table>
<thead>
<tr>
<th>Table 21.2</th>
<th>Standard Terminology Related to Precision and Accuracy of Biophysical Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precision</strong></td>
<td>Closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions (VIM07)</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Closeness of agreement between a measured quantity value and a true quantity value of a measurand (VIM07)</td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td>Measured quantity value minus a reference quantity value (VIM07)</td>
</tr>
<tr>
<td><strong>Random Error</strong></td>
<td>Result of a measurement minus the mean that would result from an infinite number of measurements of the same measure and carried out under repeatability conditions</td>
</tr>
<tr>
<td><strong>Systematic Error</strong></td>
<td>Component of measurement error that in replicate measurements remains constant or varies in a predictable manner (VIM07)</td>
</tr>
<tr>
<td><strong>Bias</strong></td>
<td>Estimate of a systematic measurement error (VIM07)</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
<td>Quotient of the change in an indication of a measuring system and the corresponding change in a value of a quantity being measured (VIM07)</td>
</tr>
<tr>
<td><strong>Diagnostic Sensitivity</strong></td>
<td>Proportion of people with the target disorder who have a positive test (Sackett et al., 2000, p. 249)</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>Proportion of people without the target disorder who have a negative test (Sackett et al., 2000, p. 250)</td>
</tr>
<tr>
<td><strong>Positive Predictive Value</strong></td>
<td>Proportion of people with a positive test who have the target disorder (Sackett et al., 2000, p. 249)</td>
</tr>
<tr>
<td><strong>Negative Predictive Value</strong></td>
<td>Proportion of people with a negative test who are free of the disorder (Sackett et al., 2000, p. 248)</td>
</tr>
<tr>
<td><strong>Likelihood Ratio</strong></td>
<td>Likelihood that a test result would be expected in a patient with the disorder compared to the likelihood that the same result would be expected in a patient without the disorder (Sackett et al., 2000, p. 247)</td>
</tr>
<tr>
<td><strong>Confidence Interval</strong></td>
<td>Quantifies the uncertainty of measurements; observations should fall within a range of values that are considered to be statistically or clinically significant (Sackett et al., 2000, p. 245)</td>
</tr>
</tbody>
</table>

\(^{a}\text{VIM = International Vocabulary for Metrology}\)
the extent to which a change in the response of a measurement device corresponds to a change in the stimulus (ISO, 2009). Sensitivity is not synonymous with, but is a function of, the minimum detectable interval (MDI) between two points on a measurement device, or the concentration of a substrate that can be distinguished from zero (ISO, 2009). The smaller the increment of change, the more sensitive is the measurement device. For example, colorimetric measuring systems are popular, relatively simple methods of measuring characteristics of biological fluids. In a study on women’s ability to accurately read their own vaginal fluid pH levels, investigators used nitrazine paper as a measuring system (Kulp, Chaudhry, Wiita, & Bachmann, 2008).

The pH strips used in this study were pHydrion® (MicroEssential Laboratory, Brooklyn, NY) in a pH range of 4.0 to 7.0. They display a sharp color change for each half pH unit. (p. 524)

The paper measured changes in pH from 4.0 to 7.0 in increments of 0.5 (the MDI) based on changes in the color of the paper from yellow, meaning no change, to dark blue, meaning highly acidic. Other nitrazine products are available with wider pH ranges (0 to 13) and more sensitive MDIs of 0.2 and 0.3 pH units (MicroEssential Laboratory, 2009), but for the purposes of this study, the investigators were concerned with women’s ability to distinguish between pH < 4.5 and ≥ 4.5; therefore, more sensitivity was not necessary. Precise measurements are a prerequisite for accuracy, the second characteristic required of biophysical measurements.

Theoretically, accuracy is the extent to which scores on an instrument reflect changes or different levels in the construct that scores are meant to represent. Statistically, accuracy is the extent to which observed biophysical scores are in agreement with true scores from a gold standard (see also the VIM definition of accuracy in Table 21.2). A gold standard is not a perfect measure, but is considered by experts as the best method to measure a particular variable (Kraemer, 1992). The best method may be another device or a master rater. Congruence studies answer the research question, Are the results from the two methods “comparable to the extent that one might replace the other with sufficient accuracy for the intended purpose of measurement”? (Altman & Bland, 1983, p. 312). Unlike precision, numbers assigned to accuracy have no predictive value. One reason that precision and accuracy are confused with each other is that many methods used to quantify them are the same. The key to distinguishing the two terms is that precision scores reflect consistency across measurements, and accuracy scores reflect congruence with a gold standard.

Methods of Measuring Precision and Accuracy

The research methods to evaluate precision and accuracy are described in Table 21.3. The key independent variables are raters and tests. Rater refers to persons who are conducting biophysical measurements with specific biomedical devices or equipment (tests). Dependent variables are the observed values (scores) from the measurement process on subjects, objects, or substances (specimens). Table 21.4 lists options for statistical analyses and their formulae, and Exhibit 21.1 shows a basic 2 × 2 matrix that is central to many tests with dichotomous outcomes (yes/no, positive/negative).

Percentage of Agreement and Kappa Coefficient

Percentage of agreement is the simplest and most commonly reported statistic for interrater, intrarater, intertest, and intratest precision and accuracy when scores are nominal level. Frequency data from any number of raters or tests can be compared from a matrix of any size. The frequency with which raters or tests agreed on the scores is divided by the total number of raters or tests, and multiplied by 100 (Table 21.4). Percentage of agreement ranges from 0% to 100%. Investigators determine the minimum acceptable level of agreement depending upon the complexity of the measurement method and clinical significance of making an error, quantified as 100% minus the percentage of agreement.

Percentage of agreement tends to overestimate true precision because chance accounts for at least some of the agreement. Cohen (1960) proposed a kappa (κ) coefficient of agreement
TABLE 21.3 Methods for Evaluation of Precision, Accuracy, and Error in Biophysical Measurements

<table>
<thead>
<tr>
<th>Research Methods</th>
<th>Precision</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interrater Method</td>
<td>On the same specimen, compare scores among ≥2 raters (assuming equal skill)</td>
<td>On the same specimen, compare ≥1 raters’ scores with a master rater’s score</td>
</tr>
<tr>
<td>Intertest Method</td>
<td>On the same specimen, compare scores among ≥2 of the same devices</td>
<td>On the same specimen, compare scores from ≥1 devices with scores from the gold standard device</td>
</tr>
<tr>
<td>Intrarater Method</td>
<td>On the same specimen, compare ≥2 scores by the same rater</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Intratest Method</td>
<td>On the same specimen, compare ≥2 scores on the same device by the same rater</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Test-Retest Method (Stability)</td>
<td>Repeated measurements on different specimens over time by ≥1 rater</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

Rater = person conducting biophysical measurements
Scores = observed values from measurement process
Specimen = subject, object, or substance that is being measured
Device = test; biomedical equipment used to conduct biophysical measurements

that statistically removes the proportion of agreement due to chance. Raters and the specimens to be measured must be independent; therefore, kappa is appropriate only for calculation of interrater and intertest precision. Kappa is calculated from a matrix of proportions rather than frequencies (Table 21.4). Theoretically, kappa ranges from –1.0 to 1.0, but in reality, the maximum possible kappa ($\kappa_{max}$) varies with the frequency of disagreements in the off-diagonal cells in the matrix. Thus, there is no standard against which to compare all kappa statistics (Cohen, 1960), although some authors have presented their own interpretations (e.g., Landis & Koch, 1977). Precision values would be more meaningful if investigators reported the maximum possible kappa, and included confidence intervals around kappa to provide more information about the precision of measurement. These two statistics are rarely reported in journal articles, perhaps because hand calculations or additional syntax in statistical software are required. The syntax is available at the software Web sites, for example, Statistical Package for the Social Sciences (SPSS, 2009).

Inter- and intrarater precision and accuracy can be maximized by training the raters to conduct measurements according to a strict protocol, with a goal toward limiting error to a certain amount, as illustrated in a study by D’Alonzo, Aluf, Vincent, and Cooper (2009). The authors knew that using calipers to make skinfold (SKF) measurements of body fat requires training to ensure that the calipers are not applied too loosely or too tightly.

To ensure intratechnician reliability, each research assistant in this study practiced taking multiple SKF measurements on approximately 60 clients (under the supervision of the lead author) until she was able to consistently obtain values that varied less than +10%. The intratechnician reliability was ensured by having two research assistants practice taking the measurements together and comparing the results. (p. 277)

The following example from the literature illustrates several points about precision versus accuracy and the need for standard terminology. In a study of 265 adult patients with erythema on their heels, hips, or sacrum, 16 nurses and a researcher independently evaluated blanching (yes or no) of the patients’ erythemic areas. The
### TABLE 21.4 Statistical Analyses for Measurement of Precision, Accuracy, and Error

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Error in Precision</th>
<th>Error in Accuracy</th>
<th>Method</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Agreement</td>
<td>✓</td>
<td>✓</td>
<td>Interrater Intrarater Intertest Intratest Test-retest</td>
<td>% agreement = \frac{(a + c)}{(a + b + c + d)} x 100</td>
</tr>
<tr>
<td>Kappa</td>
<td>✓</td>
<td>✓</td>
<td>Interrater Intertest</td>
<td>$K^a = \frac{[(a + b)(a + c)] + [(c + d)(b + d)]}{[(a + b + c + d)]}$</td>
</tr>
<tr>
<td>Confidence Intervals</td>
<td>✓</td>
<td>✓</td>
<td>Requires additional syntax in SPSS and SAS to calculate confidence intervals around a proportion</td>
<td></td>
</tr>
<tr>
<td>Maximum Possible Kappa</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>$K^a_{max} = \sum \text{[the smaller proportion of (a + b) versus (a + c)]} + \text{[the smaller proportion of (c + d) vs. (b + d)]}$</td>
</tr>
<tr>
<td>Diagnostic Sensitivity</td>
<td>✓</td>
<td>Intratest</td>
<td>Sensitivity = \frac{a}{a + c}</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>✓</td>
<td>Intratest</td>
<td>Specificity = \frac{d}{b + d}</td>
<td></td>
</tr>
<tr>
<td>Positive Predictive Value (PPV)</td>
<td>✓</td>
<td>Intratest</td>
<td>PPV = \frac{a}{a + b}</td>
<td></td>
</tr>
<tr>
<td>Negative Predictive Value (NPV)</td>
<td>✓</td>
<td>Intratest</td>
<td>NPV = \frac{d}{c + d}</td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio (LR)</td>
<td>✓</td>
<td>Intratest</td>
<td>$LR^a = \frac{\text{sensitivity}}{1 - \text{specificity}}$</td>
<td></td>
</tr>
</tbody>
</table>

### Table continued

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Error in Precision</th>
<th>Error in Accuracy</th>
<th>Method</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of Disagreement</td>
<td>✓</td>
<td>✓</td>
<td>Interrater Intrarater Intertest Intratest Test-retest</td>
<td>% disagreement = 100% – % agreement</td>
</tr>
<tr>
<td>Absolute Differences Between Observed Scores</td>
<td>✓</td>
<td>✓</td>
<td>Interrater Intrarater Intertest Intratest Test-retest</td>
<td>Minimum and maximum absolute differences, average absolute error, and the standard deviation (SD) of net differences</td>
</tr>
<tr>
<td>Coefficient of Variation (CV)</td>
<td>✓</td>
<td>✓</td>
<td>Intrarater Intertest</td>
<td>$CV^2 = \frac{(SD \text{ of net differences/average absolute error}) \times 100}{\sqrt{\frac{d^2}{2n}}}$</td>
</tr>
<tr>
<td>Percentage of Variation (CV²)</td>
<td>✓</td>
<td>✓</td>
<td>Intrarater Intertest</td>
<td>$CV^2 = \frac{(SD \text{ of net differences/average absolute error}) \times 100}{\sqrt{\frac{d^2}{2n}}}$</td>
</tr>
<tr>
<td>Technical Error of Measurement</td>
<td>✓</td>
<td>✓</td>
<td>Intertest</td>
<td>$TEM = \frac{\sqrt{\sum d^2}}{2n}$</td>
</tr>
<tr>
<td>Bland-Altman Plot</td>
<td>✓</td>
<td>Intratest</td>
<td>Plot the differences between observed scores (Y-axis) and the combined mean of the two methods (X-axis), and add horizontal lines to mark acceptable limits of error (Figure 21.2)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Notation based on 2 × 2 matrix shown in Exhibit 21.1.
Chapter 21  Evaluation of Measurement Precision, Accuracy, and Error in Biophysical Data

377

(n = 161) reading of their own vaginal pH was determined by their level of agreement with the physicians’ readings (the gold standard). Observed scores were nominal level, dichotomous frequencies similar to the matrix in Exhibit 21.1. Again, the \( \kappa \) was evaluated as “substantial.”

For patient and physician pH tests, the \( \kappa \) value \( c = 0.6 \) supports substantial interobserver reliability . . . the proportion of agreement between physicians and patients was high, at 85%. (p. 525)

Statistics for Determining Score Accuracy

The accuracy of a diagnostic test scored as positive or negative is typically estimated by comparison of the same subjects or specimens with scores obtained from the gold standard method (interest accuracy) and reported in a 2 \( \times \) 2 matrix as shown in Exhibit 21.1. Accuracy statistics derived from epidemiological theory include diagnostic sensitivity (the term “diagnostic” is added here to distinguish it from sensitivity as it applies to precision), specificity, positive and negative predictive value, confidence intervals, and likelihood ratios. Definitions for each of these statistics are listed in Table 21.2, and the formulae to calculate them are shown in Table 21.4. Few people can define all of these terms without looking them up. One method of distinguishing them is to note that sensitivity and specificity have to do with patients with and without the disorder, while PPV and NPV reflect patients with a positive or negative test. Ideally, a diagnostic test has high

nurses’ scores were compared to the researcher’s scores using two methods to evaluate blanching: finger pressure directly on the skin and finger pressure on a transparent disk over the site (Vanderwee, Grypdonck, De Bacquer, & Defloor, 2006).

The percentage of agreement between the researcher and the nurses was high and almost identical for the finger method (92.1%) and the transparent disk method (91.7%). (p. 159)

Interrater reliability was substantial for both the finger method (\( \kappa = .69 \)) and the transparent disk method (\( \kappa = .72 \)). (p. 159)

The article was not clear about whether the percentage of agreement and \( \kappa \) between researcher and nurses was a measure of precision or accuracy. If the researchers and nurses were perceived as equal in skill, then the analyses reflected precision; if the researcher was considered to be the expert (gold standard), then the analyses reflected accuracy. The term interrater reliability is inappropriate in this context, but is a clue that the authors meant to describe precision. Further, the authors evaluated the \( \kappa \) levels as “substantial” but provided no support for that evaluation. An accompanying table in the article indicated that the maximum possible \( \kappa \) for all calculations was 1.0, but this cannot be the case since there were disagreements in all comparisons.

In the vaginal pH study described earlier, the authors used the term interrater reliability to describe their analysis when they really measured interrater accuracy (Kulp et al., 2008). Women’s

\[ \begin{array}{c|cc|c}
\text{Subjects, Specimens, or Raters} & + & - & \hline \\
+ & a^b & b & \hline \\
- & c & d & \hline \\
\hline
a + c & b + d & a + b + c + d
\end{array} \]

\( ^a \) and – signs represent the outcome of measurements, for example, yes/no, high/low, positive/negative.

\( ^b \)For most measurements of agreement, \( a, b, c, \) and \( d \) represent frequency of observations. For measurement of \( \kappa \) coefficients, \( a, b, c, \) and \( d \) represent the proportion of frequencies in each cell, and the sum of proportions \( a + b + c + d = 1.00 \).
sensitivity (patients with the disorder have a positive test) and high specificity (patients without the disorder have a negative test). Likelihood ratios are easier to comprehend by an example, that is, “this test result is 10 times more likely to be seen in someone with the disorder than without the disorder.” These statistics are important because patients with false negative results do not get the treatment they need (omission errors) and patients with false positive results receive treatment that they do not need (commission errors). All of these statistics are estimates; therefore, it is essential to report confidence intervals for accurate interpretation of results (Harper & Reeves, 1999). In a prospective clinical comparative study, four experienced research advanced practice nurses followed a traditional, standardized clinical diagnostic protocol to diagnose and treat 535 active-duty U.S. military women presenting with vulvovaginal symptoms (Lowe, Neal, & Ryan-Wenger, 2009). Using an intertest accuracy method, the practitioners’ diagnoses were compared to results from a DNA probe laboratory standard (Figure 21.1).

Clinical diagnosis accuracy was highest for trichomoniasis vaginalis (98.9%) and lowest for bacterial vaginosis (76.3%). Sensitivities ranged from 80.8% (bacterial vaginosis) to 84.6% (trichomoniasis vaginalis); specificities, from 70.0% (bacterial vaginosis) to 99.6% (trichomoniasis vaginalis); positive predictive values, from 76.8% (candidiasis vaginitis) to 91.7% (trichomoniasis vaginalis); and negative predictive values, from 72.4% (bacterial vaginosis) to 99.2% (trichomoniasis vaginalis). The \([kappa]\) coefficients indicated excellent agreement between clinician and the DNA probe for trichomoniasis vaginalis, good agreement for candidiasis vaginitis, and fair agreement for bacterial vaginosis. . . . Overall, of the symptomatic women in our study, 23.4% were prescribed a medication on the basis of clinical diagnosis not supported by the laboratory standard representing commission prescriptive errors. The clinical diagnosis led to 16.1% omission prescriptive errors in which women were not prescribed a medication indicated by the laboratory result. (p. 93)

When laboratories are responsible for conducting tests on specimens, they must publish information about the consistency of their measurements over time. A commonly used visual representation of duplicate measurements of the same specimen is a Levy-Jennings control chart (Strasinger & Di Lorenzo, 2008). The difference between the duplicate measurements is plotted on the Y-axis for each day numbered 1 through 31 on the X-axis. The distribution of scores compared to horizontal lines drawn for the mean difference score and confidence intervals.

These charts can be constructed from data in an Excel program; see Peltier Technical Services Web site http://peltiertech.com for instructions on how to develop “control charts.”

**Statistics That Are “Off-Limits” for Evaluation of Precision and Accuracy**

Investigators should be aware that many commonly used statistics are erroneously reported as measures of precision or accuracy. T-tests and analysis of variance (ANOVA) are inappropriate, as they test the null hypothesis that the difference between means is zero. In the context of agreement, a non-significant difference would be the desired result. With alpha level of significance set at 0.05, approximately 95% of the differences between means will register as nonsignificant (Altman & Bland, 1983). Chi square analyses, contingency, Spearman, Pearson and phi coefficients, and regression analyses reflect the strength of association between two variables, not agreement. In the case of Pearson correlations, observations from two methods of measurement may be linearly correlated, but unless the two sets of observations cluster closely around the line of identity, they do not agree, and in the case of accuracy or validity, scores are not interchangeable; therefore, one method cannot safely replace the other (Bland & Altman, 1986). In addition, the size of a correlation is a function of variation between subjects, such that when levels of error are held constant, as variation between subjects increases, correlations...
<table>
<thead>
<tr>
<th>CD</th>
<th>Accurate</th>
<th>Inaccurate</th>
<th>Accuracy (%)</th>
<th>Kappa</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+/+</td>
<td>–/–</td>
<td>Accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>22</td>
<td>507</td>
<td>98.9</td>
<td>.87</td>
<td>84.6 (64.3–95.0)</td>
<td>99.6 (98.4–99.9)</td>
<td>91.7 (71.5–98.5)</td>
<td>99.2 (97.9–99.7)</td>
</tr>
<tr>
<td>BV</td>
<td>252</td>
<td>156</td>
<td>76.3</td>
<td>.51</td>
<td>80.8 (75.9–84.9)</td>
<td>70.0 (73.4–75.8)</td>
<td>79.0 (74.0–83.3)</td>
<td>72.2 (65.7–78.0)</td>
</tr>
<tr>
<td>CV</td>
<td>124</td>
<td>328</td>
<td>84.5</td>
<td>.64</td>
<td>83.8 (76.6–89.1)</td>
<td>84.8 (80.7–88.1)</td>
<td>67.8 (60.4–74.4)</td>
<td>93.2 (89.9–95.5)</td>
</tr>
</tbody>
</table>

CD, clinical diagnosis; +, CD or laboratory standard positive for that organism; —, CD or laboratory negative for that organism; PPV, positive predictive values; NPV, negative predictive values; TV, trichomoniasis vaginalis; BV, bacterial vaginosis; CV, candidiasis vaginitis.

Data are n or % (95% confidence interval) unless otherwise specified.

* This inaccurate diagnosis would cause a commission treatment error, i.e., prescribing a medication that is not indicated.
† This inaccurate diagnosis would cause an omission treatment error, i.e., not prescribing a medication that is indicated.
‡ Number of accurate clinical diagnoses divided by the total number of clinical diagnoses (accurate and inaccurate).
§ Measure of agreement corrected for chance.

FIGURE 21.1 Accuracy statistics from a comparison of clinical diagnoses of vaginitis with a DNA probe laboratory standard.

increase and levels of agreement decrease (Chatburn, 1996).

The body fat study by D’Alonzo et al. (2009) illustrates the linear correlation issue. An aim of the study was to evaluate the differences in body fat percentage measured on the same subjects by two different methods, skin calipers and bioelectrical impedance, neither of which were considered to be a gold standard. Therefore, precision of measurements in the form of intertest agreement was their primary interest, although the term “precision” was not mentioned in the article. The authors reported a Pearson correlation of $r = 0.98$, $p < .001$, which looks quite impressive in a scatterplot (Figure 21.2), but does not capture the actual level of agreement between the two methods. Other informative analyses that the authors conducted are described in the section below. More important than agreement is the extent of disagreement, or measurement errors.

### Methods of Measuring Error in Precision and Error in Accuracy

To further complicate the terminology confusion, many investigators use the term “precision” when they are actually measuring imprecision of biophysical measurements and the term “accuracy” when they are actually measuring inaccuracy. For example, Rodrigues (2007) defines precision as the extent to which scores on repeated measurements deviate from each other, and accuracy as deviation from a standard or true value. Deviation is actually an indicator of measurement error, such that lower levels of deviation lead to greater confidence in the precision or accuracy of results. Table 21.4 lists...
several methods of measuring interrater, intrarater, intertest, intratest, and test-retest errors in precision and accuracy. The simplest method for interval level observed scores is to calculate the absolute differences between scores (ignoring the positive and negative signs) and report the minimum and maximum absolute differences, average absolute error, and the standard deviation of net differences. The mean of these differences indicates the level of relative bias while the standard deviation is an estimate of measurement error (Altman & Bland, 1983). From these values, one of three measures of precision error should be reported. A coefficient of variation (CV) is the ratio of the standard deviation to the average of net differences (ISO 3534-1). Alternatively, this ratio may be multiplied by 100 and reported as a percentage (CV%). The third measure is the technical error of measurement (TEM). TEM is more informative than CV or CV%, because it is expressed in the unit of measure, such as percentage of body fat or millimeters of mercury, and can be compared to limits of error that are considered by the investigator or published standards to be clinically safe (Engstrom, 1988). Error in precision can be decreased by periodic calibration of a device against a reference standard or control reagent (Chatburn, 1996, #34). Calibration of biomedical devices is essential to ensure that the starting point for measurements and the intervals between measurements remain stable. The relative stability and drift of the device's calibration is easy to visualize on a graph of periodic intrarater comparisons.

Bland-Altman Charts

When observed scores are interval level, the most widely accepted method of evaluating error in precision and error in accuracy is to construct a differences versus means plot, commonly called a Bland-Altman chart, of the differences between observed scores on the Y-axis and the combined mean of the two methods on the X-axis (Bland & Altman, 1986). If the data are not normally distributed, a log transformation should be done because this is the only transformation method that provides meaningful back-transformation. If data were transformed, results should be reported in the original unit of measure. The distribution of these difference scores is viewed in the context of limits of agreement drawn as horizontal lines across the chart. Limits are set by the investigator, such as one or two standard deviations, or clinical standards for the maximum amount of error that is safe. The data points are examined for level of agreement (congruence) and for level of bias (systematic error). Outliers are readily visible from the chart, and each outlier case should be examined to identify the cause of such a large discrepancy. Clinical laboratory standards state that more than 3 outliers per 100 observations suggest that there are major flaws in the measurement system (Chatburn, 1996). Statisticians recommend that confidence intervals (CI) around the limits of agreement should be reported and illustrated in the chart as well because CIs reveal the variability of scores within the estimated limits (Hamilton & Stamey, 2007). A Bland-Altman plot from the D’Alonzo et al. (2009) study on body fat measurements is shown in Figure 21.3. This type of plot makes it easier to appreciate outliers and patterns of disagreement. The authors stated that “85% of the data points land between ±3.5%” (p. 279), which is an acceptable limit according to experts in body composition. The largest errors were made on subjects with lower percentages of body fat. Recently, Hamilton argued that the limits of agreement are reference standards, but they should not be used to make the final decision about congruence of the two methods; rather, he recommends using the confidence intervals for the upper and lower limits of agreement because they indicate the level of variability around these limits (Hamilton & Stamey, 2007).

METHODS TO MAXIMIZE PRECISION AND ACCURACY, AND MINIMIZE ERROR

Investigators are responsible for establishing the limits of acceptable error in measurement (Houser, 2008; Rodrigues, 2007). During the study design, it is the investigator’s responsibility to identify potential causes of error, and take steps to prevent or control error. Table 21.1 lists potential sources and causes of error for studies with biophysical measures and recommendations to
 prevent or control the cause of error and to measure the extent of error. Protocols for every step in the conduct of a study are essential. Careful training of study personnel and periodic auditing of data and equipment will minimize error and maximize the precision and accuracy of research data. Observed scores that mirror their “true scores” lend confidence in the results of clinical studies and decision making in clinical practice.

**REFERENCES**


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Collecting Sensitive Information

Greater emphasis on an individual’s right to privacy, concomitant with legislation aimed toward ensuring an individual’s privacy such as the Genetic Information Nondiscrimination Act (GINA) of 2008 (Hudson, Holohan, & Collins, 2008) and the Health Insurance Portability & Accountability Act (HIPAA) (U.S. Department of Health and Human Services, 2001) that is discussed in another section of this chapter, have increased the challenges facing nurses and other health care professionals studying sensitive issues. For example, Lea, Feero, and Jenkins (2009) note that clinicians and patients identify fear of discrimination as a major reason for not seeking genetic testing and that this fear has negatively affected genetic testing and the potential value of genomics in health care. Sensitive information usually focuses on personal and/or social topics of a nature likely to evoke strong emotional responses from subjects, such as embarrassment, humiliation, fear, stigma, guilt, anger, vulnerability, pain, stress, and/or anxiety. While there are some topics, such as the sudden violent death of a loved one, criminal behavior, and life-threatening illness that are generally identified as sensitive topics, there are other topics such as abortion, drug abuse, and controversial political activities that may be viewed as more or less sensitive depending upon the specific attributes of the subjects and/or the context in which the information is sought. Lee (1993) points out that large groups of respondents experience research on sensitive topics as threatening because it is intrusive to their privacy and may result in sanctions for deviant behavior or unwanted scrutiny, as in the case of organizational research.

ISSUES IN COLLECTING SENSITIVE INFORMATION

While each measurement effort in which sensitive information is sought will give rise to a unique set of concerns, there are several issues that are germane to most, and hence worthy of consideration here. Most subjects, when asked to respond to measurement methods seeking sensitive information from them, tend to refuse to participate more often than those from whom nonsensitive information is solicited. Subjects may just be too emotionally distressed to make a decision whether to respond, or they may, because of other factors, not have the time or emotional energy to participate, as in the case of an individual who has a spouse with a life-threatening illness or who has experienced a sudden death in the recent past. Refusal to participate may, in part, be a function of the timing of the measurement effort. That is, during certain stages of an intense emotional life experience, subjects may simply be unable and/or unwilling to deal with the sensitive topic. They may view participation as too threatening or they may not consider participation worth the risk to them. Hence, efforts to collect sensitive information tend to have higher nonresponse rates than other efforts.

Similarly, higher attrition rates characterize such measurement efforts in that subjects will agree to participate, but when actually faced with responding to sensitive information will experience feelings such as embarrassment, lowered self-esteem, and/or fear of appearing abnormal, and will withdraw their participation. Subjects who agree to participate, when actually faced with responding, may experience reluctance to describe their thoughts, feelings,
and/or behavior openly and instead, consciously or unconsciously, provide evasive, false, and/or socially desirable responses.

There are also concerns relative to the investigator trying to collect sensitive data. For example, Fowler (2008), in discussing the relationship between suffering and spirituality, contends that while there is an important role for nurses in regard to spiritual care, for the most part, ethics, religion, and spirituality are not viewed as being within the purview of nursing and are sensitive topics for nurses who feel they are neither prepared nor skilled enough to conduct research and/or to address them in caring for patients. Depending upon the type of measurement method employed, the investigator may experience, to a greater or lesser extent, the feeling of intruding into subjects’ personal lives, anxiety, uncertainty, and/or self-doubt when trying to get subjects to participate and/or encouraging them to continue. Similarly, the investigator may need to come to grips with his or her own preconceived attitudes toward the sensitive topic and how to handle them while conducting the measurement effort. Other challenges to the investigator include maintaining confidentiality, researcher detachment, and objectivity; avoiding overidentification with subjects; and determining what information may be too personally sensitive to seek and/or record. Cowles (1988) presents a cogent article discussing issues in qualitative research on sensitive topics that is worthy of attention.

For these reasons, when preparing for the collection of information that may be sensitive, the investigator needs to consider thoroughly the range of possible emotions that his or her subjects may demonstrate and the kinds of problems they may engender for both the subjects and the investigator within the context of the specific measurement effort. On this basis, the investigator then may select and employ strategies and techniques for the collection of sensitive information that are likely to be successful in dealing with the issues described above, and that are most likely to result in a reliable and valid measurement effort. Readers are referred to the work of Stevens (1994); Chavez, Hubbell, Mishra, and Valdez (1997); Juarbe (1998); Lesjak, Hua, and Ward (1999); and Bernhard (2001) who further address problems encountered by subjects and investigators in their work collecting sensitive information.

**STRATEGIES AND TECHNIQUES**

In addition to ethical considerations and HIPAA requirements addressed in another section of this chapter that must be taken into account, there are other strategies and techniques that are especially useful for dealing with the difficulties encountered in collecting sensitive information. Regardless of the specific measurement method employed, the probability of higher response rates and of lower attrition rates is greater if the following actions are taken by the investigator:

1. Anonymity of respondents is assured.
2. Confidentiality of responses is maintained.
3. Only the most significant and relevant information is sought and that fact is reflected in the items.
4. Information that may be too personally sensitive is avoided.
5. Items in paper-and-pencil measures are sequenced or ordered from less to more sensitive, and when more personal methods such as interviews are employed, there is flexibility to direct responses in and out of sensitive areas as necessary.
6. The amount of time allotted to respond is flexible and takes into consideration the respondents’ potential for fatigue, difficulty in focusing on sensitive items, and the need to express emotions.
7. Provision is made to stop data collection temporarily, if necessary, to accommodate respondents’ emotional needs.
8. The frequency of data collection allows participants psychological and/or emotional recovery time.
9. The time of day when data is collected is appropriate for subjects meeting their other needs and demands.
10. Procedures for dealing consistently with respondents emotional responses, if and when they occur, are devised prior to the collection of data.
In the simplest case, RRT is employed in the following manner. The purpose of the measurement is to estimate the prevalence of a sensitive phenomenon, such as elder abuse, incidents of tax evasion, theft, rape, intimate partner violence, or AIDS, in a specified population. In a one-on-one interview, each subject is given a randomization device such as a coin, die, spinner, colored sphere, ball, or card. Each subject is instructed to use the device to respond in a certain manner depending upon the outcome. For example, the subject might be instructed to flip a coin and to respond “yes” to the investigator if he or she obtains “heads” or has a history of elder abuse. If a respondent answers “yes,” it is not certain whether he or she has abused an elder or simply obtained heads on the coin flip. Thus, the respondents’ anonymity is preserved. That is, the investigator does not know what question the subject is actually responding to and merely records the answer to a random question.

Based on various stochastic relations between the questions and the response, it is possible to obtain estimates of parameters in the aggregate. For example, if 60 of 100 subjects respond “yes,” it can be assumed that 50% of the 100 correspond to “heads” on the coin flip, regardless of whether the subject has abused an elder. The surplus 10 reflect those subjects who obtained tails on the coin flip, regardless of whether the subject has abused an elder. Further, since one can assume that 50 subjects received tails on the coin flip, 10 of those 50, or 20%, is an estimate of the prevalence of elder abuse. Clearly, the 20% prevalence for those obtaining tails should exist as well for those obtaining heads on the coin flip. Thus, of the total 100 subjects, one can estimate that 20 have abused elders. Again, it should be emphasized that it is impossible to ascertain which of the 60 who responded “yes” are the elder abusers. Since only aggregate estimates are possible, not only are respondents protected, but many ethical concerns regarding the solicitation of sensitive information are minimized as well.

Warner (1965) developed the original approach to obtaining randomized responses, now known as the related-question method, that employs dichotomous response variables, where an estimate of the proportion possessing some sensitive attribute (e.g., elder abuse) is desired. With the aid of a randomizing device that is concealed from the
investigator and that follows a Bernoulli distribution with known parameters, each respondent is instructed to answer "true" or "false" to a question or its converse, depending on the outcome of the randomizing device. For example:

I have abused an elder.
I have not abused an elder.

Using probability rules, the overall probability of an affirmative response is then determined. This first effort to develop the RRT was followed by a myriad of research activities designed to make statistical improvements in the method, primarily due to concern with the large standard error and resulting low power of Warner’s method and/or to compare the utility of employing RRT relative to other more conventional methods.

Horvitz, Shah, and Simmons (1967), concerned that Warner's (1965) approach tends to evoke suspicions on the part of subjects that there is a way of mathematically determining their true status because both alternatives are sensitive, suggested a modified approach, referred to as the unrelated-question method, in which an innocuous alternative question is combined with the sensitive question. For example:

I have abused an elder. (Sensitive)
I watch the 6 p.m. TV news. (Nonsensitive)

Two samples are then employed with respective probabilities of selecting the sensitive question, and appropriate rules of probability are applied to estimate the desired proportion.

In an attempt to further preserve the anonymity of respondents as well as introduce greater precision and efficiency into the procedure, several others have suggested alternative approaches. Boruch (1971) designed a forced response method, also known as the contamination RRT, and Moors (1971) suggested a two-sample approach, in which the second sample is used exclusively to estimate the nonsensitive parameter; that is, a nonsensitive alternative is employed in the first sample, and the nonsensitive question alone is used directly in the second sample. Similarly, Folsom, Greenberg, Horvitz, and Abernathy (1973) proposed a two-sample approach employing two nonsensitive alternatives. As in Moors’s (1971) approach, the nonsensitive parameters are estimated directly, and as in the approach of Horvitz et al. (1967), both samples are still employed for estimating the parameter of the sensitive question. That is, in the first sample, the sensitive question is combined with one of the nonsensitive questions and a randomization process, and the other nonsensitive question is asked directly. The placement of the nonsensitive question is reversed in the second sample. That is, in the first sample, subjects might be instructed to respond to a randomized pair depending on the flip of a coin and then to answer a nonsensitive question directly. For example:

Have you abused an elder? (Heads)
Do you watch the 6 p.m. TV news? (Tails)
Do you own a car? (Direct)

In the second sample, the same procedure would be employed, but the placement of the nonsensitive questions would be reversed. For example:

Have you abused an elder? (Heads)
Do you own a car? (Tails)
Do you watch the 6 p.m. TV news? (Direct)

The affirmative response probabilities are estimated from the sample proportions using probability rules.

Greenberg, Kuebler, Abernathy, and Horvitz (1977) extended the technique to quantitative measures. In their approach, the subject would be instructed to answer one of two questions, depending on the outcome of a randomized procedure. For example:

How many times in the past 12 months have you abused an elder? (Sensitive)
How many times in the past 12 months have you watched the 6 p.m. TV news? (Nonsensitive)

Warner (1971) and Liu and Chow (1976) proposed alternatives using multiples added to the true value on the sensitive question and known distributions on the sensitive response, respectively.

Clark and Desharnais (1998) noted that with RRT it is possible that an unknown proportion of respondents do not answer as directed by the randomizing device, thus resulting in an underestimation of the frequency of the sensitive behavior. To address this concern, they developed a method to determine the proportion of those
whom they referred to as “cheating” respondents. Their method combines survey techniques with an experimental approach based on a between-subject manipulation of the applying random probabilities and computation of a confidence interval for the true value of the frequency of sensitive behaviors. They contend that if the rules of RRT are being followed, as determined through testing, this method makes it possible to determine the exact frequency of a socially undesirable, embarrassing, or criminal behavior of interest.

Musch et al. (2001) employed this cheating detection technique in an experimental study conducted using a Web-based survey to determine the frequency of tax evasion. Results demonstrated greater readiness to admit tax fraud when RRT was employed, as compared with a conventional survey.

Readers interested in RRT review articles emphasizing statistical developments and procedures are referred to Fox and Tracy (1986), Chaudhuri and Mukerjee (1988), Antonak and Levneh (1995), and Tracy and Mangat (1996). Readers with advanced statistical background who are interested in more technical articles describing additional RRT statistical developments are referred to the work of Singh, Joarder, and King (1996); Singh, Horn, and Chaudhuri (1998); Singh, Singh, and Mangat (2000); Tracy and Singh (1999); Singh and Tracy (1999); and Singh (2002).

Studies undertaken to compare different RRTs and other methods for collecting sensitive information (Beldt, Daniel, & Sarchia, 1982; Horvitz et al., 1967; Lamb & Stem, 1978; Van der Heijden, Van Gils, Bouts, & Hox, 1998, 2000; Wimbush & Dalton, 1997) have resulted in contradictory findings regarding whether different RRTs performed better than direct questioning, self-administered questionnaires, telephone interviews, computer-assisted self-administered interviews, and/or face-to-face interviews. Lensvelt-Mulders and Hox (2000) conducted a meta-analysis of RRT comparative studies to assess which RRTs produced the most valid results and to compare the performance of RRTs with other more conventional data collection methods across existing studies. They found that in the two unrelated questions RRT demonstrated the most evidence for validity and that RRT produced more valid population estimates for sensitive topics relative to other data collection methods.

Considerations to be made when selecting a randomized response technique include the following:

- Whether the phenomenon of interest is dichotomous or quantitative in nature
- The respondent’s ability to understand the approach; that is, more complicated approaches are less appropriate for less sophisticated and/or less educated subjects
- The potential that a given approach is more likely to minimize respondent skepticism

It should be noted that, generally, the respondent will feel more comfortable with a design as the chance of having to respond to the sensitive question decreases. That is, if a very large portion of the affirmative responses are to the nonsensitive question, then responding truthfully to the sensitive question will appear safe or nonjeopardizing for those who, in fact, possess the sensitive attribute (Fox & Tracy, 1980).

Further, in the absence of definitive findings from studies undertaken to validate results of RRTs with external criteria (Umesh & Peterson, 1991), readers who employ RRT in their research and measurement efforts are advised to stay abreast of developments in RRT, to exercise caution in how the technique is used in the absence of best practice guidelines, and to undertake rigorous investigations seeking evidence for validity within the context of their work.

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Selection and Use of Existing Instruments

During the past two decades, there has been an incredible increase in the number of instruments developed to measure nursing and health phenomena and an increased number of published reports of instrument development. As a result, a large repertoire of instruments is now available for use in research and practice. It is sometimes difficult to choose the most appropriate instrument, or even to decide whether it would be preferable to develop a new tool. On the one hand, it is generally much less costly and time-consuming to use existing instruments than to expend the effort necessary to develop and adequately test a new measure. In addition to the pragmatic advantage, the use of existing instruments is beneficial from a knowledge accumulation perspective. It allows systematic comparisons to be made across time, space, and different populations, because characteristics are being measured in the same way. Use of existing tools and devices provides an ever-increasing database for evaluating the properties of the instruments themselves, and allows information about a particular concept or variable to build systematically.

Conversely, health researchers may discover, after extensive search of the literature, that there are no instruments that measure a particular concept or variable. Existing instruments may not be adequate because of their conceptual basis, poor psychometric properties, inappropriateness for the intended settings or populations, or inadequate testing. In such instances, it is often preferable to develop a new tool or substantially modify an existing one. There is clearly a need for nurses and other health researchers to continue to develop and report the results of testing sound measures for use in health-related research, particularly regarding concepts, processes, and outcomes for which measures are nonexistent or inadequate.

The authors of this book assert that when existing instruments are appropriate for nursing measurement, they should be used in preference to developing new ones. Therefore, locating, evaluating, using, and reporting the use of existing instruments are vitally important activities, which should be carried out with attention to the same principles of sound conceptualization and measurement as those that underpin the tool development process.

LOCATING EXISTING INSTRUMENTS

The process of measurement begins with conceptualizing the phenomenon, concept, or problem of interest, and determining the measurement framework that is appropriate. These steps are preliminary to actually searching for existing instruments, because they help define some of the parameters and boundaries of the search process.

The process of locating instruments generally begins by searching databases of relevant literature. Suggestions to facilitate library and database searches for instruments include the following: (1) search computerized databases by using the name of the instrument or keywords or phrases; (2) generalize the search to the specific area of interest and related topics (research reports are particularly valuable); (3) search for summary articles describing, comparing, contrasting, and evaluating the instruments used to measure a given concept; (4) search journals, such as the Journal of Nursing Measurement, that are devoted
specifically to measurement; (5) after identifying a publication in which relevant instruments are used, use citation indices to locate other publications that used them; (6) examine computer-based and print indices, and compendia of instruments developed by nursing, medicine, and other disciplines; and (7) examine copies of published proceedings and abstracts from relevant scientific meetings.

Although computer searches have revolutionized the process of locating possible measures of a given concept, it is advisable to add at least one other search strategy. It is often very helpful to consult colleagues who are currently conducting related research and are abreast of the most recent literature. Research-focused professional meetings provide fruitful opportunities for discussing measures and for learning about recent developments.

**EVALUATING EXISTING INSTRUMENTS**

Once potential instruments have been located, they should be carefully evaluated in light of the purpose for which they are to be used. This is a process that requires sophistication in the concepts of measurement and cannot be conducted superficially or with a strong bias toward a particular discipline. For example, an instrument’s availability, previous widespread use, and purported ability to measure a concept or variable of interest are not sufficient to legitimize its use for a given health-related measurement activity. Importantly, the fact that an instrument has been developed within the context of another discipline’s domain does not automatically exclude it from consideration by researchers from other fields, as long as the perspective providing the background for the tool is clear to the user.

Evaluating the adequacy of any existing instrument requires examining its purpose, conceptual basis, development, and psychometric properties. It is the potential borrower’s or user’s responsibility to obtain the information necessary to evaluate these features. Despite the increase in publications about instrument development and the requirement that the process of instrument development be described in research reports, the needed information for a thorough evaluation may not be readily available and may require active search by the potential user. It may be advisable to establish personal contact with the instrument’s developer and others who may have used it. Although time-consuming, obtaining such information before selecting an instrument helps to prevent problems and errors that result from the use of inappropriate or psychometrically inadequate measures and that cannot be rectified after the measure has been employed. The considerations listed below provide some guidance to the potential user and highlight the information that tool developers have a responsibility to make available to others who might want to use the instruments they develop.

**Purpose and Stated Aims**

Every measurement instrument is developed for a purpose, whether or not it is explicitly revealed by the developer. The purposes for which the tool was originally developed need not be identical to those for which it is being evaluated, but they should be congruent. For example, a tool developed to measure patient satisfaction for a research study could be employed subsequently as part of a comprehensive evaluation for an entire health system. Because the purpose for which an instrument is developed is inherently linked to its content and format, it is important that the instrument as a whole and individual items be scrutinized carefully to assure appropriateness for the intended use in other settings and populations.

Instruments are developed with one of several goals in mind (e.g., description, diagnosis, screening, selection, and prediction). Each of these goals requires different information. For example, a tool developed to provide descriptive information about the mood states of patients with newly diagnosed diabetes may be too imprecise to be used for diagnosing clinical depression.

**Measurement Framework**

As detailed in Chapter 4, norm- and criterion-referenced measures are developed and interpreted differently for different purposes, and
should not be used interchangeably. Availability of norms for the former type of measure is an important consideration in instrument selection.

**Population**

A measure is developed for a particular population and is specific to individuals or groups with given characteristics, such as age, educational or reading level, culture, ethnicity, previous life experiences, and health status (including specific pathologic conditions). As a result, tools often cannot be used for different types of populations without considerable modification. Typically, standardized instruments are designed for use in large, heterogeneous and geographically distributed populations; norms are often available not only for the population as a whole, but also for subpopulations with specific characteristics.

**Setting**

An instrument may be either setting-specific or designed for use in any setting. Those that are setting-specific are designed for use in a particular type of place, such as a hospital, school, industry, or home, and cannot easily be transferred to another context. The setting may also influence measures, such as interviews and questionnaires, that require the subject to take a given environment or context into account in formulating responses. For example, an instrument designed to measure patients’ perceived control in the intensive care setting would probably be inappropriate for use in a long-term care facility.

**Time Perspective**

All instruments have an inherent time orientation. Some take only the present into account, while others require recall of past events or projection into the future. It is important to ascertain the extent to which a given instrument may be oriented toward short-term versus long-term conditions or situations, and to estimate the ability of the intended population or individual subject to adjust their thinking accordingly. If an instrument requires recall, it is subject to subjects’ tendency to forget details of past events or to remember them selectively.

**Conceptual Basis for the Instrument**

Inherent in every instrument are assumptions about the nature of the entity or phenomenon being measured and how it relates to others. These assumptions may be explicated by the developer or, more commonly, may have to be inferred. Every instrument reflects a particular perspective and conceptual mapping that must be evaluated in terms of its congruence with the orientation of the potential user. Many instruments that are useful in nursing and health research measure complex concepts, such as stress, anxiety, social support, coping, communication, role, nursing, and health, which have been conceptualized from many different theoretical perspectives. The instruments developed to measure the same concept may differ considerably in the dimensions that are highlighted if the conceptual bases differ.

A major consideration in evaluating an existing instrument is the degree of fit between the current conceptualization and that which guided the development of the tool. The rapid development of knowledge about health-related phenomena can render older instruments incomplete or inappropriate. In addition to ascertaining that underlying assumptions are compatible, important points in assessing the degree of fit include the following: (1) whether the entity to be measured is conceptualized as static or dynamic; (2) whether the entity is conceptualized objectively, subjectively, or both; and (3) the extent to which the original conceptualization includes those aspects or dimensions of meaning that are deemed essential in the situation for which it is being evaluated. A common problem is that the instrument chosen to measure a given concept is not conceptually congruent with the investigator’s perspective and theoretical definition of that concept, so validity is compromised and findings cannot be interpreted adequately. The only way to eliminate this problem is to define the meaning domain explicitly and evaluate the domains of existing instruments in that light. Information concerning the conceptual
Despite the recent emphasis on the importance of using sound measurement principles and reporting the results of psychometric assessments, there remain significant gaps in the literature. Often reliability and validity are not reported, or are reported for much earlier administrations of the measure. Where data are not reported, the tool developer should be contacted personally. If that is not possible, then recent users of the instrument may have unpublished psychometric data to share.

In addition to psychometric properties and congruence of conceptualization and purpose, some pragmatic aspects of potential instruments need to be considered: (1) the cost, time, and any special requirements or arrangements involved in purchase, administration, and scoring; (2) the demands made on potential subjects; (3) the appropriateness of the tool for the intended setting(s); and (4) whether it is possible to secure permission to use the instrument for the intended purpose. After careful review of the above features, it is often possible to identify one or more existing tools that are acceptable. If more than one instrument appears to be satisfactory, then, all else being equal, the one with the best psychometric performance should be selected.

If existing tools require modifications, such as changes in wording or the addition or deletion of items, then a new instrument has been created. Therefore, previous estimates of psychometric properties and previously established norms are inapplicable, and reevaluation must be carried out.

**Psychometric Properties**

Reliability and validity are fundamental considerations when evaluating an existing instrument for potential use, a point that has been emphasized repeatedly throughout this book. Also important for many kinds of instruments are considerations of sensitivity and specificity. Information about the psychometric properties of any instrument should be obtained and evaluated before the tool is selected for use. A thorough assessment requires that the potential user take into account the procedures that were used to develop the instrument, as well as those that were used to assess its psychometric properties, not only at the time of development, but also in subsequent applications. Consider the types of reliability and validity assessed and the specific populations and conditions of administration for which data have been reported, recognizing that psychometric properties may change under different conditions. Evaluation should take into account: (1) the number and currency of estimates; (2) the diversity of conditions for which estimates have been reported; (3) the nature of the samples from which data were obtained; (4) the degree of similarity between the situation for which the instrument is being evaluated and those for which psychometric data are available; and (5) the appropriateness of the procedures used to assess reliability, validity, specificity, and sensitivity, given the type of instrument and its intended use. Psychometric properties are viewed in light of the purposes for which the tool will be used, including the degree of precision and accuracy that is necessary. For example, considerably more measurement error can be tolerated in an exploratory study than is acceptable in a clinical trial of a pharmaceutical agent or medical device, a laboratory test or diagnostic tool, or a study of the results of an intervention designed for quality improvement.

**USE AND REPORTING**

The use of existing instruments entails considerable legal and ethical responsibility on the part of the user. Printed research instruments are subject to protection under copyright law, whether or not the tool developer has completed the process of securing the copyright. The copyright for an instrument that is published in a professional journal may be held by the publisher, the author or the author’s employer. In either case, permission must be secured from the copyright holder before the tool can be duplicated or used.
for purposes beyond what is considered to fall under the doctrine of fair use. Some developers market and sell their instruments, whereas others allow them to be duplicated without charge. Even when an instrument is not legally protected by copyright, professional ethics dictate that, if possible, permission be secured before duplicating and using it.

Fair use is a legal principle that states that "portions of copyright materials may be used without permission of the copyright owner provided the use is fair and reasonable, does not substantially impair the value of the materials, and does not curtail the profits reasonably expected by the owner" (Owen, 1987, p. 33). The Copyright Law of the United States says that "the fair use of a copyrighted work, including such use by reproduction in copies or phone records or by any other means specified by that section, for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research, is not an infringement of copyright" (United States Copyright Office, 2009, #107). Major considerations are whether the material will be used for commercial purposes, the portion of the work as a whole is being reproduced, and the potential impact on the marketability of the work.

Under this doctrine, a teacher can copy an instrument for personal use or a portion of the tool for classroom use; however, making multiple copies of the entire instrument for distribution to large classes over a number of years might well be problematic without securing permission from the holder of the copyright. Copy services that duplicate packets of materials for sale to students are careful to secure permission to do so. Likewise, publication of multiple copies of a copyrighted instrument for use with subjects in a large research study would be precluded unless permission was secured from the copyright holder. It would be particularly problematic if the developer or publisher was charging a fee for copies of the tool. The assistance of an attorney or librarian who is an expert in copyright law should be sought to clarify any issues regarding possible copyright infringement. However, an appropriate rule of thumb is to secure permission before duplicating, modifying, or using an existing tool.

Permission to use a given instrument for a specific purpose should be requested and secured from the developer and the copyright holder in writing. Correspondence related to the transaction should be kept on file as a legal record of attention to the provisions of copyright law, and credit should be given in writing on the instrument itself and in related publications.

When an instrument is a modification of an existing tool, credit should be given to the original instrument's developer. When an existing instrument is used, any instructions or conditions specified by the developer must be followed. These may include specifications regarding subjects, procedures for administration, scoring and interpretation, requirements for computer scoring, or requirements for sharing data obtained or problems encountered.

The importance of adhering to predetermined procedures in the use of standardized instruments was emphasized in Chapter 7. Adherence to specified procedures is equally important with nonstandardized measures if comparisons with previous data are anticipated.

Although psychometric information may have been secured for an existing instrument, its properties in a different sample are essentially unknown. Thus, the psychometric properties of the instrument should be reassessed with each sample. When the sample or setting differs considerably from previous applications, it is advisable to pretest the tool and calculate reliability and validity statistics using the pretest data. The statistics should be recalculated concurrently with use of the instrument and reported.

Reporting the use of existing instruments to the developer and copyright holder (where appropriate), as well as to the scientific and professional community as a whole, are important considerations. Even when the developer does not require feedback following use of an instrument, it is desirable to communicate the results of having used it, particularly if any problems were encountered. It is particularly important to communicate (1) any difficulties encountered in administration, calibration, scoring and interpretation; (2) the results of psychometric testing; (3) frequency distributions that might have implications for establishing or modifying norms; and (4) any suggestions for modification.
or future applications. Such feedback is useful, because it helps improve the tool and affects its ultimate utility.

The user of an existing instrument has responsibility to share information about the tool’s properties and its potential utility to the scientific community. Any modifications should be detailed explicitly and resulting psychometric data shared. Failures as well as successes also are important. The finding that an instrument demonstrated low reliability or validity when used with a particular population or setting, or that problems were encountered with its use, are vital to preventing future problems and encouraging needed modification.

REFERENCES


Part V

Measurement Issues
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The health professions have taken very seriously the importance of ethical considerations in research and practice. Standards, codes, and guidelines that are designed to assure ethical practice in collecting and handling data from human beings and address issues such as protection of the dignity and privacy of patients and research subjects and the security of patient information have been established and updated by the federal government and professional and specialty organizations. Examples include the American Nurses Association’s (ANA) Code of Ethics With Interpretive Statements (2001), the American Medical Association’s Code of Medical Ethics (2008), and the National Academy of Sciences (2009) guidelines for the responsible conduct of research. (See also Fowler, 2008; Grace, 2009; Morrow & Richards, 2002; and National Institutes of Health [NIH], 2003a, 2003b) Despite the existence of such guidelines and increased attention in the literature, complex ethical issues in measurement remain, in part due to rapid changes in the health care environment and technology. These include increased use of the Internet for data collection in research (e.g., Birnbaum, 2001, 2004a, 2004b; Haller, Haller, Courvoisier, & Lovis, 2009; Huntington et al., 2009; Im & Chee, 2002) and the implementation of privacy protections mandated by the Health Insurance Portability and Accountability Act of 1996 (HIPAA), more specifically, the Privacy Rule issued by the U.S. Department of Health and Human Services in 2002 and implemented April 14, 2003 (see Title 45 Code of Federal Regulations, parts 160 and 164, which may be obtained and guidance provided at the NIH Web site at http://privacyruleandresearch.nih.gov. General information about HIPAA can be obtained from http://hipaa.com).

The purpose of this chapter is to call attention to some of these issues, recognizing that there are no simple solutions. While an exhaustive discussion is beyond the scope of this book, responsibilities of nurses and other health professionals to clients or subjects, to colleagues, and to the scientific and professional community will be highlighted. Readers desiring a more detailed treatment of ethical dimensions of measurement and research should consult comprehensive sources such as Levine (1986); Beauchamp and Childress (2009), and Beauchamp, Walters, Kahn, and Mastroanni (2008).

ETHICAL ISSUES RELATED TO MEASUREMENT OF HUMAN SUBJECTS

Most of the ethical issues regarding measurement of human subjects have been addressed in connection with biomedical and social research. Following World War II and the Nuremberg trials, which called attention to abuses in human experimentation, there has been ongoing activity to assure ethical and humane treatment of human and animal subjects in research. Guidelines are provided in such well-known documents as the Nuremberg Code of 1947 and the 1964 Declaration of Helsinki; in the codes of professional organizations such as the American Nurses Association, American Medical Association, American Dental Association, American Psychological Association, American Sociological Association, American Hospital Association, American Political Science Association, American Anthropological Association, and American Personnel and Guidance Association (for information about these guidelines and reprints of some of the codes, see Beauchamp et al., 2008 and...
Levine, 1986); and in published requirements for research funded by the U.S. Department of Health and Human Services (2001a, 2001b) (see Title 45 Code of Federal Regulations, Part 46, Protection of Human Subjects, available at http://www.hhs.gov/ocr). The NIH has provided materials to assist researchers in interpreting the HIPAA Privacy Rules; as noted above, this information can be accessed at http://privacyruleandresearch.nih.gov.

The guidelines address multiple aspects of research, and hence include, but are broader in scope than, the measurement considerations that focus the following discussion. They should be consulted and followed by any health provider or researcher who is proposing to engage in data collection and/or research involving human subjects.

Ethical considerations that apply across the board to all types of research address the researcher’s honesty and integrity, objectivity, carefulness, confidentiality, respect for intellectual property and for colleagues, responsible publication and mentoring, nondiscrimination, and competency (Shamoo & Resnik, 2003). Specific standards and guidelines have been developed for research involving animal subjects (e.g., American Psychological Association, Committee on Animal Research Ethics, 2009).

Three basic, comprehensive ethical principles provide the foundation for the guidelines, recommendations, and standards that have been designed to provide for the rights and well-being of human subjects in measurement and research: respect for persons, beneficence, and justice (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1978). The principle of respect for persons includes the conviction that all persons should have autonomy or self-determination, and that those whose autonomy is reduced because of age, illness, or incapacity are entitled to protection. This principle is particularly important for underpinning subjects’ rights to informed consent, and underscores the importance of allowing research subjects to choose whether to participate, based on the receipt of information about the study, the measurement process, and data management. The principle of beneficence refers not only to the duty not to harm others (nonmaleficence) but also to the duty to maximize potential benefits and minimize possible risks associated with the research or measurement procedure. It provides important underpinnings for subjects’ rights to protection from harm and for analyzing the ratio of potential risks to benefits. In the age of Internet data collection and the accumulation of large databases that are populated with patient information, this principle also underscores the importance of protecting the patient’s privacy and maintaining confidentiality of all patient information during the measurement process and in management and storage of the data. The increasing use of the Internet for data collection and electronic storage of identifiable personal data, including health information, heightens potential risk to subjects and participants due to breaches in cyber-security. The principle of justice refers to the obligation to treat individuals equally and fairly; it underpins selection of research subjects and research designs.

In accordance with these basic ethical principles, researchers are obliged to recognize and protect the basic rights of subjects in measurement activities. Important ethical dimensions of measurement activities include informed consent, permitting refusal to participate or ability to withdraw without fear of adverse consequences, privacy, confidentiality, anonymity, and protection from harm. Measurement-related issues and responsibilities for each of these areas will be addressed.

**Informed Consent**

Informed consent applies to many types of patient-professional interaction. It can be said to occur if a patient or research subject who has substantial understanding of what he or she is being asked to do, and is not being controlled or coerced to do so by others intentionally, authorizes a professional to do something (Beauchamp & Childress, 2009). Essential elements of informed consent are (1) competence of the subject to consent (a precondition), (2) disclosure of information, (3) the subject’s understanding of the information being disclosed, (4) volition or choice in the consent, and (5) authorization of consent. While the professional’s provision
of information is important, equally important is the subject’s ability to understand and consent (Beauchamp & Childress, 2009). To try to assure the subject’s self-determination, that is, to protect autonomous choice, the subject must be competent to comprehend information and make decisions, be fully informed of and comprehend what is involved, be fully informed of the associated risks and benefits and of alternatives of participation, and must agree freely to participate before measurement can be carried out.

As detailed in the federal policy on human subjects research (U.S. Department of Health and Human Services, 2001b), the information provided to the potential subject includes:

1. A statement that the study involves research, an explanation of the purposes of the research and the expected duration of the subject’s participation, a description of the procedures to be followed, and identification of any procedures which are experimental
2. A description of any reasonably foreseeable risks or discomforts to the subject
3. A description of any benefits to the subject or to others which may reasonably be expected from the research
4. A disclosure of appropriate alternative procedures or courses of treatment, if any, that might be advantageous to the subject
5. A statement describing the extent, if any, to which confidentiality of records identifying the subject will be maintained
6. For research involving more than minimal risk, an explanation as to whether any compensation and an explanation as to whether any medical treatments are available if injury occurs and, if so, what they consist of, or where further information may be obtained
7. An explanation of whom to contact for answers to pertinent questions about the research and research subjects’ rights, and whom to contact in the event of a research-related injury to the subject
8. A statement that participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled (45 CFR 46.116a)

In addition, informed consent should address how the data from the measurement, once obtained, will be protected (ANA, 2001). This includes statements about who will have access to the data and the possible purposes for which it may be used.

The provision of information does not necessarily ensure comprehension by potential subjects. Comprehension can be increased by carefully wording the information provided, gearing the information to the subject’s reading and comprehension level, translating (or securing the services of a reliable interpreter to translate) information into the patient’s language, encouraging potential subjects to ask questions, and asking subjects to voice their understanding and interpretation of what will be required before consent can be assumed to be secured. Generally, it is desirable to provide information both orally and in writing. Im and Chee (2002) point out that research subjects in Internet studies may actually have more opportunity to ask questions and self-determine their participation than those in more traditional quantitative approaches to measurement, such as surveys.

Although the obligation to assure informed consent has been universally accepted, it raises a number of issues. One example of a hotly debated topic is how much information to disclose. Several attempts have been made to establish standards of disclosure. However, the various standards (e.g., professional, reasonable person, and subjective standards) have problems associated with them (see Beauchamp & Childress, 2009). The combined standard is to disclose whatever information a reasonable person placed in the subject’s position would need to know in order to make an autonomous decision, but to make modifications based on an assessment of the unique needs and desires of the individual subject.

These standards, while helpful, do not resolve the problem that providing information to potential subjects about the measurement activity may serve to alter the outcomes
Nurses attempting to secure informed consent for measurement and research may often encounter subjects whose ability to comprehend is limited. Examples include children, the mentally retarded, the mentally ill, the critically ill, and the unconscious. Although consent has generally been secured from a surrogate (e.g., a relative or guardian), a number of questions have been raised regarding these populations that need vigilant protection. Specific guidelines have been established for children (U.S. Department of Health and Human Services, 2001b, Sections 46.401–409). Parents or guardians must be informed of the implications of participation, and a signed consent must be secured. If possible, the child’s assent should be secured as well, particularly if the child is over the age of assent, which federal guidelines suggest to be 7 years of age. The child’s maturity and psychological state should be taken into account, and the child provided a simplified consent form. Adolescents between 13 years of age and the state-defined legal age should sign a regular adult consent form, but must have it countersigned by a parent.

In the case of adults who are unable to give informed consent because of illness or incapacity, the situation is complex. The American Association of Critical Care Nurses (AACCN) (2002) recommends that proxy consent can be considered when benefit clearly outweighs risk. According to Woods (1988), the surrogate should be someone who understands “the potential patient’s values, beliefs, and preferences well enough to accurately substitute his or her own judgment for the patient’s” (p. 91), and should act in the best interest of the patient. Individuals able to give consent include legal guardians, a designated health surrogate, or legal next of kin (AACCN, 2002). Permission to conduct measurement activities with these potentially vulnerable subjects should never be assumed simply because the relative or guardian does not raise specific objections.

Individuals who are members of captive audiences are at risk of having their right to informed consent compromised because the element of self-determination may be in question. The examples most frequently encountered in nursing are hospitalized patients, students, and
employees. The ultimate example, of course, is prisoners, for whom special provision is made in federal guidelines (see U.S. Department of Health and Human Services, 2001b, 45 CFR 46.301–306). The major problem is that these individuals may perceive pressure to comply with requests to participate in measurement activities or research and may acquiesce even though they do not really wish to do so. The perceived pressure may be due to status and power differentials between potential subject and the investigator, the real or imagined promise of rewards, or concern that failure to participate will jeopardize the subject’s condition or position. A dilemma exists as to whether such captive subjects should even be asked to participate and whether, even if they are told that a genuine choice exists, they will perceive participation to be completely voluntary. Some IRBs require that researchers request employees who are being asked to participate as subjects in research being carried out at their institution complete an additional form as part of the consent procedure.

In the measurement contexts other than research, there may be instances in which the individual may accurately perceive limited freedom of choice regarding measurement activities. For example, once having signed a general consent form upon admission, the hospitalized patient is often assumed to be willing to acquiesce to a considerable number of measurement activities, including invasive laboratory procedures, only the most potentially dangerous of which usually require special consent assurance. The American Hospital Association’s Patient’s Bill of Rights (1992) indicates that the patient has the right to receive information necessary to give informed consent before the start of any procedure or treatment; however, the extent to which such information is actually communicated for relatively routine procedures is questionable. There have been many instances in the past when patient information in hospital records has been used for research purposes without the patient’s knowledge or consent. This practice has been severely curtailed by provisions of the HIPAA Privacy Act discussed below. However, waiver provisions can be implemented with IRB approval when a researcher needs to access protected health information in data repositories, but the patient cannot be contacted for permission (NIH, 2003).

The student who has voluntarily enrolled in an educational program is the recipient of many measurement activities undertaken to evaluate attainment of competencies and mastery of content, as well as evaluation of the educational program. Such activities are a routine part of the educational environment, and failure to participate may have negative consequences for the student. In the research, clinical, and program evaluation contexts, it is essential to provide a genuine choice, to provide as complete information as possible, and to avoid applying subtle pressures to which captive subjects are susceptible. In the educational and administrative contexts, at the very least, potential subjects should be informed before entering the situation (i.e., before enrolling in an educational program or taking a position) about the measurement-related expectations and the consequences of nonparticipation. Personal student information is protected under the provisions of the Family Education Rights and Privacy Act (FERPA), which was revised most recently in December 2008 (see http://www.ed.gov/legislation/FedRegister/finrule/2008-4/120908a.html).

**Refusal or Withdrawal**

A generally accepted ethical position is that research subjects should be free to refuse to participate or withdraw from participation without recrimination or prejudice. The ability to refuse or withdraw is necessary to ensure that consent to participate in a measurement activity is given voluntarily. As noted previously, potential research subjects should be informed of this right at the time their informed consent is solicited, and subtle pressures to participate should be avoided. Special attention is required to ensure that no negative consequences stem from refusal or withdrawal from research-related measurement activities. This includes actions to prevent negative attitudes directed toward the subject. In the clinical, educational, and administrative contexts, the individual has a right to refuse or withdraw from measurement activities; however, there may be negative consequences to this action. The individual
Privacy

The principle of privacy, which is related to the principles of respect for persons and beneficence/nonmaleficence, also has many implications for measurement. Although defined in a variety of ways, the right to privacy asserts essentially that an individual should be able to decide how much of himself or herself (including thoughts, emotions, attitudes, physical presence, and personal facts) to share with others. Measurement activities are designed to yield information about individuals or groups and usually involve at least some intrusion into an individual's life and activities. They are therefore in potential violation of this basic right unless care is taken. It is also important to assure that the information shared or revealed by the individual is not used in a way that will cause harm.

Three major points regarding privacy should be borne in mind. First, individuals and cultural groups differ in the extent to which they are willing to divulge specific kinds of information, to whom, and under what conditions. For example, a client may be willing to reveal information about sexual behavior to a nurse or physician in a one-on-one interview in a therapeutic context, but unwilling to answer the same questions on a survey research questionnaire or in a group setting. Some sensitive or potentially damaging topics such as drug use, alcohol use, sexual behavior, family relationships, or certain medical diagnoses (e.g., HIV/AIDS, cancer) might be willingly discussed by some individuals, but not by others, for a variety of reasons that cannot always be anticipated. Given the social, cultural, and situational relativity with which privacy is defined, it is necessary that every effort be made to understand the social and cultural values of potential subjects and that no prior assumptions be made that a given measurement activity, even a particular question or item on an instrument, will be universally acceptable. Rather, each subject has a right to know in advance what information is to be gathered and how it will be used. In addition, the subject should be able to negotiate in advance which audiences have a right to know the information. Subjects must have the right to refuse to answer any questions or otherwise reveal information that they deem private.

Second, the nurse, by virtue of being an accepted and generally trusted health care provider, often receives information from and about clients that they would not ordinarily reveal to a nonprofessional. The nurse's unique status in relation to clients should be recognized and care be taken that it not be used to the client's disadvantage. Any intent to share the information with others should be explicitly revealed to the client in advance and permission received. Information gathered in a caregiving context should not be used for other purposes (e.g., research) without the client's permission. The HIPAA privacy rules discussed below are very explicit about the care that must be taken to assure the privacy of individuals' health information.

Third, measurement procedures differ in the extent to which they are likely to compromise the subject's privacy. The most serious questions have been raised about those procedures that allow measurement without the subject's knowledge or active involvement (e.g., unobtrusive measures, observation, content analysis of records, or covert tape recordings) and those that may encourage the subject to reveal more information than intended (e.g., in-depth interviews and psychological tests). The former are problematic in that they invalidate the subject's right to decide what to reveal. The latter pose problems, because they remove some of the subject's ability to control the content revealed. Coercion (overt and subtle) and deceit should be avoided. Further, data should be handled, interpreted, and shared carefully, with attention to potential privacy violations. In longitudinal research involving repeated measures, privacy is especially difficult to maintain. Particularly in situations in which the subject may inadvertently reveal more than intended or in which the information gathered might have negative consequences (e.g., cause others to alter their opinion of the subject), it is advisable to check with the individual before sharing any information with others. Chapter 22 concerning collection of sensitive data from subjects also addresses some
Although HIPAA was directed primarily toward insurers, health care clearinghouses, and health care providers who transmit any health information in electronic form (they are termed “covered entities”), it does have important implications for much nursing research. Researchers are not necessarily covered entities unless they also provide care and transmit health information electronically for insurance claims; however, if researchers are employees of a hospital, health insurer, or other covered entity, they probably will have to comply with that entity’s HIPAA privacy policies. In many cases, schools of nursing are required to comply with the HIPAA privacy policies of the covered entity institutions with which they have clinical affiliations. A researcher may also be impacted by HIPAA if he or she uses data provided by a covered entity. The law applies to protected health information (PHI), which is a subset of individually identifiable health information (IIHI). IIHI is any information about an individual’s physical or mental health, the health care provided to the individual, and that which identifies the individual (Olsen, 2003). “With certain exceptions, individually identifiable health information becomes PHI when it is created or received by a covered entity” (NIH, 2003b, p. 1).

HIPAA privacy regulations impact nursing research when researchers must access data from a covered entity (e.g., from the patient’s medical record), when the researcher creates individually identifiable health information in the course of the study (e.g., in a clinical trial or other intervention research), and when disclosing data (e.g., when sharing data with another researcher). Access to IIHI is monitored by the covered entity and is subject to HIPAA guidelines (unless explicitly excluded). For example, HIPAA pertains only to information gathered about living persons, and does not apply to information that has been deidentified. Deidentification is the process by which all identifiers have been removed, including names, addresses, dates (birth date, admission date, etc.), telephone numbers, e-mail addresses, Social Security numbers, patient ID numbers, photographic images, etc. (See U.S. Department of Health and Human Services, 2001a, and Olsen, 2003.) Access to IIHI is permissible if the data set is limited and the researcher has a data use agreement with the...
covered entity. In most cases, this will require that the researcher undergo HIPAA training and take steps to assure the security of the data.

According to Woods and Stockton (2002), once implemented in 2003, the HIPAA privacy rules dictate that “a health care provider may only use or disclose protected health information (PHI) for treatment, payment, and health care operations purposes. For all other purposes, including clinical research, the health care provider must obtain a written authorization from the individual, unless an exception applies” (pp. 1–2). It is also possible for the researcher to obtain a waiver to the authorization requirement from an IRB or privacy board.

In the event that the patient is being asked for an authorization to use PHI for research purposes, the authorization may be included as part of the informed consent or may be a separate document. The authorization must contain the following core elements: the description of the information to be used or disclosed, the name of the person or class of persons authorized to make the request for information use, the name of the person or class of persons to whom the covered entity may make the requested use of information, a description of each purpose of the requested use, an expiration date that relates to the individual or the purpose for the use or disclosure, and the individual’s signature and date. The authorization must include information about the individual’s right to revoke it, and should not be a condition for receipt of treatment (Woods & Stockton, 2002). Many IRBs provide templates to investigators for authorization forms that include all necessary information.

Criteria for IRBs or privacy boards to waive the requirement of authorization are:

1. The use or disclosure of PHI involves no more than a minimal risk to the privacy of individuals, as demonstrated by a plan to protect the identifiers, a plan to destroy the identifiers (unless there is research or health justification), and adequate written assurances that the PHI will not be inappropriately reused or disclosed to any other person or entity unless legally required or as part of a HIPAA compliant disclosure.

2. The research could not practicably be conducted without the waiver.

3. The research could not practicably be conducted without the PHI.

When the measurement activity results in the creation of new health information data, the subject must authorize the use of the information. The subject must be given explicit information about the groups or individuals with whom the information might be shared, and permission secured. Researchers who are involved in multidisciplinary and multisite studies, and/or who may want to share the data with colleagues and students, must conform to HIPAA regulations. The researcher is also responsible for tracking any further disclosures of the data through waiver of authorization and for informing the patient of those disclosures. These regulations underscore the importance of maintaining contact information about research subjects in case later tracking is necessary.

Confidentiality-Anonymity

Closely related to the principle of privacy and included in the provisions of HIPAA is the ethical assertion, reflected in the codes of professional associations, that the anonymity of subjects be preserved whenever possible and that information that would allow identification of the subject be held in confidence by the professional. This right not only protects the subject but also has the important measurement implication of increasing the likelihood that responses will be more truthful and complete (i.e., more valid) than if anonymity and confidentiality cannot be ensured. Complete anonymity of subjects is possible in a few types of measurement activities, such as mailed questionnaires; but even in such instances, it may be impractical to promise complete anonymity, because follow-up of nonrespondents would be precluded. Generally, the principle of anonymity has been operationalized in research by ensuring that subjects will not be identifiable in public reports by name or any other defining characteristics. As noted in the above discussion of HIPAA, deidentification of patient data is becoming more common to allow their use in research. In nonresearch contexts, the right
to anonymity may be difficult or impossible to ensure under certain conditions, such as when measurement data about a client are needed for assessment, diagnosis, and intervention, or instances in which data about a particular student or employee are used to evaluate performance. The degree to which anonymity can or cannot be ensured should be made clear to the subject prior to initiating the measurement. Promises of anonymity should never be given unless they can be guaranteed. The right to confidentiality means that the subject should have the right to assume that information yielded by measurement activities will not be made available to others without prior consent.

The specific right-to-know audiences who will have access to the information should be specified to the subject. For example, measurement data recorded on a hospitalized patient’s record are appropriately available only to those hospital personnel who must have access to the information to provide care and cannot be legitimately obtained by others without the patient’s consent, the removal of identifying information, or waiver of authorization requirements.

In addition to highlighting responsibilities of the nurse regarding informed consent and care in the handling and reporting of data, the HIPAA privacy rules have clarified some of the difficult questions that previously surrounded implementation of the right to confidentiality. For example, the rules are explicit about the conditions under which data collected in research can be shared or used for other purposes (see Connor et al., 2003; NIH, 2003b; Olsen, 2003; Woods & Stockton, 2002). Additionally, the HIPAA privacy rules limit the PHI that may be disclosed to law enforcement officials (see Frank-Stromborg, 2003, for a discussion of the practice implications of HIPAA).

**Risks and Benefits, and Protection From Harm**

The ethical principle of beneficence (and the related principle of nonmaleficence) asserts the obligation not to do harm, to maximize potential benefits, and to minimize potential harm resulting from the measurement or research. This principle is highly compatible with nursing’s norms, since nursing as a profession is dedicated to enhancing the health and well-being of human beings. It may seem self-evident that professional ethics underscore the importance of preventing or minimizing potential risks to subjects, regardless of the context for measurement. However, it is necessary to realize that all measurement activities involve possible risks and benefits which, although they may not be fully known in advance, must be anticipated and evaluated before deciding how to design a measurement tool or device and whether to initiate the measurement activity. Researchers who conduct clinical trials of medications, devices, procedures, and intervention protocols must give serious consideration to assessing the associated benefits and risks, some of which may be life-threatening.

Before proceeding with the discussion of weighing risks and benefits in measurement, it is necessary to define some frequently used terms. In the Belmont Report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1978), risk is defined as “the possibility that harm may occur” and benefit is “something of positive value related to health or welfare” (p. 15). Benefits are conceptualized to accrue to individuals (e.g., subjects) and to society as a whole. The risk-benefit ratio expresses the relation of all anticipated risks and human costs to all known and anticipated benefits. It is based on a risk-and-benefit assessment procedure described later in this chapter. Minimal risk is defined as the degree of risk that is normally encountered in everyday life or in routine medical or psychological examination and treatment. When the risks of a given research or measurement procedure are more than minimal or exceed potential benefits, the procedure is generally not justified.

**Risk Associated With Measurement**

In assessing risks associated with measurement, it is necessary to consider those that may result from the measurement procedure itself and those that may result from the way in which the results of measurement are used. The most readily apparent risks of measurement procedures are those that are associated with physical harm. The
physiologic measures employed by nurses generally involve little danger to the subject, because they are minimally invasive. This does not preclude the possibility that seemingly routine and innocuous measures may involve possible risks, particularly with subjects who are very ill. For example, withdrawal of blood for a laboratory test may introduce infection or cause pain; repeated blood pressure monitoring may cause pain or vascular problems; or an improperly maintained or operated polygraph EKG recorder could result in an electric shock. While relatively unlikely and largely preventable, such risks are inherent in some nursing measurement activities and should be acknowledged and minimized.

Less obvious, but equally important, are psychological risks potentially associated with many of the measurement activities commonly employed in nursing. A measurement instrument or activity may inadvertently expose the subject to stress resulting from loss of self-esteem, generation of self-doubt, embarrassment, guilt, disturbing self-insights, fright, or concern about things of which the subject was previously unaware. For example, an instrument measuring parent-adolescent relations may include items that cause the parent to worry about aspects of the relationship or the adequacy of specific parenting behaviors; a measure that requests factual information or recall of specific events may embarrass a subject who is not able to respond; or psychological inventories may provide the subject with insight into aspects of personality or interpersonal relationships that alter previous self-perceptions and cause distress. While most measurement-related sources of psychological harm are inadvertent, potential measures and items should be assessed carefully in light of their capacity for exposing subjects and their families to psychological risk. In some types of measurement, social risk may be involved.

A related consideration that the nurse needs to assess honestly is the extent to which planned measurement activities will make demands on the subject’s time and energy, or the patient burden that it involves. Given the importance of obtaining multiple measures of a given concept, it is easy to lose sight of the time that may be involved in a subject’s completing several instruments. Demanding requirements may result in unwillingness to participate in measurement activities, or in withdrawal, fatigue, and anger, which may ultimately compromise reliability and validity. Measurement procedures should be designed to minimize disruption and should be feasible, realistic, and possible to carry out with reasonable effort. They should also not involve financial costs to subjects.

Some measurement procedures, such as cardiac stress tests, impose energy requirements that may be risky to some clients. The amount of time and energy required to complete planned measurement activities and the condition and situation of the potential subject should be taken into account, recognizing that different types of measures impose different demands. For example, busy individuals such as employees and mothers of young children may be unable to participate in time-consuming measurement procedures such as in-depth interviews. Subjects who are ill or under stress are particularly vulnerable to fatigue and should not be expected to engage in lengthy sessions or physically demanding activities. Unrealistic or impractical demands on subjects should be avoided, even if it means sacrificing optimal measurement practices. Subjects should always be informed in advance of the time and energy requirements involved and their special needs taken into account in planning and scheduling measurement activities.

Individuals or groups may experience harm that results not from the measurement procedure itself, but from the way in which the results of measurement are interpreted and used. One of the most important social risks encountered by subjects is being labeled negatively as a result of measurement. A number of cognitive and personality measures, even some physiological measures, are designed to produce scores to which labels may be assigned (e.g., normal, abnormal, hypertensive, paranoid, obsessive-compulsive, gifted, neurotic, antisocial, other-directed). Some clearly have negative connotations. Whether the measurement results and labels are actually communicated to the subject, those that cast an individual or group in a negative light when communicated to others may have deleterious consequences.

Use of measurement information to label subjects is problematic, particularly given
considerations of measurement error and bias inherent in instruments. Unless individual and cultural differences are expressly taken into account in securing and interpreting measurement data, a given conclusion or label, whether negative or positive, can be unwarranted. Many frequently used instruments such as intelligence tests, attitude scales, personality inventories, and behavioral checklists are culturally biased and are inappropriate for some subpopulations, including those minority groups who are currently receiving considerable research attention because of health disparities. For example, instruments measuring mother-infant attachment frequently incorporate behavioral indicators that reflect American, White, middle-class behavioral patterns and have not been sufficiently well tested to establish their validity with other cultural and socioeconomic populations. Even some physiologic measures, such as the Apgar measure of the health status of the newborn, have questionable validity for non-Whites. Using unmodified tools and undifferentiated norms for potentially biased measures can result in inaccurate interpretation and erroneous, unjustified interpretations and labels. Full and frank disclosure of measurement information requires that the limitations of tools and procedures be made explicit to aid in interpretation.

In many instances, measurement information is used as the basis for decisions that may profoundly influence a subject’s life. Examples include admissions decisions in educational programs, employment decisions, and decisions about the desirability or efficacy of a particular nursing intervention. In such instances, there is invariably some degree of risk to the subject because of the possibility of inaccurate interpretation. Although it cannot be eliminated completely, risk can be minimized through carefully scrutinizing reliability and validity of measures, using only defensible information sources and disclosing relevant information about their credibility, using multiple indicators, and interpreting scores in the light of measurement.

Risk-Benefit Ratio

Since it is impossible to remove all possibility of risk from measurement activities, it is necessary to evaluate the degree of potential risk in relation to the potential benefits that will accrue to the subject or society as a result of the activity. As noted above, the risk-benefit ratio expresses the relationship of all anticipated risks and human costs to all anticipated and future benefits. To compute a cost/benefit ratio, it is necessary for the researcher or measurement expert to (1) consider all possible consequences (negative and positive) of the measure; (2) ascertain whenever possible the types (physical, psychological, social) and degree of risks involved to the subject and to society on the basis of previous empirical evidence or preliminary data; (3) identify and, if possible, quantify possible benefits to the subjects and to society; and (4) consider how the risk-benefit ratio for a given procedure or activity may change over time as additional information is accrued and plan accordingly to reassess periodically (Levine, 1986; Spilker, 1991).

Some potential benefits of measurement activities for subjects include increased knowledge about one’s health, understanding of one’s relationships to others, acquisition of new information, increased awareness of available options, opportunity to express one’s views or opinions, perceived prestige related to having been selected to participate, and having the opportunity to contribute to a worthwhile undertaking. Some measurement activities result in no potential benefits to the subject directly, but are beneficial to society in that they contribute to knowledge and understanding of health-related phenomena and the ultimate improvement of health care. All known risks and benefits must be communicated to subjects as the basis for informed consent and every effort must be made to eliminate or minimize risks and maximize benefits. An activity should not be undertaken if benefits do not justify the risks.

Risk to the Researcher

It is possible to expand the conceptualization of risk to encompass that which may be experienced by the researcher. Nurses who engage in measurement may themselves incur some personal risk. The nurse is potentially liable if found to be acting in violation of institutional
policies or subjects’ rights, or inflicting any psychological, social, or physical harm in the process of gathering, interpreting, and reporting measurement data. Peer review of planned measurement activities, accomplished through such mechanisms as IRBs, is helpful in identifying potential human rights violations and ensuring that appropriate precautions are taken. Also helpful are the guidelines of professional associations and government. Such mechanisms protect not only the subject but also the investigator, and should be viewed as a valuable resource. These mechanisms, however, do not prevent nurse researchers from experiencing guilt or self-doubt about measurement in which some risk is involved. It should be noted that violation of HIPAA privacy rules also places the researcher at risk, so training about the rules and strategies to assure that they are followed is essential.

Personal risk can also be incurred in the process of gathering measurement information from subjects. For example, data collection in some settings (e.g., dangerous neighborhoods, hospital units with high infection rates) and with some populations of interest to nurses (e.g., drug addicts, combative patients) may result in physical harm unless proper precautions are taken. Psychological problems can result from repeatedly being used as a sounding board for subjects’ problems, repeatedly being exposed to depressing situations, or undertaking personally unrealistic time and energy demands related to measurement. While all such risks cannot be eliminated, every effort should be made to minimize them. Clinical agencies that employ nurses are beginning to take steps to acknowledge and protect the rights of nurses who are expected to participate in medical or nursing research by, for example, developing policies that ensure the right to refuse to become involved in any research activity deemed unsafe or unethical. Such steps might include nursing input in the design of clinical trials, mandating that nurses be included as members of IREs, defining the procedures to be used in identifying vulnerable subjects, and securing informed consent.

In summary, protecting the rights of subjects is a basic consideration in planning and undertaking any measurement activity. The nurse has the responsibility to become informed about and adhere to existing policies and guidelines that help guarantee those rights. Only a brief and superficial overview of ethical considerations in measurement has been provided. Since many ethical issues related to nursing measurement remain open to considerable controversy, the nurse who is unsure of the ethical and risk-related consequences of a given activity is well advised to consult others before proceeding. Potential resources include ethicists, lawyers, measurement experts, and medical and nursing personnel, including IRE members. Another valuable resource is the growing body of literature in philosophy, nursing, medicine, and other fields that address ethical issues.

ETHICAL ISSUES IN RELATION TO THE SCIENTIFIC AND PROFESSIONAL COMMUNITY

Throughout this book, emphasis has been placed on the importance of adhering to sound measurement principles in the development, selection, and use of instruments and devices to measure variables of interest to the nursing community. Ethical problems result when unsound measurement practices are used. Improper use of instruments or use of those with questionable psychometric properties not only poses potential risks to subjects but also represents misuse of subjects’ and nurses’ time. It also has important consequences for nursing knowledge and practice. Inadequate measurement has the potential to produce useless or erroneous information, which, if accepted uncritically as fact, can have a negative impact on the knowledge upon which it is based. The nurse engaged in measurement has the ethical responsibility to apply sound principles at every stage of the measurement process and to disclose fully any violation of these principles in using or reporting measurement information. Likewise, the consumer of measurement information (i.e., the reader of research reports or the decision maker) is responsible for scrutinizing the procedures used in the light of sound measurement principles and evaluating and using findings conservatively.
Development of measures, regardless of how sound and sophisticated they may be, does little to advance professional knowledge and practice, unless information about them is disseminated. Hence, it is argued that it is an ethical responsibility to make instruments and information about them available to others (nurses and those from other disciplines) via publication and presentations. The developer of an instrument should honestly and accurately report the way in which it was developed, tested, and used, providing all relevant psychometric data and acknowledging its known limitations and flaws, so that potential users can make informed judgments about its utility and correctly interpret resulting data. Data about extraneous or confounding variables that may influence subjects’ scores should be reported as well.

Questions can be raised regarding the point in the development and testing of an instrument when it is appropriate to share information about it with others. On the one hand, premature reporting before the instrument has been sufficiently tested to ascertain its properties in different situations may overestimate its potential value and provide insufficient information to allow reasonable evaluation by possible users. On the other hand, inappropriate delay in reporting the availability of an instrument precludes its use by others and may impede the accumulation of data about its properties, much of which can be furnished by others using the tool. After a tool has been developed, pretested, revised, and used at least once, there is generally sufficient information to legitimize reporting its availability, provided the state of its development and testing is made explicit and appropriate cautionary statements are included. The instrument should be neither underrated nor oversold. The standard is to provide sufficient data for informed evaluation by others.

Users of existing instruments also have ethical responsibilities. The most obvious requirements, which unfortunately are not always followed, are to obtain permission for intended use of the tool and to give credit to the developer when reporting its use. These requirements should be met whether an instrument is used in its original form or modified, and whether the instrument is protected by copyright. The user is obliged to report to the developer and others the results of use and any problems encountered. Instrument development is frequently undertaken as a collaborative activity in which each individual plays an active role based on particular areas of expertise in order to produce a high-quality instrument. In addition to clearly defining roles and responsibilities, collaboration requires that professional ethics and norms be considered in assigning credit for the ultimate product and related publications. Guidelines for acknowledging contributions and awarding credit should be agreed upon before collaboration begins.

Measurement instruments and activities are important aspects of nursing research, practice, education, and administration. Thus, information about and derived from them constitutes an essential part of nursing knowledge, which the nurse has an obligation to share and use according to accepted scientific and professional ethics.

REFERENCES


http://ohrp.osophs.dhhs.gov/humansubjects/guidance/45cfr46.htm


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Measuring the quality of health care has gained increasing attention since the Institute of Medicine’s (IOM) seminal work on health care quality that highlighted the extent and consequences of medical errors in our health care system (IOM, 2000). Measuring quality is not only for purposes of research or internal quality improvement by health care providers. The public, policy makers, purchasers, and insurers also are interested in knowing about the quality of care provided to inform decisions about selecting health care providers (e.g., to provide care, include in networks, give incentive payments). Quality measurement has moved from primarily internal, confidential quality assurance activities by individual health care organizations to public reporting of scores on quality measures such as those seen on Medicare’s Compare Web sites at www.medicare.gov. Whether through selection of high-quality providers or initiation of improvement activities informed by quality measure scores, the ultimate goal of quality measurement is to increase the numbers of patients receiving quality health care and ultimately achieving improved health.

There is an increasing demand for quality measures from legislators, regulators, consumers, and purchasers that must be balanced against the need for scientifically sound measures. This chapter presents an overview of quality measurement, the steps in developing a quality measure, and the major issues related to measuring the quality of health care.
such as gender, ethnicity, geographic location, and socioeconomic status. (IOM, 2001, pp. 39–40)

**Quality Measure**

A quality measure quantifies the abstract concept of quality. With most quality measures, data are collected at the patient level (e.g., influenza vaccination), but aggregated and scored at the provider level (e.g., proportion of a provider’s patients who received the influenza vaccination). The terms “quality indicator” and “quality measure” are often used interchangeably, however in this chapter, the term “measure” will be used to signify the most specific, operational definition. For example, because we know that influenza is associated with substantial morbidity and mortality and the vaccine is effective in preventing influenza, the proportion of patients vaccinated for influenza is an indicator of quality health care. An example of a specific quality measure is the CMS influenza measure for nursing homes presented in Table 25.1. As seen in this example, measure specifications include a target event (numerator), which is the focus of measurement and the target population (denominator), as well as any exclusions. In this example, the denominator is stratified into two cohorts—short- and long-stay nursing home residents.

### TABLE 25.1 Example of a Quality Measure

<table>
<thead>
<tr>
<th>0432 Influenza Vaccination of Nursing Home/Skilled Nursing Facility Residents (CMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong> Percent of nursing home/skilled nursing facility residents given the influenza vaccination during the flu season.</td>
</tr>
<tr>
<td><strong>Setting:</strong> Nursing Homes/Skilled Nursing Facilities</td>
</tr>
<tr>
<td><strong>Level of Analysis:</strong> Facility</td>
</tr>
<tr>
<td><strong>Numerator Statement:</strong> The number of residents in the denominator who meet any of the following criteria for the most recently completed influenza season (October 1 through March 31):</td>
</tr>
<tr>
<td>(1) received the influenza vaccine within or outside the facility during the flu season (computed separately); or</td>
</tr>
<tr>
<td>(2) were offered and declined the vaccination (computed separately); or</td>
</tr>
<tr>
<td>(3) were determined to be ineligible due to medical contraindication(s) (computed separately) (i.e., anaphylactic hypersensitivity to eggs or other component(s) of the vaccine, history of Guillain-Barre Syndrome within 6 weeks after a previous influenza vaccination, bone marrow transplant within past 6 months).</td>
</tr>
<tr>
<td><strong>Denominator Statement:</strong> The measure will be stratified by resident population. Rates will be reported separately for the long-stay (chronic care) and short-stay (post-acute care) populations.</td>
</tr>
</tbody>
</table>

#### Denominator Statement for Chronic Care (Long-Stay) Residents

All residents in the chronic care influenza vaccination sample with a valid MDS target record (any assessment or discharge tracking form) during the influenza vaccination reporting period (October 1 through June 30).

**Chronic Care Influenza Vaccination Sample Definition**

The chronic care influenza vaccination sample includes residents meeting any of the following three conditions indicating a non-PPS stay (i.e., not covered under Medicare Prospective Payment System [PPS] for Skilled Nursing Facility [SNF] care) during the season:

(1) resident has a non-PPS assessment during the influenza season (October 1 through March 31); or

(2) resident has a discharge tracking form during the season and the prior MDS record was a non-PPS assessment within 100 days prior to discharge; or

(3) resident had a stay with days during the season and was discharged prior to completion of an initial assessment. (Note that the discharge can be after the flu season end.)

#### Denominator Statement for Post-Acute Care (Short-Stay) Residents

All residents in the post-acute care influenza vaccination sample with a valid MDS target record (any assessment or discharge) in the influenza vaccination reporting period (October 1 through June 30).

**Post-Acute Care Influenza Vaccination Sample Definition**

The post-acute care influenza vaccination sample includes residents meeting either of the following conditions:

(1) resident has a PPS assessment (i.e., stay is covered under the Medicare PPS for SNF care) during the influenza season; or

(2) resident has a PPS assessment before the season with the next record being a discharge during the season.
TABLE 25.1 Example of a Quality Measure (Continued)

**Exclusions: Resident-Level Exclusions**
Residents satisfying any of the following conditions on the selected target assessment or discharge are excluded from the denominator:

1. The resident was not in the facility during the influenza season.

Note: Residents are not excluded if either or both of the influenza vaccine items (W2a and W2b) have dash (-) values indicating inability to determine.

**Facility-Level Exclusions**
Facilities with small sample sizes are excluded from public reporting of the influenza vaccination measure.

**Chronic Care Facility-Level Exclusions**
Facilities are excluded if either of the following is true:
1. The chronic care influenza vaccination sample includes fewer than 30 residents; or
2. the facility has fewer than 30 non-PPS quarterly assessments (AA8a = 05) for the entire facility for the year ending with the last day of the last completed influenza season (March 31).

**Post-Acute Care Facility-Level Exclusions**
Facilities are excluded if either of the following is true:
1. The post-acute care influenza vaccination sample includes fewer than 20 residents; or
2. the facility is excluded if there are no 5-day PPS assessments (AA8b = 1) for the entire facility for the year ending with the last day of the influenza season (March 31).

**Data Source:** Data collection instrument—Minimum Data Set (http://www.cms.hhs.gov/NursingHomeQualityInitis/20_NHQIMDS20.asp#TopOfPage)

**Numerator Codes:** Included in the numerator are residents meeting any of the following criteria on the most recent MDS assessment (of any kind) or discharge tracking form during the influenza reporting period (October 1 through June 30. When a vaccination is completed at the end of the flu season, the next opportunity to report the vaccination may be after the season is over. Extending the influenza vaccination reporting period through June allows for the capture of those late-season vaccinations):
1. resident received the influenza vaccine during the most recent flu season, either in the facility (W2a = 1) or outside the facility (W2b = 2); or
2. resident was offered and declined the influenza vaccine (W2b = 4); or
3. resident was ineligible due to contraindication(s) (W2b = 3).

**Denominator Codes: Chronic Care Denominator Codes**
A resident is included in the chronic care influenza vaccination sample in any of the following 3 cases:
1. resident has a non-PPS OBRA assessment (OBRA refers to the Omnibus Budget Reconciliation Act that specified required assessments for nursing home residents) (AA8a = 01, 02, 03, 04, 05, or 10 AND AA8b = 6 or blank) with assessment reference date (A3a) during the influenza season; or
2. resident has a discharge tracking form (AA8a = 06, 07, or 08) with discharge date (R4) during the influenza season. The preceding MDS record is a non-PPS OBRA assessment (AA8a = 01, 02, 03, 04, 05, or 10 AND AA8b = 6 or blank) with assessment reference date (A3a) before October 1 and the discharge date (R4) minus the assessment reference date (A3a) is 100 days or less; or
3. resident has a discharge tracking form “prior to completing the initial assessment” (AA8a = 08). The start date of this stay is the later of the admission date (AB1) from the discharge tracking form or the 13th day prior to the discharge date (R4 date minus 13 days). Either the start date or the discharge date (R4) is within the influenza season.

**Post-Acute Care Denominator Codes**
A resident is included in the post-acute care influenza vaccination sample in either of the following cases:
1. resident has a PPS assessment whether or not it is also an OBRA assessment (AA8b = 1, 2, 3, 4, 5, 7 or 8 and AA8a = any value) with assessment reference date (A3a) during the influenza season; or
2. resident has a discharge tracking form (AA8a = 06, 07, or 08) with discharge date (R4) during the influenza season AND the preceding MDS record is a PPS assessment (whether or not it is also an OBRA assessment: AA8b = 1, 2, 3, 4, 5, 7 or 8 and AA8a = any value) with assessment reference date (A3a) before October 1 and the discharge date (R4) minus the assessment reference date (A3a) is 45 days or less.

(Continued)
Specifications also include the time frames for the focus of measurement and the data collection period, the data source, and the details for identifying the target event and population in the data source such as codes or definitions. This particular measure is specified for use in nursing homes and skilled nursing facilities; therefore, the data source is the Minimum Data Set (MDS), which is required for all nursing home residents. The terminology and codes refer to regulations for nursing homes and specific items and responses in the MDS (e.g., AA8a = 05).

Focus of Measurement

Donabedian’s (1966, 1992, 2003) structure-process-outcome framework for quality assessment is still relevant for conceptualizing how to measure the construct of health care quality. The premise of this model is that organizational capacity (structure) influences health care practices (processes of care), which in turn influence patient outcomes. In this model, data for evaluating quality of care fall into three categories:

1. Structure measures focus on the organizational capacity to provide quality care, such as staff training and experience or staffing ratios.
2. Process measures focus on the interactions between health care practitioners and patients, such as clinical interventions and what is done for patients.
3. Outcome measures focus on the change in health status as a result of health care provided and reflect the desired results of providing care such as survival, improvement in function, or comfort.

Figure 25.1 depicts an application of the structure-process-outcome model used in a project on quality measures related to influenza and pneumococcal immunizations (National Quality Forum [NQF], 2009). Health care organization systems to assess and document immunization status and deliver the vaccine lead to the care process of assessing immunization status, recommending vaccination, and administering the vaccine; which leads to the outcomes of immunity, decreased influenza, mortality, and so forth. The figure also indicates antecedent patient and environmental factors that can influence the structure, process, and outcomes. For example, the population characteristics could influence what type of health care facilities, personnel, and health care services are available in a community. Patient outcomes also are affected by patient characteristics such as age and severity of illness present before care is begun (e.g., ability to achieve immunity).

Therefore, an important consideration when measuring outcomes, particularly if comparisons of health care provider performance will be made, is risk or case-mix adjustment to account for differences in the conditions of patients at the start of care.

The IOM six key dimensions of quality (safe, effective, patient-centered, timely, efficient, and equitable) also provide a framework for identifying types of quality measures. Besides clinical process and outcome measures that address safety and effectiveness of health care, access to health care, patient experience with care and efficiency also are appropriate topics for quality measurement. The best-known examples of measures of patient experience with care are the Consumer Assessment of Healthcare Providers and Systems (CAHPS) surveys, originally developed for assessing health plans and now in existence or development for hospitals, ambulatory care, nursing homes, dialysis facilities, and home health care (Goldstein, Farquhar, Crofton, Specifications also include the time frames for the focus of measurement and the data collection period, the data source, and the details for identifying the target event and population in the data source such as codes or definitions. This particular measure is specified for use in nursing homes and skilled nursing facilities; therefore, the data source is the Minimum Data Set (MDS), which is required for all nursing home residents. The terminology and codes refer to regulations for nursing homes and specific items and responses in the MDS (e.g., AA8a = 05).

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2. Process measures focus on the interactions between health care practitioners and patients, such as clinical interventions and what is done for patients.
3. Outcome measures focus on the change in health status as a result of health care provided and reflect the desired results of providing care such as survival, improvement in function, or comfort.

Figure 25.1 depicts an application of the structure-process-outcome model used in a project on quality measures related to influenza and pneumococcal immunizations (National Quality Forum [NQF], 2009). Health care organization systems to assess and document immunization status and deliver the vaccine lead to the care process of assessing immunization status, recommending vaccination, and administering the vaccine; which leads to the outcomes of immunity, decreased influenza, mortality, and so forth. The figure also indicates antecedent patient and environmental factors that can influence the structure, process, and outcomes. For example, the population characteristics could influence what type of health care facilities, personnel, and health care services are available in a community. Patient outcomes also are affected by patient characteristics such as age and severity of illness present before care is begun (e.g., ability to achieve immunity).

Therefore, an important consideration when measuring outcomes, particularly if comparisons of health care provider performance will be made, is risk or case-mix adjustment to account for differences in the conditions of patients at the start of care.

The IOM six key dimensions of quality (safe, effective, patient-centered, timely, efficient, and equitable) also provide a framework for identifying types of quality measures. Besides clinical process and outcome measures that address safety and effectiveness of health care, access to health care, patient experience with care and efficiency also are appropriate topics for quality measurement. The best-known examples of measures of patient experience with care are the Consumer Assessment of Healthcare Providers and Systems (CAHPS) surveys, originally developed for assessing health plans and now in existence or development for hospitals, ambulatory care, nursing homes, dialysis facilities, and home health care (Goldstein, Farquhar, Crofton,
Darby, & Garfinkel, 2005; Hargraves, Hays, & Cleary, 2003). Efficiency is a developing area of quality measurement and generally involves assessing resource use such as cost and utilization in combination with process and outcome measures of safety and effectiveness (Grazier, 2006; Krumholz et al., 2008; NQF, 2008). Comparisons only on cost or resource use would need to assume the same level of quality, which is not a justifiable assumption. Low cost could be due to “cutting corners” resulting in poorer outcomes. Similarly, high cost could be the result of more errors and complications, also accompanied by poorer outcomes.

**DEVELOPING A QUALITY MEASURE**

Several authors have described the steps in developing quality measures (McGlynn & Asch, 1998; Rubin, Pronovost, & Diette, 2001; Speratus, Eagle, Krumholz, Mitchell, & Normand, 2005). As with all measures, a sound conceptual
basis informed by evidence, and application of measurement science is paramount for developing an important, reliable, valid, and useful quality measure. The National Quality Forum is a voluntary consensus standards-setting organization that evaluates and endorses health care quality measures. NQF’s measure evaluation criteria (Table 25.2) provide a framework for key considerations when developing and testing quality measures (NQF, 2008).

NQF’s criteria for importance include that the measure topic addresses a high-impact aspect of health care; that there is a demonstrated performance gap; and that the measure is either a relevant outcome or there is evidence that the measure topic improves outcomes. A high-impact area may be related to a high volume of patients affected, severity of patient or societal consequences of poor quality, or high resource use. A performance gap refers to overall poor quality or variation in quality across providers or patient groups. Variation in quality associated with population characteristics such as race or socioeconomic status also may be indicative of disparities in care.

The criteria under scientific acceptability of measure properties include typical measurement principles of precise operational definitions (measure specifications), reliability, validity, risk adjustment, and discriminating differences in performance. Usability and feasibility are important for quality measures that will be implemented in ongoing health care operations. The usability criteria address whether the measure is useful to health care providers in identifying topics for and monitoring progress in quality improvement and to consumers and purchasers in selecting health care providers. The feasibility criteria focus on the practical aspects of widespread implementation of the measure in an ongoing quality assessment program—data collection and potential unintended consequences of measurement.

Select the Focus of Measurement

Developing a quality measure begins with determining what to measure, the purpose, and intended audience. Literature reviews and evidence-based guidelines are used to identify the dimensions of quality, key quality concerns, effective practices, relevant outcomes, and whether measures for the selected topic have already been developed. The review should include strength of the evidence (Berwick, 1989; U.S. Preventive Services Task Force, 2008; Valentine & Cooper, 2008), magnitude of the relationship between process and outcome (Spertus et al., 2005), and for outcome measures, identifying patient factors that influence the outcome for potential use in risk adjustment models. A team comprising clinical experts and researchers, as well as other stakeholders such as patients and payers, is useful in selecting the focus of measurement; and sometimes they have a role in developing and testing the measure.

This step establishes the foundation for developing an important and valid indicator of quality. When it is skipped, measures may be developed that ultimately contribute little to improving health care and outcomes. Given the limited resources available to develop and test measures, collect data from providers, and develop and

<table>
<thead>
<tr>
<th>TABLE 25.2</th>
<th>NQF Major Evaluation Criteria</th>
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<tr>
<td>Importance to Measure and Report:</td>
<td>Extent to which the specific measure focus is important to making significant gains in health care quality (safety, timeliness, effectiveness, efficiency, equity, patient-centeredness) and improving health outcomes for a specific high-impact aspect of health care where there is variation in or overall poor performance.</td>
</tr>
<tr>
<td>Scientific Acceptability of the Measure Properties:</td>
<td>Extent to which the measure, as specified, produces consistent (reliable) and credible (valid) results about the quality of care when implemented.</td>
</tr>
<tr>
<td>Usability:</td>
<td>Extent to which intended audiences (e.g., consumers, purchasers, providers, policy makers) can understand the results of the measure and are likely to find them useful for decision making.</td>
</tr>
<tr>
<td>Feasibility:</td>
<td>Extent to which the required data are readily available, retrievable without undue burden, and can be implemented for performance measurement.</td>
</tr>
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maintain reporting systems, the focus of measurement should be considered important to making significant gains in health care quality and health.

This step also provides the foundation for the validity of conclusions about quality of care. The IOM definition of quality cited previously refers to health services that increase the likelihood of desired health outcomes and are consistent with current professional knowledge. Therefore, the focus of a quality measure should reflect the best evidence available regarding a care process or the outcomes that are the goal of health services, the patients for whom the treatment or outcome is indicated, and pertinent exclusions and risk factors.

**Define the Measure Specifications**

Once the focus of measurement has been identified, the operational definition (i.e., measure specifications) needs to be specified. A well-specified measure provides the foundation for reliability when the specifications result in consistent interpretation and application across potential implementers of the measure. Measure specifications include detailed and unambiguous descriptions for the focus of measurement (i.e., the target condition, event, outcome) and the target population and any exclusions; data sources and data items including any codes and definitions; time frame for the focus of measurement and the data collection period; unit of analysis; scoring (e.g., proportion, rate, average); sampling strategy, if used; analysis methods for discriminating performance; and risk adjustment variables and method for outcome measures.

The measure specifications are critical to implementing the measure and interpreting results. Even when measures are focused on the same topic, differences in how measures are specified can result in widely varying scores and rankings of the facilities being measured. For example, Braun et al. (2006) found median rates for bloodstream infections (BSI) based on administrative data varied with different specifications from 0.046 to 7.03 BSIs per 100 patients; and hospital-specific rates and rankings varied substantially.

**Conduct a Preliminary Pilot Test**

Small-scale pilot testing is conducted to determine if the measure specifications are understandable and that the required data elements are available in the specified data source. Data collection procedures such as chart abstraction or data extraction from electronic sources, as well as the scoring computations, also are tested. The goal of this step is to clarify and refine the measure specifications and determine that it is possible to obtain the data that will be needed to compute the measure before embarking on larger scale testing. Skipping this step can result in an inability to demonstrate that the measure is scientifically sound (e.g., reliable, valid, discriminating, adequately risk adjusted).

**Test the Scientific Acceptability of the Measure Properties**

Expanded testing with a larger and more representative sample of providers is conducted to establish the reliability and validity of the measure. For outcome measures, scientific acceptability also includes development and testing of the risk adjustment strategy. Many quality measures, such as percentage of patients who received the influenza immunization or percentage of hospital patients with congestive heart failure who died within 30 days, are more like single-item measures (i.e., influenza immunization, death) than those created from multi-item scales where testing internal consistency reliability would be indicated. When quality measures are not multi-item scales, reliability testing often focuses on the data items that are used to construct the measure. Commonly used reliability tests include interrater reliability, test-retest, or intrarater reliability, depending on the type of data. Another method to assess reliability of data items described by Rubin, Pronovost, and Diette (2001) is the correlation among items that should provide similar results, for example, the number of patients with an order for a lab test and the number of patients with a value for the lab test. Statistical analyses used to identify and partition sources of variation—variation within a provider, variation among providers, and random variation—also can be
Therefore, measure scores need to be analyzed to determine variability across providers and statistically and practically meaningful differences in performance. Various statistical methods have assumptions related to the structure of the data and may or may not be robust to violations of those assumptions. Considerations in selecting the appropriate analytical strategy include whether the measure scores are computed from a sample or the entire population, the number of cases in the target population per provider, whether the focus of measurement is a rare event, the type of scale of measurement (e.g., nominal, ordinal, interval, ratio), the distribution of the scores, and independence or correlation of the data. Determining the amount of uncertainty around an estimate is important to identifying whether a score reflects differences in performance and making valid conclusions.

**Test the Usability of the Measure**

Outside of the research context, quality measures generally will be used to inform decisions regarding selection of health care providers and to identify areas for and monitor progress with quality improvement. Additional testing relates to the end users of proposed quality measures, for example, determining whether consumers understand and find the measure results useful for decision making and providers can use the data for quality improvement purposes. Focus groups have been used to evaluate consumers’ understanding of quality measures (Hargraves et al., 2003). Using quality measures in a quality improvement initiative to identify baseline performance and monitor progress as improvement actions are implemented also demonstrates usability in the context of quality improvement (Dull, Baird, Dulac, & Fox, 2008; Kerr & Fleming, 2007).

**Identify and Address Feasibility Issues**

In the context of public reporting where data are collected and reported on an ongoing basis, feasibility becomes an important consideration. Feasibility concerns include the ease, time, and cost...
Although measuring Hba1c is necessary, it is not sufficient in itself to achieving good diabetes control and ultimately the health of the patient. Other aspects of care are more directly linked to desired outcomes, such as the intermediate outcome of Hba1c values or a process measure of appropriate medication management in response to the Hba1c values. These may provide a better reflection of quality, but are technically more challenging to measure.

Related to the above example is some debate over whether it is better to measure the processes or outcomes of care. This tension often is seen between various stakeholders. Often consumers and purchasers advocate measuring outcomes since they represent the reason and goals for seeking and providing health care in the first place. Often health care providers advocate the use of process measures because they represent the actual care provided. In 1992 Donabedian addressed this debate and noted that the best strategy is to include a mix of indicators from all three sources of quality data—structure, process, and outcome (Donabedian, 1992).

When process measures are chosen, they should focus on the aspects of care most directly related to the desired outcome. Most care processes begin with assessment to diagnose and define a problem in order to identify the appropriate intervention. The necessity of assessment in providing quality health care is unquestioned; however, in most cases, it is insufficient in achieving desired outcomes. Thus, assessing immunization status won’t change immunity; or assessing blood pressure or LDL cholesterol won’t change those values—it requires choosing and administering the correct intervention. In the preceding examples, administering the vaccine or appropriate medication is more directly related to the desired outcomes. Intermediate outcomes of the actual values for blood pressure and LDL cholesterol are even more directly related to outcomes of improved function, fewer complications, less morbidity, and lower mortality.

Both process and outcome measures can be useful indicators of quality. Measured processes should be known to influence the relevant outcomes as supported by the best quality evidence. Relevant outcomes are those that reflect the reasons and goals for seeking and providing health care for the particular focus of assessment based on the evidence for effective care to the extent it is available. With the demand for quality performance measures, there may be a tendency to focus on aspects of care that are more easily measured, such as whether an Hba1c test was performed for a patient with diabetes. However, that may not be most useful in determining the quality of health care because
care such as improving survival, preventing illness, decreasing morbidity, improving function, and so forth. Even when adequately operationalized, both process and outcome measures have pros and cons (Rubin et al., 2001). Process measures provide information on whether recommended care has been given and can directly guide improvement actions. However, process measures focus narrowly on one care process and multiple measures often are needed to adequately measure all the important aspects of quality.

Outcome measures reflect the reason for receiving health care and are integrative, reflecting the result of multiple care processes and all disciplines involved in the care. For example, an outcome such as surgical site infection is influenced by care that is provided before, during, and after surgery by nurses, physicians, and other care providers. Outcomes are more complex and require risk adjustment when comparing providers, and also require further investigation to identify potential care processes that need improvement (Donabedian, 1992). If a hospital’s risk-adjusted score on a measure of surgical site infection is significantly higher than other hospitals, then it knows there is a potential quality problem, but it will need to review and investigate its cases and care processes to identify the specific causes of the infections and potential strategies for improvement.

**Application of Classical Measurement Theory and Level of Rigor**

Another issue is how best to apply measurement theory and standards for reliability and validity (DeVon et al., 2007) to quality measures. As described, quality measures often are based on single items (e.g., receipt of antibiotic to prevent surgical infection) rather than multiple-item scales and testing such as factor analysis and internal consistency reliability are not appropriate. However, scales to measure patient experience with care and health-related quality of life are notable exceptions. Individual quality measures also may be combined into a composite comprising multiple individual measures reflective of various domains of quality (Shahian et al., 2007), similar to scales and subject to testing suitable for scales.

For many quality measures, reliability testing is focused on the data elements used to construct the measure, rather than the computed score. The computed scores are usually generated through computerized algorithms and calculations, and once tested, will produce consistent scores if the data elements are reliable. The potential threat to reliability occurs with errors in the source data used to compute the measure score. For example, the home health measure, improvement in ambulation, is computed from standard assessment items generated by clinicians and interrater reliability studies examine the concurrence between two clinicians’ assessments of the same patient at the same time.

Reliability testing for measures based on data from medical record abstraction examines concurrence between the data collected by two abstractors. However, with the use of large administrative datasets such as Medicare claims, the medical record data needed to conduct interrater reliability studies that examine the concurrence between the codes generated by two coders generally are not available and not tested, except as in special studies. The AHRQ quality indicators (AHRQ, 2007) use claims data and AHRQ has undertaken studies to confirm the accuracy of the most important data elements for the measures—the complications and outcomes that are the focus of measurement (Romano et al., 2009).

Small case volume also poses a threat to reliability because the effect of random variation is more pronounced and affects the precision of the estimate. For example, the effect of one case on a measure in a provider with 10 cases is very different than a provider with 200 cases. Many advocate for reporting confidence intervals with quality measures scores so that valid conclusions can be drawn about differences in quality of care (Shahian et al., 2001; Zaslavsky, 2001).

The operational definition (measure specifications) provides the foundation for reliability. The measure specifications include detailed instructions for identifying the target population and appropriate exclusions, the measured topic (such
as patients who had the outcome or received the care being measured), the data elements and source, definitions, codes, unit of analysis, and time frame. In the absence of formal reliability testing, the only indication of reliability is from the preciseness of the specifications. That is an important evaluation, but falls short of empirical analyses of reliability.

Along with the question of what reliability tests should be conducted are what level of rigor is necessary for nonresearch purposes and what thresholds should be met to be considered an adequate demonstration of reliability. The NQF evaluation criteria that call for reliability testing do not specify acceptable reliability statistics. The determination of adequacy is made by the expert review panels and ultimately through a process of review, comment, and voting to arrive at a consensus opinion on whether a measure should be endorsed as suitable for public reporting and quality improvement. This is an area that requires more research and debate.

There are several challenges to establishing the validity of a quality measure. Validity studies of quality measures ideally address whether the conclusion about the quality of care inferred from the resulting score is correct. That is, if a provider scores low on a particular measure, is it correct to conclude it provides poorer quality care? Validity studies often are based on correlation with other valid measures of quality; however, for many quality measures there may not be known criterion measures. Another approach is to test hypotheses about the relationship with other quality measures, for example, whether hospitals with low scores on a measure of appropriate hair removal have higher surgical site infection rates.

There is some question over whether formal validity studies are needed for quality measures when the measure focus is based on sound evidence. The rationale is that because evidence guides what is considered quality care, measure topics that are aligned with the evidence should be considered valid indicators of quality. However, this assumption is less tenable for many aspects of health care that do not have formal studies providing evidence for effectiveness. It also does not address whether scores from the measure as specified actually do discriminate good from poor performance. Nevertheless, in the absence of formal validity testing, there is a reliance on the face validity of the measure, that is, whether experts in the field think it is an indicator of quality. At a minimum, attention should be given first to whether the measure is aligned with the evidence, then to face validity. If face validity is all that is addressed, it should be systematically assessed such as with the RAND appropriateness method, which combines a systematic review of the literature with ratings by an expert panel (McGlynn et al., 2003). With this method, expert panels rate the validity of quality indicators on a 9-point scale, followed by discussion of the ratings, and then by another round of rating the indicators.

The aim of quality measurement is to make valid conclusions about the quality of health care whether for research, public accountability, or quality improvement and ultimately to improve health care and health. Measuring health care quality for research purposes requires the same level of rigor to establish reliability and validity as for any other research study. Measuring quality for purposes of internal quality improvement can be accomplished with measures that generally do not require extensive testing to be useful to the needs of the individual organization that uses them. The biggest area of debate is the level of rigor required for quality measures that are publicly reported (Milstein & Lee, 2007). One could argue that the stakes of valid conclusions from quality measurement are high. For example, the choice of a hospital or surgeon could affect the probability of good versus poor outcomes. In the current environment, publicly reporting quality measures can affect a provider’s reputation, reimbursement, and continued viability as a health care organization (Vetter, 2004). Competing interests of various stakeholders such as consumers and providers often center on questions of what is a good enough measure. Some see establishing reliability and validity with formal studies as a barrier to making information available to the public and that the absence of such testing information does not necessarily mean that a measure is not reliable or valid. Others argue that unless a measure is demonstrated to be reliable and valid, it cannot provide useful information for anyone.
The quality enterprise needs to continue to seek common ground to move forward with quality measurement through such multistakeholder forums as the National Quality Forum. For the most part, there is agreement on the need for measuring quality and access to reliable and valid information.

**Attribution Issues**

As mentioned above, public reporting of quality measures and their potential use in reimbursement policies raises the stakes regarding the validity of the measures as true indicators of quality for the entity being measured. It is important that the quality measure scores include data that can be attributed to the care of the entity being measured. Concerns about attribution of quality measures cover several aspects, including identifying the correct patients under the care of the provider, identifying the appropriate clinician, and isolating the effect of health care on patient outcomes.

Issues with identifying if a patient should be attributed to a particular health care provider most often arise with measures focused on individual clinician performance. A patient may have seen a primary care provider at some time in the past but does not return for follow-up encounters, or was assigned to a primary care provider by a health plan, but does not have any encounters with that provider. The question is, at what point is that patient included or excluded from the primary care provider’s quality measure data? The answer may vary depending on the focus of measurement and the structure of health care services. For example, it may be valid to include all patients enrolled in a health plan regardless of their use of health care services in measures of preventive care such as influenza immunization at the health plan level or even for the primary care providers if they can identify their assigned patients and are paid for preventive services. However, in a fee-for-service environment, only patients seen in the measurement year by the primary care provider might be included. There is no one correct answer and the decision ideally should be based on the evidence and concept of quality for the measure. However, it is important to also incorporate the practical restrictions imposed by data sources and the structure of health care services.

Another aspect of attribution relates to whether the measured process or outcome can be attributed to one out of potentially many types of health care clinicians, for example, nursing versus physician. Nursing is attempting to identify and measure nursing care quality. Needleman and colleagues (2007) reviewed the state of the science linking nurse staffing measures to patient outcomes and identified that the evidence for such a connection has been inconsistent. Riehle, Hanold, Sprenger, and Loeb (2007) identified that implementation of the NQF-endorsed nursing-sensitive measure set (NQF, 2004) will provide an opportunity to further study such associations. Naylor (2007) identified research priorities to expand the set of measures influenced by nursing care. A counterpoint to the development of nursing-sensitive quality measures (or measures for other disciplines) is the increasing demand for patient-centered outcome measures across episodes of care and settings and acknowledgement of the team approach to the delivery of most health care (Institute of Medicine, Committee on Redesigning Health Insurance Performance Measures, Payment, and Performance Improvement Programs, 2006).

Another aspect of attribution is identifying what is under the control of the providers being measured. There is little disagreement regarding measuring quality for the care that is directly provided (e.g., tests performed, medication administered, procedures, and surgeries). The questions arise as to how to account for factors such as patient choice (e.g., decline immunization), nonadherence (e.g., not following prescribed diet), and lack of resources (e.g., unable to purchase medications). An approach seen with some measures is to exclude patients who decline or do not adhere to recommended treatments or adjust for factors that make it more difficult for patients to follow prescribed treatment, such as socioeconomic status. Another approach is to restrict exclusions and risk adjustment to clinical factors because health care includes patient education, motivation, and activation for self-management after leaving the providers’ domain; and that treatment
approaches should be tailored to the patients’ preferences, resources, and understanding (e.g., prescribing low-cost generic drugs vs. latest brand-name drug). Race and SES are sometimes included in risk models with the idea of not disadvantaging those providers who care for a poorer patient population. However, risk adjustment also has the effect of confounding the effect of these variables on quality and masking disparities in care for disadvantaged populations (Iezzoni, 2003; Krumholz et al., 2006). Another approach is to use stratification to compare providers’ quality scores for similar patient populations, which also allows for identification of potential disparities in care so that strategies to improve can be initiated.

In order to be useful for quality assessment, outcomes should be attributed to the health care received. Although multiple factors can influence outcomes, outcomes that are used for quality measurement should be influenced by care processes (McGlynn, 1998). With outcome measures, it also is important to isolate the effect of health care from intrinsic patient factors and natural disease progression. Outcome measures should be risk-adjusted to account for potential differences in patient severity of illness at the start of care (Iezzoni, 2003; Spertus et al., 2005). For example, older patients and those with chronic illnesses such as heart disease, diabetes, and cancer would be expected to have a higher probability of death than younger, healthier patients and those factors should be controlled using risk adjustment methods in order to make valid comparisons across providers. Risk adjustment requires collecting additional data besides that required to identify the outcome and target population, which increases the burden of data collection so it is important that the risk factors be evidence-based and the risk model be developed and tested with model performance documented (Iezzoni, 2003; Krumholz et al., 2008; Murtaugh, Peng, Aykan, & Maduro, 2007; Render et al., 2008).

**Resources Needed for Quality Measurement**

In addition to the differences in opinion about the level of scientific rigor needed, another challenge to conducting reliability and validity studies is the demand for reliability and validity and the limited resources available. Measure development by the health care field often falls short of testing, or when conducted, is usually limited to measure development with no periodic checks on reliability.

The burden of data collection and reporting is an issue that needs to be considered for ongoing quality measurement, particularly for public reporting initiatives. Therefore, measures used for public reporting should be useful to the intended audiences. Feasibility of data collection is another issue for measures considered for public reporting because it can be a limiting factor. Measures that require medical record abstraction are time-consuming and burdensome; however, currently, electronic sources are primarily administrative data with limited clinical information. Data from electronic health records would provide good quality clinical data and minimize data collection burden.

Quality measures that are publicly reported should be important enough to expend resources on collecting and reporting data that are usable by the target audiences for selecting providers and improving quality (McGlynn, 2003). Measuring and reporting on quality requires resources to develop and test measures, resources for providers to collect and report the data required to compute the quality measures, and resources to process the data and publicly report it on Web sites or formal reports. In recognition of the resources required for quality measurement, the National Quality Forum has identified importance to measure and report as a threshold criterion for endorsement as a voluntary consensus standard (NQF, 2008). There are finite resources to devote to quality measurement, so measures considered for public reporting should focus on the most important aspects of health care and potential for achieving the most significant gains in improving health care and health.

The best way to address the issues that arise with quality measures is through a systematic process to develop and test quality measures. This will assure attention to the foundation for a reliable and valid measure of quality as well as guide appropriate and efficient testing.
INFORMATIONAL RESOURCES

Some resources for quality measurement include the following.

• The National Quality Forum Measures endorsed as national voluntary consensus standards and measure evaluation criteria (http://www.qualityforum.org/)


• Centers for Medicare & Medicaid Services Compare tools for comparing health care quality (http://www.medicare.gov/) Information on health care quality data (http://www.qualitynet.org/)

SUMMARY

Quality measurement is fundamental to improving the quality of health care and health. In an environment of public accountability, the stakes are high for reporting measures that are reliable and valid indicators of quality. Developing scientifically sound measures begins with a strong conceptual and evidence base for identifying quality health care. Although measurement of a complex and abstract construct of quality health care will not be perfect, close adherence to basic measurement principles will facilitate achieving reliable and valid quality measures. Adequate resources are needed to scientifically develop and test quality measures in a time frame that meets the needs of those who want access to health care quality data. In addition, the policy implications of the measures, regardless of their reliability and validity, cannot be ignored. Further research is needed to establish thresholds for adequate reliability, validity, and risk model performance metrics; how best to address disparities and small case volumes in measurement; standards for analyses to identify statistically significant and meaningful differences in quality.

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Part V Measurement Issues


This chapter addresses selected measurement issues that threaten the reliability and validity of the measurement effort. Topics include social desirability, process and outcome measurement, measuring state and trait characteristics, cross-cultural measurement, and triangulation. In most cases, if sound measurement principles are carefully employed, along with the strategies and techniques discussed in this chapter, the researcher will be well positioned to resolve these issues, thus increasing the likelihood that results will be reliable and valid.

**SOCIAL DESIRABILITY**

Social desirability is usually defined as the tendency of individuals to project favorable images of themselves during social interaction. Social desirability is a potential concern in interpreting responses to socially related measures, especially affective self-report measures (Dyer, Bell, McCann, & Rauch, 2006; Hebert et al., 2008; Krosnick, 1999; Nunnally & Bernstein, 1994; Strosahl, Linehan, & Chiles, 1984), personality measures (Bentler, Jackson, & Messick, 1971; Hogan & Nicholson, 1988; Johnson & Fendrich, 2002; Otto, Lang, Magargee, & Rosenblatt, 1988; Wenger & Flowers, 2008), and surveys (Dillman et al., 2001; Krause, 1985; Krosnick & Chang, 2001; Murray & Mobjley, 2009; Phillips, 1972; Yetter-Read, 2004).

Social desirability is a response set that influences how one responds to a measure (Cronbach, 1949; Edwards, 1957; Gillis & Jackson, 2002; Rorer, 1965). A set according to Rorer (1965) “connotes a conscious or unconscious desire on the part of the respondent to answer in such a way as to produce a certain picture of himself” (p. 133). A response set is the tendency on the part of the respondent to consistently respond differently to test items from how he or she would respond if the content were presented in a different form (Cronbach, 1949). Hence, a response set is determined by the format of the measure (Berg, 1961; Rorer, 1965). According to Polit and Beck (2008), social desirability is a response bias that “refers to the tendency of some individuals to misrepresent their responses consistently by giving answers that are congruent with prevailing social values or professional expectations” (p. 432).

A socially desirable response is defined as a favorable response to an item with a socially desirable value, or as an unfavorable response to an item with a socially undesirable value (Berg, 1961; Edwards, 1957; Nunnally & Bernstein, 1994). Sensitive questions are especially prone to socially desirable responses. The reasons for this are that (1) content is often perceived as an invasion of respondents’ privacy; (2) there is the risk of disclosure of their answers to third parties; and (3) answers might be perceived as socially undesirable (Dyer et al., 2006; Johansson, Jamora, Ruff, & Pack, 2008; Tourangeau, Rips, & Rasinski, 2000). Thus, it is essential that items on measures be scrutinized both a priori and empirically to ascertain if there is anything about them (e.g., wording or format) that might cause subjects to respond to them in a socially desirable manner rather than on the basis of item content. In addition, Nunnally and Bernstein (1994) note that social desirability varies as a result of the context in which measurement occurs, using as an example that individuals seen in a psychotherapeutic setting would tend to find it more appropriate to endorse self-descriptive
questions about pathology than would individuals in an employment setting (p. 315).

**STRATEGIES FOR MINIMIZING SOCIALLY DESIRABLE RESPONSES**

During the selection and/or development phase of instrumentation, the investigator should consider how the respondent is likely to think about each item when responding to the measure of interest. In this regard, Klockars (1975) found that when a forced-choice format is employed, social desirability may be minimized by giving respondents two socially desirable options rather than one socially desirable and one socially undesirable option. This would serve to remove the evaluation dimensions from the ratings of the phenomenon of interest, that is, by requiring the respondent to choose between pairs of items matched for social desirability. Knowles (1988) notes that when an individual has to consider the same general issue repeatedly across the items in a multi-item, single-dimension measure, there is a tendency toward polarization of the respondent’s judgment on the issue, and for the addition of cognitions consistent with the subject’s judgment about the issue that allows the individual to reinterpret evidence to be consistent with his or her judgment. He further notes that item formats such as direct questions that require greater depth of processing tend to generate more thoughts and more polarized answers. Thus, he concludes the probability of socially desirable responses is increased when the respondent is required to repeatedly respond to closely related items in a single dimension scale.

Babad (1979) cautions that the investigator needs to be sensitive to the suggestibility or influence of the information within the item on the response. For example, providing a scenario and then asking an individual to respond to an item on the basis of how he or she would react in the situation described is likely to induce a socially desirable response since the respondent may be influenced by the information given in regard to what would put him or her in the most favorable light. Gibson, Wermuth, Sorensen, Manicucci, and Bernal (1987) note that socially desirable responses may be minimized when a single measure is employed with multiple sources to corroborate the results. Similarly, McCrae (1986) notes that multiple methods of measurement may also be employed in this regard.

Nunnally and Bernstein (1994) caution that to the extent that there are tendencies to respond in a socially desirable manner, measures may tend to correlate because they share social desirability variance (p. 315). Becker (1976) found that requiring subjects to indicate their names and Social Security numbers on response sheets biased their responses to an item in a measure, whereas requiring a Social Security number did not bias their response. He concluded from his work that the less subjects believe there is a potential for identification of their responses, the less social desirability is likely to come into play. Hence, anonymity, since it decreases subjects’ concern for social approval and/or awareness that others will evaluate their responses and know who it was that responded, also tends to minimize the probability of social desirability.

Other actions that may be taken by the developer to reduce the potential for social desirability include:

1. Using “do guess” directions when multiple-choice measures are employed.
2. Wording directions as clearly and concisely as possible to avoid ambiguity and to ensure that each subject responds with the same response set.
3. Avoiding item formats that use fixed-response alternatives such as true/false and yes/no.
4. Using items with a general rather than a personal referent.
5. Designing measures whenever possible that assess multiple dimensions of a phenomenon rather than only one dimension.
6. Avoiding any words or actions that might communicate to subjects that the investigator would positively or negatively value certain responses.
7. Recognizing that certain approaches to measurement have more or less probability of eliciting socially desirable responses and accordingly selecting a method in situations where social desirability is expected.
to a sensitive question remains unknown, alleviating concerns with privacy invasion, and a population estimate of the sensitive topic is computed. Various approaches employed in RRT can be found in Chapter 22 where collecting sensitive information is discussed. Using a logistic regression approach allows for the sensitive behavior estimates to be linked to explanatory variables (Maddala, 1983; Scheers & Dayton, 1987; Van der Heijden & Van Gils, 1996). Gupta (2002), comparing RRTs with personal interview surveys involving sensitive questions and the Bogus Pipeline Technique, found that RRTs were at least as effective in reducing social desirability as the BPL, while being less intrusive.

The survey and interviewing literature suggests that the use of computer-administered surveys on highly sensitive topics minimizes or eliminates the effects of social desirability (Taylor, 2000), even when humanizing features such as voice are employed (Dillman et al., 2001). For this reason, there has been increased use of computer-assisted interviewing, especially use of Web-based surveys (Couper & Nicholls, 1998) and computer-assisted self-interviewing (CASI) methods, whereby the respondent interacts directly with the computer to answer questions. For example, when the audio CASI method is employed, the respondent listens to the questions read over headphones using a digitized voice and enters the responses into the computer. Studies comparing CAI and audio CASI to other data collection methods have found a reduction in social desirability bias relative to surveys administered by an interviewer and a paper-based self-administered approach (Tourangeau & Smith, 1998; Turner et al., 1998a, 1998b).

On the other hand, in the field of human-computer interaction, a basic premise under investigation is that humanizing cues, such as voice, in a computer interface can result in responses similar to those in human-to-human interaction (Fogg & Nass, 1997; Nass, Fogg, & Moon, 1996; Nass, Moon, & Carney, 1999).

MEASURES OF SOCIAL DESIRABILITY

In addition to the a priori actions to minimize the probability of socially desirable responses
that may be taken by the investigator during the instrument selection and/or development stage of the measurement process, the extent to which this response set exists also may be investigated empirically during the reliability and validity testing phase of the measurement effort. Several tools and methods for measuring social desirability have been developed for this purpose (Blake, Valdiserri, Neuendorf, & Nemeth, 2006; Ethier et al., 2000; Gillis & Jackson, 2002; Hays & Ware, 1986; Johansson et al., 2008; Nunnally & Bernstein, 1994).

Edwards (1957) developed the first such measure, the Edwards Social Desirability Scale, based upon his belief that social desirability scale values of personality statements can be obtained by various psychological scaling methods in order to obtain a scale value for any personality statement on a single dimension, the social desirability–undesirability dimension, relative to other personality statements. His basic premise is that if one knows the position of a statement on the social desirability continuum, one can predict, with a high degree of accuracy, that the statement does describe the respondents (p. 3). When his measure is employed, one obtains for each personality statement, a social desirability scale value. The more favorable the social desirability response of an item, the greater the likelihood of its endorsement under standard test-taking instructions. On the basis of the resulting values, one is able to detect the extent to which social desirability comes into play, and hence, the credibility that can be attributed to the resulting scores (Edwards, 1957, 1970). Studies providing information regarding the use of Edwards’s scale, including reliability and validity data, are discussed in Edwards (1957, 1970), Millham and Kellogg (1980), and Carstensen and Cone (1983).

Viewing, as a limitation of the Edwards scale, the fact that the items were drawn from clinical scales that could be characterized by their pathological content, Crowne and Marlowe (1964) developed the Marlowe-Crowne Social Desirability Scales, which are designed to include items that are culturally appropriate and yet untrue of virtually all people and that have minimal pathological or abnormal implications (p. 22). They based their scales on the premise that people describe themselves in favorable or socially desirable terms in order to achieve the approval of others. They view social desirability as a response style or personality trait rather than a response set. When administering their scale, they note that little concern needs to be given to the testing situation as a social context that might influence the subject’s need to give a socially desirable response. Factors that could influence how an individual responds were identified as (1) the need to attain success in academic, social-recognition, or competitive business situations; (2) the need to win approval and affection from others; and (3) dependence needs, such as help, protection, and succorance. If it is important for a subject to gain approval, deny inadequacies, obtain dependency gratifications, or achieve recognition or status, the investigator would anticipate that the individual’s responses to items would tend to serve these aims (Crowne & Marlowe, 1964). The Marlowe-Crowne scales have been widely used. Johnson and Fendrich (2002) conducted a study to investigate the validity of the Marlowe-Crowne scale. Findings from their study supported the original conceptualization of social desirability as a personality trait. Additional information regarding reliability and validity is reported in the literature by Jacobson, Berger, and Millham (1970), Phillips (1972), Hogan and Mookherjee (1980), Holden and Mendonca (1984), Strosahl, Linehan, and Chiles (1984), Ellis (1985), Helmes and Holden (1986), and O’Grady (1988). Short forms of the Edwards scale and the Marlowe-Crowne scale have been developed and tested for reliability and validity (Ray, 1984; Reynolds, 1982; Silverstein, 1983).

The Multi-Dimensional Social Desirability Inventory was developed by Jacobson, Kellogg, Cauce, and Slavin (1977), who contend that social desirability is a multidimensional construct. Their instrument is essentially a social approval inventory that is designed to assess factors that comprise the assumed need for approval. The measure comprises four scales of 17 items each. The scales are (1) attribution of positive traits, (2) attribution of negative traits, (3) denial of positive traits, and (4) denial of negative traits. Scores on each scale provide a measure of the extent to which the subject accepted or denied...
traits differing in social desirability value. In addition to their own studies of the inventory, reliability and validity information has been reported by Jacobson, Brown, and Ariza (1983), and Kral (1986).

Measures of social desirability have been employed both a priori and a posteriori in the development of measures of sensitive topics. For example, to address concerns regarding social desirability response bias in scores resulting from items on a newly developed self-report measure prior to development of the new measure, the Marlowe-Crowne Social Desirability Scale (SDS), (Crowne & Marlowe, 1964) could be used to scrutinize and remove items from the developing measure that correlate with items on the SDS prior to construction of the final version of the new measure. In addition, a posteriori statistical techniques could be employed to investigate and control for social desirability in the final version of the new self-report measure.

According to Nunnally and Bernstein (1994), “preferences for the socially desirable response are a function of (1) level of adjustment, (2) knowledge of one’s self, and (3) frankness” (p. 391). One approach to investigating these factors is Watson’s (2000) suggestion that, in concert with established measures of social desirability, postadministration interviews be conducted to provide insight into how respondents conceptualize and rate themselves on the measure of interest.

Readers can find additional examples of methodological studies undertaken to examine the reliability and validity of social desirability measures in the works of Sodowsky, Kuo-Jackson, Richardson, and Corey (1998) who employed a multicultural-specific social desirability scale designed to be employed in concert with the Multicultural Counseling Inventory (MCI); Blake et al. (2006) who investigated the validity of the SDS-17 measure of social desirability; Kinder (2008) who developed and validated an instrument to measure student activation, defined as a level of engagement in learning that a student has in reaching his or her academic goals, and Murray and Mobley (2009) who conducted a systematic review of empirical evidence regarding methods employed in research about same-sex intimate partner violence.

Examples of research undertaken to investigate the potential impact of social desirability on study findings can be found in the works of Motl, McAuley, and Distefani (2005) who assessed the association of social desirability with self in preventive medicine; Dyer and colleagues (2006) who analyzed socially desirable responses and the nature of aggressive traits after traumatic brain injury; Johansson and colleagues (2008) who explored factors, including social desirability, associated with aggression in traumatic brain injury patients and the ecological validity of the Ruff Neurobehavioral Inventory (RNBI) anger scale and comorbid and premorbid factors associated with aggression in this patient group; Schwarzbold and colleagues (2008) who examined the impact of social desirability in a group of patients with psychiatric disorders and traumatic brain injury; Hebert and colleagues (2008) who studied the influence of social desirability traits on self-reported dietary measures among diverse participants in a multicenter multiple risk factor trial; Hebert and colleagues (2008) who assessed social desirability bias in self-reports derived from two dietary assessment methods within the context of multiple behavior change interventions in an adult population; and Wenger & Flowers (2008) who examined the paradox between differences in parenting and the high levels of satisfaction in terms of positive illusions, and found biological parents with children between 2 and 5 years of age reported unrealistically positive views of their children.

**PROCESS AND OUTCOME MEASUREMENT**

Process and outcome measurement has become very popular and highly valued in nursing and health care in general. This trend has come about because of an increased emphasis on investigating the worth of health care programs and activities in clinical and educational settings, and because health care providers have become more interested in understanding the relationship between health care activities and practice outcomes. In addition, consumers have become more concerned about knowing what they are buying and whether health services
should be used judiciously to inform treatment or policy decisions (Melnyk & Fineout-Overholt, 2005; Rubin, 2008).

With all of this activity, process and outcome measurement has not proven to be a simple matter. Issues have been raised regarding frameworks that should be used, the approaches to process and outcome measurement, and the meaning of findings. This section will address such issues. However, before focusing specifically on measurement of process and outcomes per se, it is necessary to provide definitions of these terms.

**Definitions**

**Process** is the manner or approach by which a program or provider delivers services to clients. Outcomes are the outputs or results of the program or the activities of the provider. It is noteworthy that one should be careful not to confuse process/outcome measurement with process/outcome research and evaluation. **Process/outcome research** involves investigating relationships among process variables or outcome variables in order to make decisions regarding statistical hypotheses and inductive inferences concerning the probable truth or falsity of a research hypothesis. Process/outcome research is conducted primarily to build theory and to add to the knowledge base in an area.

**Process/outcome evaluation** is a decision-making process by which one examines the manner in which a program or provider delivers services or their outputs and makes judgments about what is done or how well objectives are met. Evaluation of processes and outcomes can be expected to lead to suggestions for action to improve effectiveness and efficiency. Nursing quality of care assessment and nursing audit are examples of process/outcome evaluations.

**Process/outcome measurement** relates to how a specified process or outcome is operationalized, that is, quantified or classified. Measurement is a part of the research process and the evaluation process but is not synonymous with either.

**Process Measurement**

The term “process” by its very nature is dynamic, and it projects a sense of movement and fluidity.
This quality makes the measurement of a particular process quite challenging. However, the approach to operationalizing a process follows the same basic principles as for measurement of most other variables. Since measurement should be based on how a variable is conceptualized, this indicates that the measurement of process must consider its dynamic quality. The specific process that is the focus of measurement should be clearly defined in a manner that captures the essence of its characteristics. Within nursing, specific nursing interventions or programs are common processes that are the focus of measurement. Interventions are any therapies that are designed to improve a client’s health condition toward desired health outcomes and may be treatments, procedures, or other actions implemented by providers to and with clients (Sidani & Braden, 1998).

The determination of the conceptual framework for the process is one of the first essential steps in the development of a reliable and valid measurement approach. The conceptual framework or conceptual model on which a process is based determines the variables that should be selected and studied within the process itself to ensure the quality of its implementation, as well as the outcome variables that need to be assessed to determine the effectiveness or efficacy of the process (Strickland, 1995, 1997). Since most processes are not unitary phenomena, a number of concepts may be required for the formulation of a sound definition. Each concept in the framework must be defined and the relationships between key constructs identified. Previous descriptive research can be used to help identify constructs that are likely to account for large amounts of variance in the intervention, whether the intervention should be targeted for a specific population or setting, and aid in the identification of outcome variables that are most likely to be affected by the intervention. Related previous intervention studies can be examined to ascertain intervention doses, and attributes of effective interventions included in other experimental investigations (Conn, Rantz, Wipke-Tevis, & Maas, 2001). The level of specification or generality of the intervention also is important because underspecified conceptual frameworks can lead to the lack of identification of constructs that are important to address within the intervention, while overspecification can introduce unimportant constructs and make operationalization of the intervention unnecessarily burdensome. Specification errors in the conceptual framework can lead to an invalid measurement procedure. When formulating a conceptual framework for a process, such as a nursing intervention, specification errors can arise from three sources: (1) underspecification (missing key variables) or overspecification (including extra variables), (2) inaccurate or incomplete definitions of the key variables, and (3) inaccurate identification of the relationships among the key variables (Atwood, 1980, p. 105).

The conceptual framework for an intervention should also give some guidance relative to whether a single or bundled intervention should be designed. The study of some phenomena may require bundled or multiple interventions. “Bundled interventions are appropriate when a multidimensional problem is located in a conceptual framework that suggests combining multiple interventions” (Conn et al., 2001, p. 437). A limitation of bundled interventions is that it may be difficult to interpret the effects of the various components of the intervention. However, use of a factorial design where individual interventions can be assessed for the effectiveness of components can address this issue (Piantadosi, 1997).

Another important issue related to operationalizing interventions is the degree to which they can be designed to be patient-centered or to fit the individual needs of clients and still maintain their measurement integrity. Patient-centered care focuses on respect for and integration of individual differences when delivering patient care. Clearly, standardized interventions are much easier to test than patient-centered interventions since the needs of individual patients vary. The assessment of patient-centered interventions is important to measure and test to clarify the situations in which such interventions are likely to be the least or most effective. However, a concern that has been raised regarding outcomes from patient-centered intervention studies is that they often result in small effect sizes (Lauver et al., 2002). As patient-centered studies are implemented in the future, it will
be necessary to carefully document variations in different patient interventions within such studies in order to elucidate differences in effect sizes.

The dose of interventions is another issue in developing interventions. Even when the content of an intervention is appropriate, if it is delivered in insufficient doses then the potential effectiveness can be obscured. Decisions related to dose of an intervention also include those regarding duration of delivery over hours, days, weeks, or months. Increasing treatment doses can make a psychosocial nursing intervention more robust. However, increasing treatment dose needs to be carefully considered in relation to demands placed on participants since this could lead to high subject attrition. Testing intervention dose may also be the focus of study (Conn et al., 2001), as was done by Rothert and associates (1997) who studied empowerment of menopausal women by varying dose by offering one group only written materials, another group written materials and didactic information, and yet another group written materials, didactic information, and additional activities.

The most common conceptual frameworks used in nursing to facilitate process specification and outcomes assessment are (1) the structure-process-outcome framework, (2) the condition-focused or disease-focused model, and (3) the sequential model (Strickland, 1995). Within the structure-process-outcome framework, the inputs, prerequisites, or structures for patient care are identified, along with the processes (interventions) and outcomes or outputs. These components are studied in relation to each other. In the condition-focused or disease-focused model, clinical conditions or diagnoses are identified for a specific patient population and nursing treatments or interventions for the conditions are designed to specifically address identified symptoms and problems along with expected results. Outcome variables are selected based on the expected results as indicators of the efficacy or effectiveness of the intervention. The sequential model is used in situations where specific stages or phases of a condition or disease can be identified, such as during pregnancy or in cancer. Symptoms and health problems associated with each stage are identified, interventions are designed to address the specific problems, and expected outcomes of the interventions are identified and measured (Strickland, 1995).

Once the conceptual framework of the process has been delineated, the blueprint or specific approach to measurement is developed. The measurement approach should address the key variables that are included in the conceptual framework; therefore, several variables or dimensions may be included in the measurement process. If the nursing process model were used as the conceptual framework for measuring the process of nursing care, one would include assessment, planning, implementation, and evaluation as key components in the measurement.

For the most part, measurement of process in nursing has been approached conceptually in two ways: by focusing on the services or care provided by the nurse, and by focusing on the services or care received by the client. In addition to a well-developed and explicit conceptual framework for the intervention, operationalization of an intervention involves developing a detailed written protocol that includes (1) the protocol’s purpose, (2) the equipment, materials, and resources required to conduct the intervention, (3) a step-by-step description of the procedures to be followed during implementation, (4) timeline for implementation, (5) persons responsible for implementing the protocol and their characteristics, training, and qualifications, (6) the manner by which the intervention is to be delivered, such as by telephone, mail, printed materials, Internet, or in person, and (7) the person(s) responsible for evaluating whether the intervention is conducted according to the written protocol. A well-written protocol and training of those who conduct it are necessary to ensure that the persons who implement it do so consistently (reliably) and accurately (validly) (Strickland, 1997).

When process measurement is conducted during process evaluation, criteria or standards are specified that describe the nature and, when appropriate, the events that should occur in the process and the expected interaction of activities and participants involved in the process. The criteria serve as the basis for making judgments regarding the adequacy of the process. In developing criteria, one seeks to specify the important
aspects of the process in measurable terms. For example, the process criteria for nursing care on a specified nursing unit might include the following:

- Comatose patients will be repositioned every two hours.
- A psychiatric nurse specialist will assess each patient having an alteration in body image.

Process criteria for a nursing education program might include:

- Admission criteria and procedures are closely followed.
- Students are provided opportunities to evaluate the curriculum.
- Faculty members involve students in their research activities.

Several types of measurement methods are amenable to measuring processes and included among these are observation, interviews, diaries, record audit, focus groups, and questionnaires. Tools that employ the branching technique are particularly useful when the nature of the process involves several interrelated steps that are dependent upon each other, such as with measurement of the process of decision making. The branching technique provides several options or choices along the way at various stages of the process. The option selected will determine other situations or options that will be presented to the subjects. Hence, the various available options, if selected, subsequently provide different situations or options in a sequential manner similar to the branches of a tree. However, it has been recently questioned as to the extent to which decision-making processes used by human beings are invariant across tasks (Corcoran, 1986). This indicates that the process of decision making is highly contingent on the complexity of the task and this has a major implication for measurement.

Because of the complexity of the nature of most processes and the number of key variables that may be involved, multiple measures can increase the reliability and validity of results. Therefore, use of multiple measures in process measurement is encouraged.

A major concern related to process measurement is that the act of measuring the process may alter the process and, thereby, the subsequent findings. This issue might not be crucial during process evaluation in which information obtained may be intentionally used for making decisions for change. Clearly, process measurement can give clues to corrective action and provide a means for elucidating consequences of certain actions. However, this problem could be a severe limitation to research studies that require the measurement of process variables. In any case, efforts should be made to conduct measurements as unobtrusively as possible.

**Outcome Measurement**

A major issue for nurses regarding outcome measurement is that of selecting appropriate outcomes for study. In a given situation, a wide array of variables may be appropriate for outcome measurement. As with process measurement, in most instances, there is no single concept that is likely to adequately represent the outcomes of a particular intervention or process. Therefore, the outcomes selected must be based on and be consistent with the conceptual framework that is being considered. In other words, the outcomes selected must be meaningful and salient to the focus of the investigation. If the focus of the study is concerned with health state, then the appropriate outcome variables should relate to health state. If the basic problem is conceptualized in terms of cognitive phenomena, then appropriate cognitive outcomes should be selected.

Outcomes may be categorized based on the focus of measurement, such as a particular disease or the patient. Disease-oriented outcome variables indicate the extent of disease present and include histopathologic, physiologic, or surrogate results such as blood sugar, blood pressure, coronary plaque thickness. Patient-oriented outcome variables are those that matter to patients’ health and well-being and include such variables as reduced morbidity, reduced mortality, symptom improvement, improved quality of life, and lower cost.

Clinical outcomes that are discussed in the general nursing literature frequently are limited
Part V Measurement Issues

1. Something that should or should not occur in the status of the patient (or client).
2. The level at which it should occur.
3. The point in time at which it should occur.
4. Something that is expected to occur in good measure as a result of the care (or process), which is to be assessed.

Patient care goals should be formulated in such a manner that they can serve as the outcome criteria for assessing the quality of the process of nursing care provided to an individual patient (Strickland, 1995). Examples are:

The patient will care for the colostomy without assistance prior to discharge.
The patient will lose 10 pounds within 6 months.

Another issue that causes concern about the selection of outcomes is that most outcomes are influenced by many factors beyond those that are the focus of study. A client’s attitudes, behaviors, health state, or knowledge may be influenced by care or services received from other providers. It is difficult to select outcomes that can be solely attributed to any one factor, such as nursing care or a particular health care program or educational program. However, in most instances, it is possible to select outcomes that can be related temporally to the intervention or process that is the focus of investigation. Temporally relating variations in outcomes to the expected sources of such changes support the validity and usefulness of the outcome selected. Thus, timing of measurements is important. Outcomes are selected that are expected to respond to the type of action, intervention, or process that is conducted. The prevention and healing rate of decubitus ulcers is an example of an outcome that would be expected to respond to nursing care. Another related issue is that nursing addresses, to a great extent, subtle psychosocial problems. The impact of nursing on the client’s state may be difficult to measure, because psychosocial variables often are difficult to measure.

As with the measurement of process variables, the use of multiple measures of outcome variables can provide more support for reliability.
and validity. Interview, questionnaires, record audit, direct observation, and use of laboratory data are among the various approaches that may be employed for the measurement of outcomes and for the assessment of quality of care. However, it should be noted that record audit will not provide reliable and valid indicators unless measurement or the method of recording data is reliable and valid. Whereas certain information on a record, such as temperature readings or results of laboratory tests, may be highly reliable and valid, others, such as behaviors learned by the client for self-care, may not be adequately documented. Strickland (1995, 1997) has identified several important points that should be considered in the selection and measurement of outcomes of care:

1. They should be conceptually appropriate and compatible with the conceptual framework of the intervention or program.
2. They should represent the full conceptual model of the intervention or program.
3. Variables should have an effect size to allow adequate statistical power given the sample that is selected or that is available.
4. Intended and unintended outcomes should be selected, since planned and unplanned outcomes may occur from any intervention. The investigator needs to be aware of potential unintended outcomes and measure them.
5. Positive and potentially negative outcomes should be selected based on expected results from the intervention.
6. Outcomes should be important to clients.
7. Longitudinal assessments of outcomes need to carefully consider timing of the data collection to reflect the most important and relevant time points for the expression of outcomes; selection of measures that are sensitive to small changes in the variables studied; and the selection of variables that represent intermediate outcomes that may be precursors to longer-term outcomes.

There also are several client-related measurement issues that need to be considered during outcome measurement. These include the impact of comorbidity on outcomes, which could mask the impact of the intervention; the fact that some variables are characterized by periodicity and circadian rhythms, which could influence measurements taken; and population subsets may respond differently for certain outcomes. In addition, outcome measurements need to be feasible and practical to use, and be compatible with the age, education, gender, and cultural backgrounds of clients.

Finally, qualitative approaches can be very useful to aid in outcomes assessment. Data collected using qualitative approaches can also clarify findings obtained from quantitative measures. Chinn and Kramer (1999) suggest that several types of quality-related outcomes are particularly suited for planning deliberative validation of theoretic relationships. Among them are qualitative data to assess the scientific competence of nurses, functional outcomes, satisfaction of nurses, and quality of care perceived by those who receive care.

MEASURING STATE AND TRAIT CHARACTERISTICS

Most attributes that are measured are conceptualized as stable or exhibiting little variation over time. However, in the real world, a number of attributes can and do vary from moment to moment and day to day. Those attributes that are conceptualized as being stable with little variability are referred to as trait characteristics. State attributes are conceptualized as dynamic and changeable over relatively short periods of time and from one situation to another. In essence, while traits are more enduring characteristics, states are more temporary and fleeting in nature (Knapp, Kimble, & Dunbar, 1998).

Trait Attributes

A trait description provides a statistical summary of the attribute of interest over many situations. Scores on a trait measure for an attribute represent the probability that an individual will react in a defined way in response to a defined class of situations or stimuli (Cronbach, 1970). For example, if assertiveness were conceptualized
Individuals exhibit situational specificity for many attributes. A particular situation may elicit a specific attribute or behavior quite differently than another situation. For example, a person might be calm during a physical examination if there has been no indication of potential problems, but may on another occasion be highly anxious during a physical examination if there are signs of illness. Similarly, a person who cheats on income taxes might be scrupulously honest in money matters with business associates. Hence, there is a person-by-situation interaction in the exhibition of many attributes, because a person may exhibit an attribute differently in different situations.

State attributes reflect the variability of phenomena over rather short periods of time and from situation to situation. For example, the concept of pain for the most part is considered as a state in nursing and measured from the state perspective because it fluctuates over time. A nurse may have good reason for wanting to measure how an attribute changes from time to time or from one situation to another. For example, a nurse might want to know under what circumstances a patient’s blood pressure increases or decreases or whether it changes in response to treatment. Within this context, blood pressure would be conceptualized as a state attribute. Many physiologic variables that are observed within nursing clinical settings are conceptualized as state characteristics, since such variables are measured to assess responses to illness or treatment over time. Nurse researchers often study state attributes within the realm of their investigations. There may be an interest in studying the effects of a mood-altering drug on the anxiety and depression levels of clients, for example. Hence, the focus of measurement of state attributes is on the nature of a particular attribute at a particular time or in a particular situation. Phenomena are perceived as possessing the potential for having an affinity to time and situation, and the aim of measuring state attributes is to detect the state of phenomena at a given moment or in a given situation. It is common for state attributes to be measured with visual analog scales, such as is often done with pain (Good et al., 2001). A specific concept may be conceptualized either as a trait or state.
For example, Speilberger, Gorsuch, Lushene, and Jacobs (1983) have conceptualized anxiety as a trait and a state characteristic. Trait and state measures of anxiety have been developed for adults (Kulik, Mahler, & Earnest, 1994; Speilberger et al., 1983) and for children (Baker-Ward & Rankin, 1994). A measure of trait anxiety would be used in a study when the researcher is concerned about understanding how one’s general personality level of anxiety might be associated with or influences some other variable. The state measure of anxiety would be used when the researcher is concerned about how some particular situation, such as being in labor while having a baby, influences anxiety. Grimm (1989) has conceptualized hope as having state and trait characteristics such that one has a general level of hope and a level that fluctuates from situation to situation, such as during the trajectory of cancer. On the other hand, Hinds (1988) has conceptualized hopefulness as a state phenomenon, which is a dynamic internal state that may be influenced by external factors. The manner in which the concept is conceptualized and used will determine whether it should be measured as a trait or state.

**Implications for Measurement**

Conceptualization of an attribute as either a trait or state has implications for how a measurement tool is constructed, how a measurement procedure is conducted, how a device is used, and how reliability and validity are assessed. Consider that state characteristics are conceptualized as dynamic and changeable, while trait attributes reflect typical responses. A device designed to measure a state attribute must possess the sensitivity and precision to detect changes over time. On the other hand, a tool designed to measure a trait attribute should consistently measure the attribute over long periods of time given the same measurement circumstances.

The usual trait inventory is phrased in a manner to obtain information about a person's lifestyle or typical behavior, and it does not elicit information regarding present state or state at a particular moment. When tools are constructed to obtain information on a subject's state, questions are framed in terms of the present moment or a limited time period of interest, such as “Are you tense?” This same question framed in terms of a trait attribute would be “Are you usually tense?” The way in which items are framed in a tool affects the information obtained by altering the response set (Cronbach, 1970).

Zuckerman and Lubin (1985) have developed the Multiple Affect Adjective Check List, which measures trait and state mood, specifically, anxiety, depression, and hostility. This questionnaire was developed in two forms: general and today. The general form measures trait mood and the today form measures state mood. The only difference between the two forms is in the directions to the respondent. The subject is instructed to respond to the general form according to how he or she generally feels. On the today form, the subject is instructed to respond according to how he or she feels at the moment. The adjective checklists for both forms are identical and are scored by the same keys to arrive at scores for anxiety, depression, and hostility. Retest reliabilities for the trait scale were satisfactorily high; but this was not the case for the state scale, for which temporal stability is not expected. The internal-consistency reliabilities on both forms of the tool at a single testing were high.

For the most part, physiologic phenomena are highly variable, even within the same individual, and often are conceptualized as state attributes. However, there are times when determining whether a physiologic measurement is reflective of a trait or state is important. For example, in the case of blood pressure, one would not want to initiate long-term treatment for hypertension unless the client is typically hypertensive. Therefore, it would be important to have a good estimate of the individual's typical or trait blood pressure. If the nurse took the client’s blood pressure while he or she was unusually anxious, the blood pressure reading might be unusually high due to his or her present emotional state. Hence, the results of the measurement would be a state measurement instead of a trait measurement. The nurse must be clear about the purposes for which a specific physiologic variable is being measured, understand under what conditions such
measurements are likely to be most stable and variable, and obtain measurements at times and in situations that will provide the type of data that are most useful.

Since state attributes are changeable from situation to situation and trait attributes are considered relatively stable, this must be given consideration in the assessment of reliability. Given that state measures are not expected to be stable over time, if one did a test-retest reliability assessment and found a high coefficient, then this would be evidence against the reliability of the tool unless the original situation under which the subjects were measured could be replicated. In most situations, this is difficult to do. Therefore, test-retest reliability should not be done with state measures unless the point is to show that there is not consistency in the state measure over time. However, internal-consistency reliability assessment would be appropriate since the object of this approach to reliability estimation is to determine the level of homogeneity or consistency of the items. One should expect a high internal consistency reliability index for both state and trait measures. Other measures of reliability for a state measure in addition to internal-consistency reliability assessment include parallel forms reliability, and where appropriate, interrater reliability.

When validity is assessed, the approaches that are useful for assessing tools that measure trait attributes also are useful for assessing state measures. Hypothesis testing as a means of construct validation often is employed to support the validity of state measures. For example, a group of subjects might be administered the measure at a time when or in a situation in which the state attribute would be expected to be low and at another time when it would be expected to be significantly higher. If significant differences were found between the measurements over time or from one situation to another in the direction expected, this would support the validity of the tool. For example, in validity assessments of the Multiple Affect Adjective Check List, college students scored significantly higher on the today form of the tool on examination days than on nonexamination days (Zuckerman & Lubin, 1985).

**Interpreting State and Trait Measurements**

As noted previously, when tools are selected to measure an attribute, care should be taken that the conceptual orientation of the tool is consistent with the purpose for which the tool is used. This is particularly important in terms of whether a state or trait characteristic is the focus of measurement. A nurse would not want to use a tool that measured trait anxiety, for example, when the purpose is to measure state anxiety, or vice versa. Whether state or trait attributes are measured will influence the type of interpretations that can be validly made about the results. If a nurse were interested in the long-term effects of a particular phenomenon, it would be more appropriate to employ a trait measure. The reason for this would be that the nurse is really interested in making interpretations about the influence of the phenomenon on the general responses or behaviors of the subject in terms of that attribute, that is, on the trait expression of the attribute. If, on the other hand, the concern were with the changes that occur within a relatively short time period or in a particular situation, then a state measure would be employed. One cannot assume that changes reflected by a state measure are long-lasting. Neither can one assume that lack of change in scores obtained by a trait measure also indicates lack of situational or short-term fluctuations in the attribute. The interpretations that can be appropriately made about trait and state characteristics are directly linked to the nature of the measurement tool and the circumstances under which the measurements are made.

**CROSS-CULTURAL MEASUREMENT**

To eliminate health disparities, health care professionals need to be prepared to function in a global environment with other health care disciplines (Braveman, 2006; U.S. Department of Health and Human Services [DHHS], 2005). Recognizing the need for nurses to respond to global health needs (Andrews & Boyle, 2008; Giger & Davidhizar, 2008; Purnell & Paulanka,
Cross-national refers to research conducted in more than one country. Cross-national work may not be cross-cultural if the two nations are similar in the phenomenon of interest. Cross-national research is often cross-cultural, but cross-cultural research may or may not be cross-national (Bullinger, Anderson, Cella, & Aaronson, 1993; Corless, Nicholas, & Nokes, 2001). An example of cross-national research can be found in the work of Sheer and Wong (2008) who examined the development of advanced practice nurses globally using data collected from documentary resources, a key informant survey, and self-administered questionnaire across 14 countries and 3 regions from 5 continents to compare respondents’ similarities and differences in education level, roles assumed, and regulatory measures.

Whenever possible, existing measures should be employed in cross-cultural research rather than developing a new instrument or measurement method. When measures are employed and tested over time, more substantial evidence for reliability and validity is accrued than is possible within the context of a single study, and the cost of instrumentation is less than when developing and testing a new measure. Examples of the use of existing measures in cross-cultural research can be found in Lee and colleagues (2009) and Omari (2009). Additional information regarding measurement equivalence in cross-cultural research is provided by Shrout (2009) who discusses the potential value of integrative data analysis, a systematic approach to data analysis of multiple samples, in adjusting for sample differences and combining datasets across studies of cross-cultural differences.

Applicability is an important validity consideration in selecting an existing measure for use in cross-cultural research, especially when the intent is to use the measure and implementation of findings in the clinical setting. When the following questions are addressed during the process of selecting a measure, the probability that evidence will support validity is increased:

- Do items reflect culturally relevant theoretical propositions that served as the basis for the measure’s development?
Part V Measurement Issues

- Is the type of measure appropriate for the culture and/or setting in which it will be employed?
- Are scores likely to provide information that will assist in decision making with respect to the phenomenon of interest within the culture and/or setting?
- Can the measure be implemented for the purpose and manner as intended?
- Are conditions under which the measure will be administered consistent with the intended conditions and setting?
- Are measurement results likely to be congruent with the intended setting philosophy, subjects, personnel, financial and administrative structure?
- Is the target population for the measure similar to that in the culture and/or setting?
- Are the time and resources, including copyright permission to use and/or translate, required to administer and evaluate the measure appropriate for the setting in which it will be used?

Use of a tool from one culture to another requires, first and foremost, attention to the cultural relevance of the measure for the cultures for which it is being employed. An existing tool or method when used in measuring a phenomenon in another cultural group for which the tool was not designed often requires translation. An important consideration then is whether the tool can be translated from the source language (i.e., the original language of the tool) into the target language (i.e., the language into which the tool is to be translated) without losing meaning in the translation process.

Carlson (2000) points out that translation means literally changing word-by-word without considering conceptual meaning. When an instrument or measurement method is translated word for word, the result is apt to be an instrument in the target language that has awkward sentence structure and that lacks clear and comprehensible meaning. Further, difficulties in translation result from the fact that, in some cases, there are no words within the target language that are equivalent to those in the source language and/or there are no equivalent parts of speech between the two languages. For this reason, in recent years as translation methodology has further developed, the emphasis has shifted from a focus on instrument translation to instrument adaptation.

Instrument adaptation is the preferred process because, unlike translation, it takes into account conceptual meanings in the source language within the context of the translation process. The final goal of tool adaptation according to Hambleton (1994) and Sireci (1997) is to maintain construct equivalence and content representation across the two languages. When measures are employed across cultures, several issues that can affect the reliability and validity of the measurement results must be considered and steps must be taken to resolve them. These issues are discussed below.

Cultural Equivalence

A primary issue to be considered in regard to cross-cultural equivalence relates to the concept being measured. Equivalence (Van de Vijver & Leung, 1997) refers to the extent to which scores obtained from the same measure when employed in different cultural groups are comparable. One cannot assume that specific concepts or ideas present in one culture are also present and/or have the same meaning in another culture (Brislin, Lonner, & Thorndike, 1973; Hilton & Skrutkowski, 2002; Hwang, Yan, & Scherer, 1996) or that they are readily transferred from one culture to another (Carlson, 2000). For equivalence to be present when measures are employed across cultures, it is necessary to consider equivalence in terms of the meaning of the concepts (e.g., depression) that serve as the basis for the measure’s development and to ascertain that they have the same meaning within each of the cultures in which the measure is employed. One way in which this can be accomplished is to pretest the measure with subjects from each of the cultures of interest to ascertain similarities and/or differences in their response patterns.

For example, Byrne and Campbell (1999) administered the Beck Depression Inventory to groups of Bulgarian, Canadian, and Swedish subjects and compared the response patterns across groups using the degrees of skewness and kurtosis. They found that the concept of
Chapter 26  Other Measurement Issues  449

depression among the Swedes differed in that the Swedes were prone to either acquiescent or socially desirable responding, tendencies which they accounted for as a reluctance to openly acknowledge any evidence of weakness in terms of depressive symptoms.

Additional examples of efforts to validate conceptual equivalence across cultures can be found in the works of Krethong, Jirapaet, Jitpanya, and Sloan (2008) who hypothesized a conceptual model of health-related quality of life (HRQOL) in Thai heart failure patients based on Wilson and Cleary’s (1995) HRQOL conceptual model; Lim, Waters, Froelicher, and Kayser-Jones (2008) who assessed social cognitive theory in relation to its relevance to produce culture-specific direction for gerontological nursing practice to guide the design of interventions for Korean-American elders; Melby, Dodgson, and Tarrant (2008) who employed a phenomenological approach to describe the lived experience of English-speaking Western nurse educators teaching in East Asian countries and found nurses providing direct care and nurse educators who work with people from a different culture find the discussion of cross-cultural misunderstanding useful; Corless et al. (2001) who examined cross-cultural measurement of quality of life and issues to consider in adapting existing quality-of-life measures for cross-cultural use; and Chen, Lee, and Stevenson (1995) who studied response styles of East Asian and North American students and concluded that the response patterns of Asian subjects differed in that they tended to be influenced by their beliefs, based on Confucian philosophy, that they should not stand apart from the group.

Hwang et al. (1996) note that successful translation efforts depend upon the concepts being understood in a similar manner within the two cultures. Thus, prior to translation, it is essential to establish cultural equivalency. Within the translation literature, two terms are frequently used in this regard: *emic*, from the word “phonemics” (sounds that occur in only one language), and *etic*, from the word “phonetics” (sounds that occur in all languages).

*Emic concepts* refer to ideas and behaviors that are culture-specific. Emic concepts do not survive backtranslation aimed at cultural adaptation. *Etic concepts*, on the other hand, refer to ideas and behaviors that are universal. Etic concepts survive backtranslation. During the translation process, an emic concept in the source language becomes an imposed etic in the target language; thus, modifications may be needed for an imposed etic to become an emic concept in the source language, in order to make emic concepts in both languages comparable (Banville, Desrosiers, & Genet-Valet, 2000).

### Cultural Bias

A major factor that threatens the validity of cross-cultural measurement is bias. Cultural bias may manifest when the concepts measured differ in meaning across cultural subgroups, that is, when they are not conceptually equivalent, or if the items in the tool differentially represent or underrepresent the concept across cultural subgroups measured, and/or as a result of the measurement method employed, especially in regard to how it is administered.

Specifically, cultural bias can result from poor item translations, inappropriate item content, and/or lack of standardization in administration procedures. Thus, three types of bias are of concern in cross-cultural measurement: construct, method, and item bias. **Construct bias** is a threat to validity when the construct measured is not identical across cultural groups, when there is no associated construct and/or dissimilar behaviors define the construct across culture(s), or when the construct is underrepresented in the instrument or method being employed to measure it. Van de Vijver and Poortinga (1997) identify the following sources of construct bias:

- Differences in the appropriateness of content
- Inadequate sampling of all relevant behaviors
- Underrepresentation of the construct
- Incomplete overlap of the construct across cultures (p. 26)

This threat can be avoided by pretesting the measure with informants representative of the cultures of interest, asking them to describe
the concept and its characteristic behaviors (Serpell, 1993), or by comparing factor structures of scores across the cultural subgroups. For example, Wilson, Hutchinson, and Holzemer (1997) used a grounded theory approach with an ethnically diverse population of Hispanic, Anglo-American, and African American people living with advanced HIV, family and significant others, caregivers, and experts in HIV/AIDS to ascertain their conceptualization of quality of life; and Avci and Kurt (2008) studied the concept of health beliefs, measured using the Champion Revised Health Belief Model Scale, and mammography rates of Turkish women living in rural areas.

Bias can also result from the method of measurement employed and/or from the manner in which it is administered. For example, Hui and Triandis (1989) found that Hispanics tended to choose extremes on a five-point rating scale more often than did White Americans. Similarly, Iwata, Roberts, and Kawakami (1995), who employed Likert-type scales with a Puerto Rican sample of diabetic patients, and Bernal, Wooley, and Schensul (1997), who compared Japanese and U.S. workers using a depression scale, found differences across cultures in how subjects responded to this method.

Method bias is a function of how members of different cultural groups respond to a specific type of measurement instrument or method. For example, experience with the procedures for responding to a particular type of measure may vary across cultures, and/or communication between an interviewer and interviewee may be adversely affected by language problems when the interview language is the second language of the interviewer. Specific sources of method bias according to Van de Vijver and Poortinga (1997) include:

- Differences in tendency toward social desirability
- Response style differences such as tendency to acquiescence
- Lack of sampling comparability on variables such as age, gender, educational background
- Physical conditions of administration differ
- Familiarity with response procedures differs
- Interviewer effects
- Interviewer-respondent effects such as communication problems (p. 26)

Van de Vijver and Poortinga (1992) note that cross-cultural studies often involve highly dissimilar groups as a result of how subjects are sampled across cultural groups. As a result, groups often differ in background characteristics that may not be relevant to the measurement purpose, thus adversely affecting the validity of resulting scores and their comparability with scores of other groups.

Aitken and colleagues (2008) described the effectiveness of strategies used to administer an international multicenter clinical trial, involving a sample of 3,522 subjects from 3 countries, to determine whether a brief education and counseling intervention delivered by a nurse could reduce prehospital delay in the event of symptoms suggestive of acute coronary syndrome in patients previously diagnosed with cardiovascular disease. They concluded multidimensional approaches to maintain consistency across study sites, while allowing for flexibility to meet local expectations and needs, contributed to the success of this trial.

Owens et al. (1999), in studying responses of minority group respondents and members of acculturated immigrant groups to four large health-related surveys, found higher nonresponse rates among one or more of the minority groups when compared with non-Hispanic White respondents. African American respondents commonly had higher item nonresponse rates to health questions as did males. In both subject groups, they found higher item nonresponse rates among those who had lower incomes, males, and those who were less educated. More educated respondents were more likely to refuse to answer income questions and less likely to answer “don’t know” to them. Older respondents were more likely to refuse to answer income questions. They concluded that trends in refusals and “don’t know” responses suggested problems with information processing, and social desirability explained differences
Bias at the item level is evidenced when subjects of the same ability level who are members of different cultural subgroups differ in their responses to an item(s). This type of bias is referred to as Differential Item Function (DIF). The relationship between item format and DIF of translated items has been studied by Angoff and Cook (1988) who found greater DIF in antonym and analogy items and less DIF in sentence completion and reading comprehension items in translating from English to Spanish. Similar findings resulted from the studies of Gafni and Canaan-Yehoshafat (1993) and Beller (1995) who also found that items translated from Hebrew to Russian demonstrated the most DIF in analogy items and the least DIF in the logic and sentence completion items.

In an attempt to understand the causes of DIF with an eye to developing item writing guidelines to minimize DIF in translated items, Allalouf, Hambleton, and Sireci (1999) conducted a study to identify the types of verbal items most likely to display DIF when translated from one language to another, Hebrew to Russian. To detect causes of DIF, they employed two procedures: (1) analysis of DIF direction, that is, which group performed better on which items and item types, and (2) analysis by translators of the type and content of the DIF items (p. 187). Their findings indicated that 34% of the items demonstrated DIF across languages, and that the most problematic item formats were analogy items (65%), and sentence completion items (45%), respectively. Further, they found that the primary reasons for DIF were changes in word difficulty and item format, differences in cultural relevance, and changes in content (pp. 194–195).

DIF is discussed in Chapter 6 along with suggested approaches for detecting when it is present in a measure. Other examples of studies of cross-cultural differences in response patterns can be found in the work of Jones and Kay (1992); Iwata et al. (1995); and Lee, Jones, Mineyama, and Zhang (2002).

Strategies for minimizing the effect of method bias include the following:

1. Adverse effects from the presence of a culturally different individual (such as an interviewer or researcher or data collector) at the time of administration can be minimized by:
   - introducing the individual to respondents and affording them opportunities to become familiar with the individual before the measurement
   - adequately training individuals to perform in a culturally relevant manner and by making them aware of potential adverse effects and how to avoid them
   - statistically assessing the effects a posteriori, employing a procedure such as analysis of covariance using attributes of the individual (e.g., attitudes toward the phenomenon being measured, age, gender, ethnicity) as the covariant
   - conducting postadministration interviews and/or focus groups with respondents to assess these effects.

2. Sampling procedures in cross-cultural measurement may result in inclusion of subjects who differ within a specific culture, as well as across cultures, with
Part V Measurement Issues

regard to variables not measured that may affect the phenomenon of interest and hence may have an adverse impact on the measurement results. To avoid such effects, it is important to:

- consider a priori respondent attributes identified in the literature and in previous studies that potentially may have an impact on how they respond to the measure.
- undertake a pilot study to investigate the reliability and validity of the measure that includes assessment of differences in the attributes of those selected for inclusion in the sample that may affect the phenomenon under study, and the ability of those selected to respond to the specific method of measurement being employed.

3. Bias resulting from the measurement method, item format, and/or administration procedure can be reduced by:

- administering the measure to a sample of respondents from the target group and either during or immediately following the completion of the measure, interviewing them regarding their reactions to various attributes of the measure, and/or asking them to explain or interpret their responses to the items included in the measure.
- assessing the extent to which the type of measurement method employed influences respondents’ scores on the measure, using multitrait-multimethod analysis that is discussed in Chapter 6.
- conducting interviews or focus groups with subjects during pretesting to ascertain their familiarity and/or previous experience with the method of measurement and/or item format to be employed.
- undertaking a covariate analysis post-measurement to assess the effect of previous experience on resulting scores.

Further, Allalouf et al. (1999) note that differential item functioning (DIF) detection is an important component of test adaptation and, if known, factors affecting DIF should be taken into account before test administration rather than post hoc, as is now often the case.

Translation Approaches

Increased awareness of worldwide health problems and the formation of international educational, research, and clinical collaborations to address them have made the need to develop instruments that can be readily translated into other languages a salient concern. Brislin et al. (1973) proposed the following rules that are still relevant today for developing instruments in English that can be easily translated into other languages:

- Use short, simple sentences of less than 16 words with a single or main idea in each sentence.
- Use the active voice, since it is easier to translate, and avoid the passive voice.
- Repeat nouns rather than using pronouns.
- Avoid metaphors and idioms, because they are least likely to have equivalent meanings in the target language.
- Avoid the conditional mode, that is, verb forms with would, should, and could.
- Give additional sentences to provide a context for key ideas.
- Avoid the use of adverbs and prepositions (i.e., where or when, frequent, beyond, and upper) since they do not usually have direct equivalent meanings in other languages.
- Avoid possessive forms since the concept of ownership may not have the same meaning across cultures.
- Use specific terms and avoid general terms.
- Avoid words that can generate vague meaning regarding a thing or event (e.g., probably, maybe, or perhaps).
- Avoid sentences that contain two different verbs if those verbs suggest different actions.

Other considerations in employing measures cross-culturally are the reading level required of subjects responding to instruments, and the methods requiring them to read and provide a written response. The Flesch-Kincaid readability index computed for the source language
instrument should be determined and should, as a rule of thumb, be at the grade level of 6 or 7, as is commonly recommended for patient educational materials (Estrada, Hryniewicz, Higgs, Collins, & Byrd, 2002).

Asymmetrical translation (unicentered) refers to translation where the target language remains loyal to the source language. A uncentered translation strategy is employed when operational goals are used to examine the cultural distance between groups or the degree of acculturation and the source language group functions as the criteria for interpreting scores of the target group. This strategy allows the target language version to remain loyal to the original.

When the study purpose is to examine cultural differences or acculturation, a symmetrical approach is indicated. Symmetrical translation refers to a translation where both source language and target language are open to revision. Both languages are considered equally important and a researcher does not focus on one particular language. Decentering is a process used in symmetrical translation. A decentered translation strategy is used when the target language is unnatural and/or very different, thus requiring comparative goals to be used to examine the phenomenon across cultures. A decentered strategy allows the source and target languages to remain loyal to meanings and allows revision in order to improve meaning and meaning equivalence. Decentered translation is preferred for use with new measures. Werner and Campbell (1970) suggest that instruments should be developed by collaborators from the two cultures. In the decentering process, the researcher reads the backtranslation to identify words and concepts that cannot be well translated and then consults with bilinguals to revise the source language version, a process that continues until evidence for equivalence is obtained. Steps undertaken when a decentered translation strategy is employed include:

- Translation from the source to the target language
- Translation from the target language back to the source language
- Committee review of the translation and backtranslation

- Pretesting for equivalence using appropriate techniques
- Assuring cross-cultural equivalence with regard to content, semantics, technical issues, criteria, and conceptual equivalencies

Backtranslation, a process to verify a translated version, includes the following:

- The translated version is translated back into the source language
- Psychometric equivalence for original and target versions are assessed using monolingual or bilingual subjects
- A translation error may be influenced by whether the source and target language are similar in structure
- Translation errors can be corrected through the comprehensive process of translation and backtranslation.

Establishing evidence for reliability and validity is essential for credibility of the measurement results. Comparing the psychometric properties of the source and target language versions provides additional data for assessing equivalence.

Issues addressed earlier in this section that need to be considered and adequately addressed when translation methodologies are undertaken include linguistic adaptation, cultural concepts, and psychometric properties. As noted earlier, when undertaking a translation process, it is necessary to be aware of linguistic differences between the two cultures. Linguistic differences may involve grammatical structures and literal meaning of words. When there are grammatical and structural differences between the source and target languages, the process of translation is more difficult than when there are none. Relevance of the concepts to be measured should be investigated by conducting a review of the literature in the culture in which the translation is to occur to ascertain the importance of the phenomenon in that culture and the extent to which it has been measured and/or researched. Cross-cultural equivalence should be considered by examining the characteristics of philosophy and the written and spoken language, and their congruence or lack thereof within the culture in which the original tool was developed and
measures or copyrighted materials, which is a drawback to the use of these translation strategies. The advantage of translation by committee is that it is less time-consuming than backtranslation. Disadvantages stem from the fact that translators who have similar backgrounds may share common cultural perceptions, may be influenced by their peers, and/or are reluctant to criticize each other’s work. In addition, the committee may produce an accurate translation, that could, however, be inappropriate for the target population and/or they may not take into account relevant socioeconomic and cultural factors of the target population, thus rendering the translated instrument not applicable.

Backtranslation, also referred to as double translation, involves the use of two translators. Working independently, one translates the items from the primary (source) to a second (target) language, and the second translates the items back to the original source language. The two original language versions are compared to identify flaws in the target language version. In many cases, original items are prepared in a dual-language format in which items in the source and target language appear next to each other, allowing bilingual responders to double check the understanding of a statement by reading each item a second time in the alternative language, thus, enhancing the understanding of the question by incorporating the best sense derived from each language version. This format also allows for instruments to be completed with the assistance of family or friends, who may be at various levels of competency in either language, and who, therefore, can also benefit from the immediately available translation.

A key to successful use of this method is the use of translators who are native speakers and readers of the target language. A drawback to the method is that the cultural context in which the translation is imbedded involves the life experience of only two individuals who may share a common worldview due to similar backgrounds. Limitations of backtranslation can be minimized by emphasizing instrument adaptation instead of translation (Geisinger, 1994), and by providing explicit instructions to translators regarding inference, wording, and phrasing to enhance conceptual equivalence (Marin & Marin, 1991). It is

Translation Methodologies

One-way translation refers to the use of a bilingual translator who translates the instrument from the source language into the target language. The advantage of one-way translation is that it is simple and inexpensive. The disadvantages are that the translated instruments are solely dependent upon the skill and knowledge of one translator and that the translated instruments are likely to have less evidence for reliability and validity when compared with the original ones.

With forward translation, multiple translators work in collaboration to conduct a source-to-target language translation. A second group of translators judges the equivalence of the two versions. Variations of this approach are referred to as “decentering” or “focus group translation” or “translation by committee.” An equal value is placed on both languages in each of these approaches. That is, a word in the source language is subject to change in order to more closely approximate the word that is most appropriate to use in the target language. Adaptations of source language cannot be made to standardized tested and the culture within which it will be employed.

Psychometric properties of the target language instrument may differ from that of the source language version. Thus, it is imperative that reliability and validity studies of both instruments be undertaken and compared, and that necessary modifications are made in either or both prior to use in research. For example, Lee, Chaboyer, and Wallis (2008) examined predictors of health-related quality of life in Taiwanese patients who experienced moderate to severe traumatic injury. Demographic and clinical data were collected using two instruments: the Illness Perception Questionnaire (Moss-Morris et al., 2002) that was modified and translated into Chinese and its psychometric properties tested following the established protocol for translating research instruments (Brislin, 1986; Jones, Lee, Phillips, Zhang, & Jaceldo, 2001), and the Chinese version of the Medical Outcome Study Short Form 36 (Ware, Snow, Kosinski, & Gandeck, 1993) that was tested and norms established for the Taiwanese population by Lu, Tseng, and Tsai (2003).
In translating idioms, translators recognize differences in meaning and take steps to assure that idioms have equivalent meanings in the two languages.

The source version and the target version of the instrument are administered in the same manner so that valid comparisons of the findings from the two measures can be made.

Methods for assessing concepts are comparable between the two cultures in terms of the resulting data.

### Evaluative and Psychometric Testing

Translated instruments are usually pretested using three techniques: random probe technique, committee approach, and field testing with bilinguals. When the *random probe approach* is employed:

- A researcher selects a random sample of items from a translated instrument.
- Individuals from the target population are then asked individually to read or listen to each item and paraphrase their understanding of the item.
- An open-ended question such as “What do you think this question asks?” is used for this purpose and individuals verbalize their understanding by answering the question, or individuals are asked to answer each question in the instrument and then asked, “What do you mean?”
- If they cannot justify their responses or their justification is unusual, it suggests that the intent of the question is not being conveyed.
- Responses are expected to closely resemble the source language version, and if discrepancies are found, they are analyzed for mistranslation so changes can be made.

When the *committee approach* is employed:

- Two or more experts review the clarity and linguistic appropriateness of the translated version of an instrument (Geisinger, 1994).
• Experts usually meet face to face and discuss the merits of each item (Brislin et al., 1973).
• An optimum translation is selected based upon all contributed opinions.

Field testing with bilinguals involves the following:

• Both versions of the instrument are administered to bilingual individuals from the target population, with the intent of detecting possible discrepancies (Guillemin et al., 1993).
• Subjects are asked to rate each item regarding its equivalence between the source and target versions.
• Items rated low on equivalence or items with discrepancies are revised.
• Item scores of respondents can also be compared with their total scores between the two versions.
• Items with different scores should be examined and retranslated.
• Item and total scores that are highly correlated between the two versions are desirable and suggest that the two versions are likely to be equivalent.
• Item analysis is performed to examine if specific items perform differently on the two versions since total scores may hide inconsistency (Hilton & Skrutkowski, 2002).

Such field testing with bilinguals may not be feasible in all settings because of difficulty in finding representation from the target population. Having bilinguals rate the equivalence of the two versions affords insight into the quality of the translation. On the other hand, bilinguals are used based on the assumption that they represent the monolingual target population. Criticisms of employing bilinguals, however, stem from the fact that they may differ from monolinguals to which the translated instrument will be administered in that they most likely have adopted culture, concepts, norms, and/or values of the second language they mastered (Hilton & Skrutkowski, 2002). Translators whose items are consistently rated low on equivalence may not be qualified to translate the instrument. Herrera, DelCampo, and Ames (1993) suggest the inclusion of representatives of the monolingual source and target populations in field testing. Their approach includes:

• Pretesting and posttesting a source language version of the instrument with the monolingual source population to establish a baseline reliability index.
• Pretesting and posttesting a target language version of the instrument with the monolingual target population to determine the reliability of the translated version with the target population.
• Pretesting and posttesting with two bilingual groups and controlling for administration effects by administering two versions of the instrument in alternative sequences.

Once the final version of the translated instrument is obtained, the psychometric properties of both versions of the tool are tested in the target and source groups employing approaches to determining evidence for reliability and validity discussed in Chapters 5 and 6. Examples of evaluative and psychometric testing of translated instruments can be found in Chen, Horner, and Percy (2002), who undertook a study to validate a translated smoking self-efficacy survey for Taiwanese children, and in Haddad and Hoeman (2001), who tested a translated version of an Arabic-language version of an English-language questionnaire.

Effect of Cultural Practices

To examine cultural practices and their effect on preferences and outcomes of cross-cultural measurement in order to identify issues and take actions to minimize their effect on measurement outcomes, the following questions regarding concept relevance, measurement method, translation strategies, and cultural practices should be considered:

1. Does the concept of interest have the same meaning in both cultures?
2. Do attributes of subjects within the cultures of interest differ in ways that may affect the variables studied?
For example, suppose a group of clinicians and researchers in South Korea are interested in the transferability of U.S. mental health methods to health care and research in South Korea. At first glance, it might appear that meaning is the same. In the United States, mental health is viewed as an interpersonal process to assist clients in growth and recovery and the focus is on evaluating outcomes resulting from biological and psychotherapeutic approaches. In Korea, mental health is synchronous with psychiatry and the focus is on providing psychopharmacological intervention for psychobiological disorders with support for clients. Differences in subject attributes affecting the meaning of mental health become more apparent when considering practice preferences. In Korea, knowledge and practice is influenced by cultural practices such as social desirability and importance of accepting views of those in authority. Because mental health practitioners are viewed as authority figures, clinical decision making is strongly affected by practitioners’ own experiences rather than practice protocols or research findings. Patients’ preferences in Korea result from the desire to maintain harmony rather than to focus on individual outcomes (Waltz & Song, 2006).

Regarding measurement methods, questions to be considered include:

1. Do subjects within the cultures of interest respond in the same manner to specific methods of measurement?
2. Is there any suggestion that subjects within the cultures of interest may respond differently because of tendency toward social desirability, acquiescence, and/or other response style differences?
3. Are there differences in familiarity with study procedures, interviewer/respondent effects?
4. Are communication problems present?

For example, in addition to tendency toward social desirability and acquiescence to authority figures, there are differences between U.S. and Korean subjects in effectiveness of measurement methods employed. Specifically, Koreans tend not to take questionnaires seriously and tend not to provide accurate answers. Considering age, gender, and tendency to acquiescence, an interactive interview is a preferred method for Koreans. A direct, confrontational approach is not effective with Koreans. Rather an indirect approach to mental health is desired because having a mental issue is viewed as placing shame and guilt on one’s family (Waltz & Song, 2006).

Regarding translation strategies, questions should include:

1. Were appropriate translation strategies employed?
2. Were translators ethically and culturally representative of the population among whom the findings will be employed?
3. Were translators fluent in both the original and source language and the target language to which the tool was translated?
4. Were translators familiar with both cultures?
5. Were translators knowledgeable about the concepts measured and how results will be used?

Ideally, translation should be done by a bilingual who is culturally competent for both countries; who has a good understanding of the concept, measurement methods, and procedures and is familiar with the source and target language by training.

Additional examples of the affect of cultural perspectives and practices on research outcomes can be found in the work of Chang and Roberts (2008) who investigated factors related to feeding difficulty in Taiwanese elderly with dementia in long-term care facilities and found significant differences in Chinese culture and characteristics of Chinese long-term care settings, caregivers, and residents with dementia as compared with Western cultures; Resick (2008) who explored the meaning of health among mid-life Russian-speaking women from the former Soviet Union who migrated to the United States; Brodsky and Van Dijk (2008) who evaluated Israeli nurses’ and physicians’ attitudes toward the introduction of new nursing roles and the expanding scope of practice; and Barnoy, Volfin-Pruss, Ehrenfeld, and Kushnir (2008) who studied factors affecting nurses’ attitudes in Israel toward patients who present them with Internet medical information.
In summary, caution must be used in employing measures and methods developed for use in one culture for data collection in a clinical study or setting in another culture. Attention must be given to transferability by addressing salient questions regarding concept relevance, measurement methods, and translation strategies. It is important to look beyond apparent sameness or similarity in how a concept of interest is defined within each culture by evaluating how that definition is actually viewed within the context of cultural preferences in each of the cultures to determine if in fact it may not be the same or similar in meaning. It is important as well to assess the applicability of a measure and resulting findings to a given clinical setting within the context of patient preferences, practice preferences, and existing resources within the clinical setting of interest. Inconsistencies in preferences and/or response tendencies, variation in translators, and translation strategies employed not only threaten reliability and validity, but can increase study costs. It is imperative that each method be systematically evaluated using the criteria presented here and decisions to employ methods across cultures be made on the basis of carefully evaluated evidence from a group of studies relative to the criteria. When a tool is employed across cultures, outcomes of its use must be systematically evaluated to monitor reliability and validity within each culture on an ongoing basis.

**TRIANGULATION**

In nursing and health research, triangulation is advocated by many researchers as an important strategy for combining qualitative and quantitative methods in order to provide stronger evidential support for a hypothesis and produce more reliable and highly confirmed results than either method would when employed alone and to enhance validity of findings (Dadich & Muir, 2009; Duffy, 1987; Haase & Myers, 1988; Mitchell, 1986; Polit & Beck, 2008; Risjord, Dunbar, & Moloney, 2002; Shih, 1998; Sinclair & Ferguson, 2009). Within a measurement context, combining qualitative and quantitative data within a single study can serve several important purposes, including to:

- Develop instruments where qualitative data are used as a basis for developing items/questions for a quantitative measure that is then subjected to rigorous testing using quantitative methods
- Provide insights regarding constructs or relationships among them that are identified using qualitative methods and then tested using larger samples in quantitative studies
- Employ qualitative data to explicate the meaning of quantitative description or relationships that demonstrate systematic relationships among variables but do not provide insight into why they are related
- Test alternate interpretations of data
- Obtain support for the theory/conceptual framework used in developing a measure as a basis for clinical practice, development of effective clinical and/or evidence-based practice interventions

*Triangulation* affords a means for combining multiple methods in the study of the same phenomenon (Denzin, 1970; Eid et al., 2009; Haase & Myers, 1988; Kimchi, Polivka, & Stevenson, 1991; Polivka, Chaundry, & Sharrock, 2009; Thurmond, 2001; Webb, Campbell, Schwartz, & Sechrest, 1966). When employed within the context of a given study, it enables one to gain a broader perspective on a phenomenon of interest, reduces the probability of bias, and increases the researcher’s ability to interpret the findings with a greater degree of confidence (Breitmayer, Ayres, & Knafl, 1993; Foster, 1997; Jick, 1979; Mitchell, 1986; Thurmond, 2001).

Triangulation is an important strategy for eliminating or minimizing systematic bias in study findings. *Bias* is an influence that distorts or induces error in measurement. Bias can result from a number of factors that may occur deliberately or unconsciously that need to be considered and minimized in planning a study. Bias may be random, occurring by chance, affecting only a few or systematic consistent or uniform throughout. For example, participants’ tendency to present themselves in what they believe to be the most socially desirable manner may adversely affect the accuracy of their behavior or self-report. Other sources of bias may include:
Researchers’ expectations, hypotheses, and/or experiences may lead to subjectivity on their part that leads to distortion in information provided or may lead them to unintentionally communicate their expectations to participants, thus introducing bias into subjects’ responses or behavior.

- A biased sample resulting from a faulty sampling approach and/or poor retention of study participants.
- Use of inadequate data collection methods, for example, using a method that does not capture key concepts or one that does not demonstrate evidence of reliability and validity.
- An inadequate study design as when a researcher may structure the study in a manner that precludes an unbiased answer to the research question.
- Flawed implementation of the study design.

Steps should be taken to reduce or eliminate bias to the extent possible, establish mechanisms to monitor it, detect it when it exists, and take known bias into account when interpreting findings. Since triangulation employs multiple sources of information or points of view, it tends to counterbalance biases and offer ways to identify them. The aim of triangulation is to overcome the intrinsic bias resulting from use of a single method, observer, and/or single theory.

The basic tenet underlying all approaches to triangulation is that the weaknesses in each method employed are compensated for by the counterbalancing strengths of other methods employed within the same measurement effort. It is assumed that triangulation exploits the assets of each measurement method and neutralizes, rather than compounds, the liabilities of other methods (Bouchard, 1976; Campbell & Fiske, 1959; Rohner, 1977; Webb et al., 1966). When qualitative and quantitative methods are employed in triangulation, they are conceptualized as complementary rather than opposing perspectives—with neither approach necessarily given precedence over the other. Working in combination with each other in an iterative fashion, they enable the investigator to derive a more complete understanding of the phenomenon under study (Dadich & Muir, 2009; Duffy, 1987; Knafl & Breitmayer, 1996; Mitchell, 1986; Rossman & Wilson, 1985; Shih, 1998; Sohier, 1988).

According to Mitchell (1986), four principles must be taken into account whenever triangulation is employed:

1. The problem, the kind of data needed regarding the problem, and the relevance of the problem to the methods chosen must be evident.
2. The strengths and weaknesses of each method employed should complement each other.
3. Methods should be selected on the basis of their relevance to the nature of the phenomenon of interest.
4. The methodological approach employed should be continually monitored and evaluated to ensure that the first three principles are being followed. (pp. 22–23)

Triangulation was first applied by Campbell and Fiske (1959) within the context of their multitrait-multimethod approach, which is discussed and illustrated in Chapter 6. More recently, the term “triangulation” has been used to refer to a variety of approaches to employing multiple methods. For example, Cavendish and colleagues (2004) in their study to describe nurses’ spiritual perspectives as they relate to education and practice employed a multiple triangulated research design that included two data sources (qualitative and quantitative), two methodological approaches, and nine investigators.

**Types of Triangulation**


Data triangulation involves the use of multiple sources of data within the same measurement effort to elicit information regarding the phenomenon of interest. Data sources may vary by person, place, or time. For example, information regarding the phenomenon may be collected from different groups of subjects, in different settings, or during different time periods. Each data source
is chosen to represent dissimilar comparison to obtain diverse data regarding the phenomenon. Variances in person, place, and time may serve to increase confidence in the findings according to Fielding and Fielding (1986), because it increases the possibility of revealing atypical data or potential for identifying similar patterns. Banik (1993) further notes that an advantage of data triangulation is the nature and amount of data generated for interpretation. Polit and Beck (2008) caution that time triangulation, since it involves gathering data at different times of the day, or at different times of the year, is conceptually similar to test-retest reliability assessment, and emphasize that it is important to note that the intent is not to study a phenomenon longitudinally to determine how it changes, but to determine the congruence of the phenomenon across time.

Examples of data triangulation can be found in the work of Piven and colleagues (2006) who studied how the relationships of Minimum Data Set coordinators with other nursing home staff influenced processes of care, and Aitken and colleagues (2008) who employed multiple methods to collect data across multiple sites to determine effective strategies for implementing a multicenter international clinical trial.

When **investigator triangulation** is employed, multiple investigators collect and analyze data in regard to the phenomenon of interest. Denzin (1970) suggests that all investigators should be experts in the phenomenon and all should be directly involved in the conduct of the effort. This type of triangulation increases the probability of greater reliability in the data collection and analysis because it allows for the comparison among investigators and for the detection of potential bias in reporting, coding, or analysis. When data are confirmed by investigators who have had no prior discussion or collaboration with each other, the findings have greater credibility than when this is not the case (Denzin, 1970). Additional advantages of using investigator triangulation include increased credibility of findings from having a team of investigators who are versed in employing both qualitative and quantitative methods (Beck, 1997; Connelly, Bott, Hoffart, & Taunton, 1997; Duffy, 1987) to keep each other on target (Lincoln & Guba, 1985), thus reducing the potential for bias in data collection, reporting, coding and/or analysis of the data (Denzin, 1970; Mitchell, 1986) and contributing to increased reliability (Banik, 1993), internal validity (Boyd, 2000), and value of the findings (Thurmond, 2001). Examples of this type of triangulation can be found in the work of Breitmayer et al. (1993); Knaff, Breitmayer, Gallo, and Zoeller (1996); and Cavendish and colleagues (2004).

**Theoretical triangulation** involves the use of multiple perspectives and/or hypotheses regarding the phenomenon of interest within the same measurement effort. This approach, which is similar to the method of multiple working hypotheses referred to by Chamberlin (1965), allows several alternative perspectives, each theoretically different but related enough to be considered together and tested within the same dataset. When an accepted hypothesis has been tested against rival hypotheses within the same dataset, more confidence can be placed in the results. Advantages of theoretical triangulation result from the fact that it enables one to test various theories by analyzing findings from a common dataset (Boyd, 2000), uses more than one theoretical perspective or hypothesis testing to decrease alternative explanations for a phenomenon (Mitchell, 1986), and provides a broader, deeper analysis of findings (Banik, 1993).

**Methodological triangulation**, in large part because of the various terms used to describe it in the literature, is often the most difficult type to understand. Specifically, it has been referred to as *multi method*, *mixed-method*, and *methods triangulation* (Barbour, 1998; Greene & Caracelli, 1997). Goodwin and Goodwin (1984) note that in some cases methodological triangulation when discussed in the literature refers to research designs and at other times to data collection methods. Further complicating the issue, according to Thurmond (2001, p. 254), is the fact that some authors discuss methodological triangulation in reference to qualitative and quantitative methods, indicating a paradigmatic connection (Barbour, 1998; Greene & Caracelli, 1997) and others in reference to qualitative and quantitative data collection methods, analysis, and interpretation rather than philosophical viewpoints (Goodwin & Goodwin, 1984). In any case, methodological triangulation involves the use
of multiple methods in an attempt to decrease the weaknesses and biases of each method and to increase the potential for counterbalancing the weaknesses and biases of one method with the strengths of the other methods (Mitchell, 1986, pp. 19–21).

Within the context of measurement, the interest in methodological triangulation relates to its use as a strategy that employs several different methods or procedures for collecting data within a single measurement effort. This type of triangulation is best exemplified by the multitrait-multimethod approach of Campbell and Fiske (1959). Jick (1979) notes that this type of triangulation is most appropriate when the intent is to study complex concepts with multiple dimensions. This approach to triangulation usually takes one of two forms: within method or between method. The within-method approach is most often employed when the phenomenon of interest is multidimensional, in that it uses multiple techniques within a given method to collect and interpret data. It is important to recognize that the within-method approach involves the use of two or more data collection procedures from the same design method, that is, qualitative or quantitative (Kimchi et al., 1991). For example, when the survey method is employed, it might involve the use of multiple scales or indices of the phenomenon or, in the case of a qualitative method like participant observation, the use of multiple comparison groups (Jick, 1979) or a blend of unstructured methods such as documents, interviews, and observations. While the within-method approach allows for assessing the reliability of the data, especially internal consistency, it still uses only one method and, hence, has more potential for bias and threats to validity than do other approaches (Jick, 1979; Webb et al., 1966). An example of the within-method approach can be found in Whiting and Mallory (2007) who used multiple quantitative instruments and school data to identify behavioral and attitudinal outcomes of a mentoring program for middle-school students offered by nursing and other college students.

The between-method approach, also referred to as across-method triangulation, is more complex and allows for the assessment of external validity, especially convergent validity. Jick (1979) notes that this approach, the most frequently employed, is largely a vehicle for cross-validation when two or more methods are found to be congruent and yield comparable data. In contrast to the within-method approach, between-or across-method triangulation employs both qualitative and quantitative methods within the context of the same study (Boyd, 2000; Denzin, 1970; Kimchi et al., 1991; Mitchell, 1986; Thurmond, 2001), for example, using a combination of a questionnaire and focus groups in the same study or employing an unstructured interview with a Q-sort. An example of the between-method approach can be found in Blackwood and Wilson-Barnett (2007) who employed qualitative and quantitative methods to determine the impact of nurse-directed protocolized weaning from mechanical ventilation on nursing practice.

A second variation of the between-method approach described by Rossman and Wilson (1985) provides for one type of data (e.g., qualitative) to elaborate findings of another (e.g., quantitative). They advocate this approach because such elaboration may not only add to the credibility of the findings, but provide a different perspective on the same phenomenon as well. For example, one method might be used to generate ideas that are tested by another method, as when researchers employ qualitative methods such as interviews of participants and participant observation to better understand a phenomenon, and then use the results to develop or test quantitative methods such as questionnaires. Likewise, results from the administration of a quantitative method such as a questionnaire might be followed by a qualitative investigation using focus groups to better understand and/or expand upon the findings from the questionnaire.

Yet another elaboration of between-method triangulation is referred to as holistic or contextual triangulation, where the purpose is to identify areas where findings do not converge; that is, to uncover paradox and contradiction rather than to seek confirmatory evidence (Rossman & Wilson, 1985). This approach to triangulation, according to Bargar and Duncan (1990), has the potential to produce a significant alteration in the overall perspective with which the phenomenon as a whole has been viewed. Similarly, Jick (1979) recognizes that it allows qualitative methods to
Advantages of methodological triangulation include broader representation of worldviews than is obtained by combining qualitative and quantitative methods (Lincoln & Guba, 1985), qualitative findings that may help to explain the success of interventions when quantitative findings fail to do so (Polit & Hungler, 1995), and quantitative data that can enhance understanding by revealing outliers or unique individual cases (Duffy, 1987; Hinds, 1989). Examples of methodological triangulation can be found in Burr (1998), Connell et al. (1997), Wilson and Hutchinson (1991), Floyd (1993), and Woodgate (2006).

Data-analysis triangulation employs two or more approaches to the analysis of the same set of data. It usually involves using different families of statistical testing or different statistical techniques to determine similarities or to validate data (Kimchi et al., 1991). Examples of this approach can be found in Fontaine, Stotts, Saxe, and Scott (2008) who employed multiple approaches to data analysis in their study of shared faculty governance in decision making; Eid and colleagues (2009) who investigated differences between statistical models in analyzing multitrait-multimethod data; and Polivka et al. (2009) who employed a variety of data analysis methods to evaluate a pediatric assessment network education training program.

According to Mitchell (1986), “when two or more different examples of a particular type of triangulation are present within a single study, that study is said to be triangulated. For example, a triangulated study is any study that has several different data sources, or involves multiple investigators or tests multiple competing hypotheses or includes two or more kinds of data collection methods, such as qualitative and quantitative methods” (p. 19). She further notes that the term multiple triangulation refers to studies where two or more types of triangulation are represented.

Analysis of Data Resulting From Triangulation

The primary task in analyzing data from triangulation efforts is to determine whether results have converged. Jick (1979), in discussing the difficulties in making such a decision, notes that “if there is congruence, it presumably is apparent. In practice, though, there are few guidelines for systematically ordering eclectic data in order to determine congruence or validity” (p. 607). When analyzing triangulation data, the investigator needs to consider the following:

1. Does each method employed demonstrate reliability and validity in its own right?
2. Should all methods employed in the analysis be given equal weight in terms of importance and usefulness? If not, on what basis should the data be weighted?
3. What will constitute evidence for consistency or congruence of methods? It is essential to be aware of the fact that while statistical tests can be applied to a particular method, there are no universally accepted methods for describing the statistical significance among methods. The concept of significant differences when applied to qualitative methods does not readily compare with statistical tests of the significance of differences in quantitative methods. Similarly, if convergence or agreement is the concern, is it appropriate to use statistical differences as a criterion or should congruence be assessed using relational techniques such as correlation and regression?
4. When different methods yield dissimilar or divergent results, how will the investigator reconcile and/or explain the differences? Useful information may be obtained whether or not there is convergence in results. Where there is convergence, one can place more confidence in the reliability of the results and with the probability that they result from trait, rather than method, variance. Another important variance component not provided for in Campbell and Fiske’s (1959) multitrait-multimethod approach is measurement error. Eid, Lischetzke, Nussbeck, and Trierweiler (2003, pp. 38–39) recognize that since Campbell and Fiske’s (1959) original work, multitrait-multimethod and multimethod strategies in general have gained in importance, and for this reason, a wide array of
multidimensional measurement methods for analyzing trait, method, and measurement error components of such datasets have been developed, including confirmatory factor analysis (CFA) models, covariance components models, and the direct product model (Browne, 1984; Kenny & Kashy, 1992; Millsap, 1995; Wothke, 1995, 1996). Readers interested in a more advanced discussion of these approaches to data analysis are referred to their articles.

When divergence results, it is necessary to consider alternative explanations for the unexpected findings. Jick (1979) states that “Overall, the triangulating investigator is left to search for a logical pattern in mixed-method results. His or her claim to validity rests on judgment, or as Weiss (1968, p. 349) calls it, ‘a capacity to organize materials within a plausible framework.’ One begins to view the researcher as a builder and creator, piecing together many pieces of a complex puzzle into a coherent whole. While one can rely on certain scientific conventions for maximizing the credibility of one’s findings, the research using triangulation is likely to rely still more on a feel of the situation. This intuition and first-hand knowledge drawn from multiple vantage points is centrally reflected in the interpretation process” (p. 608).

In general, the following steps should be undertaken in analyzing the data generated from triangulation:

1. Each method employed should be assessed within the context of the present effort for evidence of reliability and validity in its own right.
2. Data in regard to the phenomenon of interest resulting from each method should be analyzed separately according to accepted principles and practices for that particular type of method.
3. Significant findings from the separate analyses should be identified and examined for obvious convergence or divergence across methods.
4. Significant variables should be examined from a conceptual perspective to identify logical patterns of relationships and meanings among findings from the application of different methods, with an eye toward generating new questions or hypotheses to be examined by later measurement efforts.

Triangulation is an approach that may not be appropriate in all measurement situations. Because of the need to employ multiple methods, investigator and/or administrative costs may be a factor in some situations in deciding whether to use the approach. Because of the challenges in regard to the analysis of data, the approach is best employed in those situations where appropriate resources are available for designing complex analyses, handling large datasets, and/or obtaining the necessary variable-to-subject ratio required for the use of multivariate procedures. Similarly, triangulation may only be undertaken in those instances in which it is possible to identify a common unit of analysis for the design, data collection, and analysis. Mitchell (1986) notes that such a common focus of the data is critical for data from different sources or methods to be combined, and must be part of all aspects of the triangulation.

Summary

Since triangulation employs multiple sources of information or points of view, it tends to counterbalance biases and offer ways to identify them. The aim of triangulation is to overcome the intrinsic bias resulting from use of a single method, observer, and/or single theory. In addition to minimizing intrinsic bias that is more likely when a single method, observer, and/or theory is employed, triangulation can also help to capture a more complete and contextualized picture of the phenomenon under study. Data and method triangulation are especially relevant.
to data collection. As noted earlier, method triangulation involves using multiple methods of data collection about the same phenomenon; for example, in qualitative studies, this might include a blend of unstructured methods, documents, interviews, and observations to more comprehensively understand the phenomenon. Multiple data collection methods provide opportunity to evaluate the extent of consistency and coherency of emerging phenomenon. Data triangulation involves the use of multiple data sources for the purpose of validating conclusions.

**PROXY RESPONDENTS**

Clinicians and researchers may encounter situations where an individual from whom they would like to collect data is unable to provide data for the completion of interviews, such as for health histories or questionnaires, due to the individual’s inability to communicate effectively. A proxy respondent may be used when the desired respondent, or index respondent, cannot adequately respond to the data collection task. A proxy respondent must be purposefully chosen and the process of data collection carefully implemented because the quality of the data collected will influence the reliability and validity of the data and the quality study results or decisions that may be made based on the data. Several questions are raised when using a proxy respondent. “Under what circumstances is a proxy respondent likely to be needed? What considerations should be taken into account when selecting a proxy respondent? What is likely to be the quality of data collected from proxy respondents? Are there approaches that can enhance the accuracy and quality of proxy data? What are the implications of using of proxy respondents for data analysis and interpretation?” (Strickland, 2004, p. 3).

Proxy respondents are most commonly used for completion of questionnaires or providing responses to interviews in situations where the index respondent is not able to communicate or has difficulty doing so. This includes situations where the index respondent has a disabling condition, has difficulty understanding language or the written word, or is not available to provide the required information. Some disabling conditions that may require the use of a proxy respondent are blindness, poor vision, deafness or difficulty hearing when interviews are conducted, and mobility impairment or manual dexterity problems if writing or typing responses on a computer keyboard is needed for a response. Those that may require a proxy respondent include young children, persons with limited education with compromised writing ability or language comprehension levels, immigrants or persons from cultures who do not speak the primary language of the data collector, and persons with health conditions that interfere with communication such as those who have severe emotional disorders, who have had a stroke, or who have suffered brain damage or cognitive impairment. Older senior citizens are more likely to have physical and mental conditions that impair their ability to be respondents than younger senior citizens and adults.

Once it becomes clear that a proxy respondent is needed, several guidelines should be followed. First, the nature of the data that will be collected should be considered, and a proxy respondent who is most likely to have the information required from the index respondent should be selected. For example, information needed from a young child in the school setting would require a proxy from that setting, such as a teacher; while information on child behaviors at home would necessitate a proxy from the home setting, such as a parent or another person in the home who has the opportunity to observe the child’s actions (Prosser, Hammitt, & Keren, 2007). The proxy must be able to understand and communicate effectively on behalf of the index respondent. For example, information needed from a young child in the school setting would require a proxy from that setting, such as a teacher; while information on child behaviors at home would necessitate a proxy from the home setting, such as a parent or another person in the home who has the opportunity to observe the child’s actions (Prosser, Hammitt, & Keren, 2007). The proxy must be able to understand and communicate effectively on behalf of the index respondent. For example, it is not uncommon for a child in an immigrant family who understands and reads English to serve as a proxy for an adult in the family who has poor command of English. Hence, the proxy must have access to the required information that would normally be obtained from the index respondent, understand the information that is sought, and must be able to accurately give responses on behalf of the index respondent in a manner that would reflect how that person would respond on his or her own if he or she could. The validity of data collected from the proxy will depend on how well
They need to be cautioned not to give their personal responses and opinions and should be reminded that they are to give the responses that the respondent would give if he or she could. Proxy respondents must be taught to respond in a manner that they believe the index respondent would if he or she could provide the information himself or herself.

Bias is likely to be introduced into results when data are collected from proxy respondents. Even using proxy assistance, such as having someone read, write, or translate for the index respondent has been shown to influence the results during data collection (Elliott, Beckett, Chong, Hambrooans, & Hays, 2008). Bias will likely be rather systematic across all respondents when all of the data are collected from proxies for every subject. Therefore, validity would be systematically affected. However, bias in the data is of particular concern when proxies provide data for some respondents while data for others are provided directly by the index respondent. In cases where groups will be compared statistically and some responses are provided by proxies while others were given by index respondents, it is important to know whether one or more groups have a significantly higher proportion of proxy respondents than others, since results could be biased and differences found between groups could be due to the use of proxies. “This issue can be addressed directly by statistically comparing the responses obtained from proxies in each group with those obtained from index respondents. If there is not a statistically significant difference within any of the groups, then the use of proxies is not likely to have drastically affected the results. However, if there is a statistically significant difference, then caution will need to be exercised in the interpretation of the results” (Strickland, 2004, p. 5). In such a case, it should be noted that the responses of proxy respondents were different from those provided by index respondents, and how responses differed.

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Absolute decisions, 77
Abstract concepts, 31
Accuracy
  defined, 374, 380
  maximizing, 382
  measuring, 374
  measuring error in, 380–381
  precision versus, 374
  statistics erroneously reported as measures of, 378, 380
  statistics for determining, 377–378
Achievement measures, 19
Acquiescence, by questionnaire respondents, 304
Acquired behavioral dispositions, 12
Across-method triangulation, 461–462
Activities of daily living (ADL), 91–92
Adequacy, in operationalization, 43
Adjusted Goodness-of-Fit Index, 174
Administration bias, 452
Administrative data, 241, 242
  See also Databases
Affective domain taxonomy, 94
Affective measures, 11
Age-equivalents, norms expressed in, 216–217
Agency for Healthcare Research and Quality (AHRQ), 245, 315–316, 426, 430
Agreement, percentage of, 148, 154, 159, 195–196, 374–375, 377
Alpha coefficient, 149–151, 165–166
American Association of Critical Care Nurses, 404
American Hospital Association's Patient's Bill of Rights, 405
American Medical Association, 243
Analysis, unit of, 50, 281–282
Analysis of covariance structures, 172
Analysis of variance (ANOVA), 76, 167–168
Anchors, 13, 320
Animal models, 340
Anonymity, 312, 313, 408–409, 434
ANOVA, See Analysis of variance
Anti-Retroviral Therapy, 145
Applicability, in cross-cultural measurement, 447–448
Aptitude tests, 19
Archive data, 271
Area Resource File (ARF), 246
Asymmetrical distributions, 54
Asymmetrical translation, 452
Asymmetrical weights, 158
Asynchronous communication, 265
Attitudes, 12
Attributes, 50, 78, 130–131
  See also State attributes; Trait attributes
Attribution issues, 428–429
Attrition rates, 385–386
Auditability, 228–229
Authenticity, 228
Average congruency percentage, 189
Backtranslation, 452, 454–455
Beck Depression Inventory, 448–449
Behavioral objectives, 92–93, 102–103, 165
Belmont Report, 409
Benchmark data, 248
Beneficence, 402, 409
Benefits, 409, 411
Between-method triangulation, 461–462
Bias
  administration, 452
  construct, 449–450
  cultural, 449–452
  defined, 458
  item, 451, 452
  in measurement theory, 371
  method, 450–452
  proxy respondents and, 465
  sources of, 458–459
Bilinguals, field testing with, 456
Bimodal distributions, 55
Bioelectrical impedance, 380
Biomedical instrumentation
  calibration of, 381
  characteristics, 343
  classification of, 337–338
  display equipment, 342–344
  invasive, 337
  in vitro, 337–338
  in vivo, 337
  measurement schema, 338, 340
  noninvasive, 337
  physiological measurement using, 336–337
  sensing equipment, 340–342
  signal conditioning equipment, 342
  See also Physiological measurement
Bispectral Index, 348–349
Blanching, 375, 377
Bland-Altman charts, 381
Blood pressure measurement, 17, 67, 337, 349–350, 445
Bloom's taxonomy of the cognitive domain, 93–94, 103
Blueprinting, 103–105  
Body fat study, 375, 380, 381  
Body plethysmography, 358  
Bogus Pipeline Technique, 435  
Borderline-group method, 138  
“Borrowed” concepts, 31  
Boyle’s law, 358  
Branching technique, 441  
Bundled interventions, 439  

Calibration  
biomedical device, 381  
in item response theory, 78, 80  
transducer, 342  
Calipers, 375, 380  
Calorimetry, 359  
Capnography, 356  
Carbon dioxide measurement, 356–357  
Caregiver Reciprocity Scale II, 170  
Care quality measurement. See Quality measurement  
Case studies, 227, 230, 232  
Case volume, 426  
CASI. See Computer-assisted self-interviews  
CAT. See Computer adaptive testing  
Categorical scheme, 282–283  
Categories  
exhaustive, 51  
missing, 140  
mutually exclusive, 51  
Cathode ray oscilloscopes, 342  
CCX Software, 251  
Cellular products measurement, 359–360  
Centers for Medicare and Medicaid Services (CMS), 245, 246, 418–420, 430  
Central tendency error, 157–158  
Central tendency measures, 56–58  
Centrifugation, 338  
CFA. See Confirmatory factor analysis  
CGI programs. See Common Gateway Interface programs  
Chance errors, 66–67, 146–147, 371  
Charts  
Bland-Altman, 381  
item-response, 184–186  
profile, 219  
Cheating detection technique, 389  
Checklists, 15, 275  
Children  
informed consent and, 404  
parents as proxies for, 69  
Chi square-based procedures, 148  
Chromatography, 360  
Clarity, in operationalization, 43  
Clark-type, polarographic oxygen electrodes, 341, 342, 354  
Classical measurement theory, 69–76  
applying to quality measurement, 426–427  
described, 69–71  
domain-sampling model, 74–76  
formulas, 70, 73  
model of parallel measures, 74, 75–76  
observed score variance, 71–73  
statistical definition of reliability, 73–74  
See also Random errors  
Classical test theory, 371  
Clinical and Laboratory Standards Institute, 373  
Clinical data, 243–245  
Clinical interviews, 296  
Clinical outcomes, 441–442  
Clinical Performance Examination for Critical Care Nurses, 273  
Clinical practice, criterion-referenced measures in, 126–127  
Closed-ended questions, 291–292, 294, 303, 307  
Cluster samples, 212, 214  
CMS. See Centers for Medicare and Medicaid Services  
Coder selection and training, 284  
Coding interviews, 297  
Coding scheme, in content analysis, 282, 283  
Coefficient of stability, 148  
Coefficient of variation, 381  
Coefficients  
alpha, 149–151, 165–166  
generalizability, 76  
heterotrait-heteromethod, 182  
heterotrait-monomethod, 182  
validity, 173  
Cognitive domain taxonomy, 93–94, 103  
Cognitive measures, 11  
Cohen’s kappa. See Kappa  
Combination standard-setting methods, 135, 138  
Commission errors, 378  
Committee approach to testing translated instruments, 455–456  
Common Gateway Interface (CGI) programs, 260  
Common Rule standards, 407  
Complete observers, 234  
Complex concepts, 30–31  
Comprehension, and informed consent, 403, 404  
Computer adaptive testing (CAT), 253–257  
benefits, 256–257  
challenges, 257  
described, 253–254  
NCLEX-RN examination, 254–255, 256  
Patient-Reported Outcomes Measurement Information System, 255–256, 257  
Computer-assisted content analysis, 282, 283, 284, 285  
Computer-assisted interviewing, 435  
Computer-assisted self-interviews (CASI), 291, 435  
Computer-based testing, 251–257  
computer adaptive testing, 253–257  
computer simulation, 251–252  
fixed computer testing, 252–253  
Computer simulation, 251–252  
Concept of information, in item response theory, 80  
Concepts  
abstract, 31  
“borrowed,” 31  
complex, 30–31
Index 479

defined, 3, 27
described, 3–4
immature, 27
mapping meaning of, 37–39
mature, 27, 29, 35
nursing, 29–31
observables versus, 28
operationalization of, 28–29
specifying variable aspects of, 40–41
in theories, 27–28
See also Operationalizing nursing concepts; Theoretical definitions

Conceptual models
defined, 3
existing instruments, 395–396
process/outcome measurement, 439–440
Concurrent validity, 176, 177–178
Condition-focused model, 440
Confidence index, 177, 178
Confidence intervals, 381
Confidentiality, 409
Confirmatory factor analysis (CFA), 170–176
assessing model fit, 174
identification, 172–173
model modification, 174–175
other uses for testing measurement models, 175–176
parameter estimation, 173–174
specifying model, 170–172
Consensus, in operationalization, 44
Consistency, in operationalization, 43
Constant errors, 66, 67–69, 146, 371
Constrained parameters, 172
Construct bias, 449–450
Constructs, 170–171
Construct validity
in content analysis, 285
criterion-referenced, 189–190
norm-referenced validity procedures, 167–176
Consumer Assessment of Healthcare Providers and Systems, 420
Contamination
criterion, 179
in vitro biomedical instruments and, 338
Contamination RRT, 388
Content analysis, 279–285
advantages, 285
categorical scheme, 282–283
characteristics/concepts to be measured, 281
coder selection and training, 284
coding scheme, 282, 283
counter-assisted, 282, 283, 284, 285
deductive, 279, 282
disadvantages, 285
features, 279–280
inductive, 279, 282–283
pretesting, 282–283
procedure, 280–284
qualitative research, 279, 280, 282–283
quantitative research, 279, 280, 284
reliability, 284
sampling plan, 282
unit of analysis, 281–282
universe of content, 281
validity, 284–285
Content validity, 140, 165–167, 187–189
Content validity index, 165
Contextual triangulation, 461–462
Continuous ST-segment monitoring, 346–347
Continuum models, 134
Contrasted groups approach, 138, 167–168, 189–190, 321
Convenience samples, 215
Convergent validity, 180, 181
Co-oximeters, 355
Copyright protection for existing instruments, 396–397
Correlation measures, 60–65
CPT codes. See Current Procedural Terminology codes
Credibility, 228
Criteria
criterion-related validity and, 178–179
feasibility, 422
outcome, 442
process, 440–441
usability, 422
Criterion contamination, 179
Criterion groups difference index, 194, 195
Criterion-groups technique, 192–193
Criterion-referenced measures, 127–139
in clinical practice, 126–127
constructing, 134, 139–140
defined, 7, 91
described, 7–8
developing, 127–133
in educational programs, 127
explicating objectives or domain definition, 129
in health research, 125–126
meaning of, 123–124
norm-referenced measures versus, 124
preparation of test specifications, 129–133
scoring rules and procedures, 133–134
setting standards for interpreting results, 134–139
specifying purposes of, 127–129
test restrictions and givens, 133
utility in health and nursing measurement, 125–127
Criterion-referenced reliability procedures, 153–159
interpretation of percent agreement and kappa values, 159
intrarater and intrarater agreement procedures, 157–158
parallel-forms procedure, 156–157
test-retest procedure, 153–156
weighted kappa, 158–159
Criterion-referenced validity assessment, 186–197
construct validity, 189–190
content validity, 187–189
item-analysis procedures, 190–197
Critical scores, 190
Cross-cultural measurement, 446–458
cultural bias, 449–452
cultural equivalence, 448–449
effect of cultural practices, 456–458
Cross-cultural measurement (continued)
evaluative and psychometric testing, 455–456
translation approaches, 452–454
translation methodologies, 454–455
validity, 447–448
Cross-cultural research, 447
Cross-national research, 447
Cross-validation, 179
Cultural bias, 449–452
Cultural equivalence, 448–449
Cultural practices, effect of, 456–458
Curvilinear graphic recorders, 342
Cutoff scores, 190
Cut scores, 134, 135–139, 190

Data
access to, 246–247
administrative, 241, 242
archive, 271
benchmark, 248
clinical, 243–245
demographic, 242–243
hospital discharge, 245
secondary, 241–242
self-reported, 298
See also Databases
Data analysis, 235–236, 462–463
Data-analysis triangulation, 462
Databases, 241–249
access to data, 246–247
analyses, 249
appropriateness of, 247
clinical data, 243–245
common data elements, 242–246
demographics, 242–243
existing health data, 241–242
geography, 246
locating existing instruments, 393–394
measurement, 247
methodological issues with existing data, 247–249
organizational characteristics or identifiers, 245–246
reliability, 247–248
study design, 247
validity, 248–249

Data collection, 232–235
See also Internet data collection
Data-related validity, 284
Data security, 260
Data triangulation, 276, 459–460
Decentering, 452, 454
Decision studies, 77
Decision validity, 189–190
Deductive content analysis, 279, 282
Definitions
dictionary, 34
evaluating theoretical and operational, 43–44
operational, 31, 32, 418, 420, 423, 426–427
preliminary, 35
See also Theoretical definitions; specific terms
deidentification, 407, 408
Delphi conference, 312
Delphi technique, 311–317
advantages, 312–313
application in nursing and research, 314–317
applications, 311
conducting, 311–312
defined, 311
limitations, potential, 313–314
Delta, 171
Demographics, 230, 242–243
Demographic sampling, 231
Deoxyribonucleic acid (DNA), 361–364
Dependability, 228–229
Derived scores, 121
See also Percentage scores; Percentile ranks; Z scores
Descriptive validity, 228
Deviation score, 59
Diagnosis related groups (DRG) algorithm, 245
Diagnostic tests, 19
Diagramming, 38–39
dichotomous scoring, 150
Dictionaries, for content analysis, 282, 283, 284
Difference scores, 83
differential item function, 186, 451, 452
direct arterial blood pressure monitoring, 350
direct calorimetry, 359
direct nursing practice, 4
direct observation, 16–17, 271
discharge plan compliance, 103–104
discriminant validity, 180, 321
discrimination index, 184
disease-focused model, 440
disease-oriented outcomes, 441
dispersion, 58–60
displacement transducers, 340–341, 342
disproportionate sampling, 215
disseminating research results, 413
distractor response analysis, 186
distractors, in multiple-choice items, 331–332
distributions
asymmetrical, 54
bimodal, 55
flat, 54
frequency, 52–53, 117–118, 215–216
negatively skewed, 55, 57
normal, 54, 55, 57, 119
positively skewed, 55, 57
skewed, 54, 55
statistical principles and procedures, 52–53
symmetrical, 54, 119
distribution shape, 53–56
dna. see deoxyribonucleic acid
documentation, database, 247, 248
domain definition, 129
domain-referenced tests, 124
domain-sampling model, 74–76, 147, 252–253
domain scores, 74–75, 135
doppler cardiography, 352–354
dose of interventions, 440
Double translation, 452, 454–455
DRG algorithm. See Diagnosis related groups algorithm
DxR Clinician (software), 251

ECG. See Electrocardiogram
Edwards Social Desirability Scale, 436
EEG. See Electroencephalogram
EFA. See Exploratory factor analysis
Effectiveness, 417
Efficiency, 417
Electrical noise, 342
Electrical potentials measurement, 344–349
Electrocardiogram (ECG), 344–345, 346, 347
Electroencephalogram (EEG), 347–349
Electrophoresis, 360
ELISA. See Enzyme-linked immunosorbent assay
E-mailed questionnaires, 304, 305, 306, 307–308
Emic concepts, 449
Empirical item-analysis procedures, 192–193
Empirical standard-setting methods, 135
Endotracheal suctioning, 340
Enzyme-linked immunosorbent assay (ELISA), 360
Equity, 417–418

Error of measurement, 70, 71
Error of standards, 157
Errors
  central tendency, 157–158
  chance, 66–67, 146–147, 371
  commission, 378
  constant, 66, 67–69, 146, 371
  logic, 157
  measurement, 65–69, 146–147, 219
  minimizing, 381–382
  omission, 378
  in precision, 380–381
  random, 66–67, 146–147, 371
  response, 288, 295
  similarity, 157
  specification, 439
  systematic, 66, 67–69, 146, 371
  variable, 66–67, 146–147
Error scores, 70–71, 371
Erythema, 375, 377
Esophageal Doppler monitoring, 352–354
Essay tests, 18
Estimated true-change scores, 83–84
Ethical issues, 401–413
  anonymity, 408–409
  confidentiality, 409
  existing instruments, 413
  HIPAA’s implications for measurement and research, 401, 402, 406, 407–408, 412
  human subjects, measurement of, 401–412
  informed consent, 402–405
  Internet data collection, 265
  observational methods, 277–278
  privacy, 401, 402, 406–408, 412
  refusal or withdrawal, 405–406
  risk associated with measurement, 409–411
  risk-benefit ratio, 409, 411
  risk to researchers, 411–412
  scientific and professional community, 412–413
Ethnicity, as data collection category, 243
Ethnography
  focused, 227
  Internet data collection, 264
  logs and field notes in, 275–276
  in qualitative research, 226–227
  sample size, 232
  Etic concepts, 449
  European Committee for Standardization, 373
  Evaluative testing, 455–456
  Evaluative validity, 228
  Event sampling, 274–275
  Evidence-based practice, 438
  “EXCEPT” in multiple-choice item stems, 330
  Exhaustive categories, 51
  Existing data. See Databases
  Existing instruments, 393–398
    advantages, 393
    aims, stated, 394
    conceptual basis for, 395–396
    copyright protection for, 396–397
    cross-cultural measurement, 447–448
    disadvantages, 393
    ethical issues, 413
    evaluating, 394–396
    locating, 393–394
    measurement framework, 394–395
    population, 395
    psychometric properties, 396
    purpose, 394
    reporting use of, 397–398
    setting, 395
    time perspective, 395
    use, 396–397
  Experimental manipulation approach, 168–169
  Experimental methods, 189–190
  Explicating objectives, 91–103, 129
  Exploratory factor analysis (EFA), 169–170
  External reliability, 229
  External validity, 228, 229
  Face validity, 166–167, 427
  Factor analysis, 169–176
    confirmatory, 170–176
    exploratory, 169–170
  Factor loadings, 171
  Factors, 169, 170–171, 175
  Fahrenheit temperature scale, 51
  Fair use, 397
  False-negative criterion-referenced interpretations, 136
  False-positive criterion-referenced interpretations, 136
  Feasibility, in operationalization, 43
  Feasibility criteria, 422
  Feasibility issues, in quality measures, 424–425
  Federal funding guidelines, 230
  Federal Information Processing Standards (FIPS) codes, 246
Fiberoptic pulmonary artery catheters, 356
Field notes, 275–276
Field testing of translated instruments, 456
50th percentile, 56–57
Filter questions, 292, 294, 303
FIPS codes. See Federal Information Processing Standards codes
FISH. See Fluorescence in situ hybridization
Fittingness, 228
Fixed-alternative questions, 291–292, 294
Fixed computer testing, 252–253
Fixed parameters, 172
Flash drives, 343
Flat distributions, 54
Flesch-Kincaid readability index, 452–453
Flow, measurement of, 349–354
Flow-sensing spirometers, 358
Fluorescence in situ hybridization (FISH), 363
Focused ethnography, 227
Focused interviews, 289
Focus groups, 227, 230, 264, 424
Focus group translation, 454
Forced response method, 388
Form equivalence, 149
Forward translation, 454
Free parameters, 172
Frequency domain analysis, 345–346
Frequency polygons, 118
Functional status, 41
Fundamentalist view of measurement rules, 51–52
Funnels, 293
Gases, 354–357
  oxygen saturation, 355–356
  regional carbon dioxide measurement, 356–357
  transcutaneous measurement of, 355
Gas flow measurement, 357–358
Gastric tonometry, 356–357
Generalizability, 229
Generalizability coefficient, 76
Generalizability studies, 77
Generalizability theory, 76–77
Generalization
  universe of, 76
  validity, 179–180
Genetic Information Nondiscrimination Act (GINA), 385
Geographic characteristics, 246
Givens, 133
Glass thermometers, 358–359
Goodness-of-Fit Index, 174
Graphic recorders, 342–344
Graphs, 217
Grounded theory, 9, 226, 232, 264
Grouped frequency distribution, 117–118
Halo error, 157
Hand-scoring, 209
Harmonized Terminology Database, 373
Harris-Benedict equation, 359
Health, defined, 335
Health care quality, 417–418
See also Quality measurement
Health Insurance Portability and Accountability Act (HIPAA)
  administrative simplification standards, 242, 246
  privacy protections, 401, 402, 406, 407–408, 412
Health research, criterion-referenced measures in, 125–126
Healthy People 2020, 242
Heart rate variability analysis, 345–346
Height, measuring, 67
Helium technique, 358
Hemodynamics, 349–354
Heterogeneous items, 132–133
Heterotrait-heteromethod coefficients, 182
Heterotrait-monomethod coefficients, 182
Heywood case, 174
Higher-order factors, 175
HIPAA. See Health Insurance Portability and Accountability Act
Histograms, 53, 118
Holistic triangulation, 461–462
Holter monitors, 343
Homogenous items, 132, 133
Hospital claim codes, 245
Hospital discharge data, 245
Hospitalized patients, and informed consent, 405
HTML, 262
Human Genome Project, 335
Human subjects, measurement of, 401–412
Hypothesis testing, 168–169, 186
Identification, in confirmatory factor analysis, 172–173
Immature concepts, 27
Immunohistochemical staining, 360
Impedance cardiography, 352
Implied covariance matrix, 173
Improper solution, 174
Income, as data collection category, 243, 248
Incremental weights, 158
Indicators
  confirmatory factor analysis, 170–171
  defined, 170
  quality, 418
  reliability of, 173
Indirect arterial blood pressure monitoring, 349–350
Indirect calorimetry, 359
Indirect nursing practice, 4
Indirect observation, 17, 271–272
Individual gain index, 194, 195
Individually identifiable health information, 407
Inductive content analysis, 279, 282–283
Influenza vaccination of nursing home residents, 418–420
Informal tools and methods, 19
Informed consent, 265, 295, 402–405
Infrared spectography, 356
Infrared thermometers, 358
In situ hybridization, 362–363
Index

Institute of Medicine (IOM), 417–418, 420, 423
Institutional Review Boards, 404, 405, 408, 412
Instrument adaptation, in cross-cultural measurement, 448
Instrumentation, 4
Instruments, existing. See Existing instruments
Interests, 11–12
Intergroup comparisons, 218
Interindividual comparisons, 218
Intrajudge agreement, 157–158, 187–189
Internal consistency procedure, 149–151
Internal reliability, 228–229
Internal validity, 228
International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), 243, 244, 245, 247, 248
International Hospital Outcome Study Questionnaire, 49
International Organization for Standardization (ISO), 372–373
International Vocabulary of Metrology, 372
Internet data collection, 259–266
advantages, 259
disadvantages and potential problems, 260
ethical issues, 265
guidelines, 266
informed consent for, 403
qualitative data collection, 264–265
quantitative data collection, 261–264
recruitment of respondents, 260–261
reliability, 265
response rates, 261
sampling issues, 260–261
validity, 265
Interpretive reliability, 282, 283, 284
Interpretive validity, 228
Interrater agreement, 157–158, 187–189
Interrater reliability, 151–152
Interrater agreement procedures, 157–158
Invariance of the measurement model, 175
Invasive biomedical instruments, 337
Investigator triangulation, 460
In vitro biomedical instruments, 337–338
In vivo biomedical instruments, 337
IOM. See Institute of Medicine
Ipsative comparisons, 218, 219
IRT. See Item response theory
ISO. See International Organization for Standardization
Item-analysis procedures
criterion-referenced, 190–197
norm-referenced validity procedures, 183–186
Item attributes, 78
Item bias, 451, 452
Item calibration, in item response theory, 80
Item characteristic curve, 77, 186
Item discrimination, 78, 193–197
Item independence, in item response theory, 78
Item nonresponse, 306
Item-objective congruence, 191–192
Item p level, 183–184, 193, 196
Item pool information function, 80
Item–response charts, 184–186
Item response theory (IRT), 77–81, 253, 256–257
See also Computer adaptive testing
Items
developing, 293–294, 302–304
difficulty of, 107, 115, 183–184, 193, 196
heterogeneous, 132–133
homogenous, 132, 133
norm-referenced measure design, 106–116
objective, 107
selection-type, 107
sequence of, 294, 304
subjective, 107
supply-type, 107
types, 291–293
as unit of analysis in content analysis, 281
See also Questions
Joint Committee for Guides in Metrology, 372
Judgmental standard-setting methods, 135, 136–138
Justice, 402
Just identified models, 173
**Kappa**

- **computation of**, 155
- **defined**, 154
- **interpretation of values**, 159
- as item-discrimination index, 195–196
- maximum possible, 155–156, 196, 375
- for measuring precision and accuracy, 374–375, 377
- weighted, 158–159
- $K_{max}$ (maximum possible kappa), 155–156, 196, 375
- KR 20/KR 21, 149–151
- Kurtosis, 55–56
- $K_W$ (weighted kappa), 158–159

**Labeling subjects**, 410–411

**Lambda**, 171

**Latent content analysis**, 280

**Latent variables**, 170–171

**Leptokurtic curves**, 56

**Literature review**, 35–37, 393–394

**Local norms**, 211

**Logic error**, 157

**Logs**, 275

**Longitudinal studies**, 262, 443

**Machine-scoring**, 209

**Magnetic tape, as data storage device**, 343

**Magnitude estimation scaling (MES)**, 325–327


**Mainstream sampling**, 356

**Manifest variables**, 170–171

**Mantel-Haenszel procedure**, 186

**Mastery-referenced tests**, 124, 127

**Mature concepts**, 27, 29, 35

**Maximum likelihood estimation**, 173

**Maximum performance measures**, 18–19

**Mean**, 57

**Meaning/adequacy, in operationalization**, 43

**Measurement**

- **defined**, 4, 50
- **error of**, 70, 71
- **frameworks**, 6–8
- **risk associated with**, 409–411
- **scales of**, 50–52
- **unit of**, 50, 371

**Measurement errors**, 65–69, 146–147, 219

**Measurement rules**, 50, 51–52

**Measurement terminology standards**, 372–373

**Measure of Goal Attainment Tool**, 7–8

**Measures of central tendency**, 56–58

**Measures of correlation**, 60–65

**Measure specifications**, 31, 32, 418, 420, 423, 426–427

**Measure types**, 8–19
  - **how responses are obtained and scored**, 17–18
  - **type of performance measured**, 18–19
  - **what is measured**, 11–17
  - **who constructs measures**, 19

**Median**, 56–57

**Medical Outcomes Study**, 209

**Member checking**, 233, 276–277

**MES. See** Magnitude estimation scaling

**Mesokurtic curves**, 55–56

**Metabolism measurement**, 359

**Method bias**, 450–452

**Methodological triangulation**, 460–462

**Method variance**, 180

**Metrology**, 371

**Metropolitan statistical area (MSA)**, 246

**Middle-Range Theory of Unpleasant Symptoms**, 37

**Minimal risk**, 409

**Minimum Data Set**, 420

**Minimum detectable interval**, 374

**Missing categories**, 140

**Mixed method approach**, 10–11

**Mixed-method triangulation**, 460–462

**Mode**, 56, 57

**Modification indices**, 174–175

**Molar approach to observation**, 273

**Molecular approach to observation**, 273

**Molecular cloning**, 361–362

**MSA. See** Metropolitan statistical area

**Multi-Dimensional Social Desirability Inventory**, 436–437

**Multi method triangulation**, 460–462

**Multiple Affect Adjective Check List**, 445, 446

**Multiple-choice items**, 329–333
  - **reliability**, 330, 331
  - **writing the options**, 331–332
  - **writing the stem**, 330–331

**Multiple triangulation**, 462

**Multistage cluster sampling**, 212, 214

**Multistage sampling**, 282

**Multistage stratified cluster sampling**, 212, 214

**Multitrait-multimethod triangulation**, 180–183, 461, 462–463

**Mutually exclusive categories**, 51

**Narrative/storytelling**, 227, 232

**Nasogastric tube insertion**, 132

**National Center for Health Statistics**, 242, 246

**National Council Licensure Examination (NCLEX-RN)**, 127, 254–255, 256

**National databases. See** Databases

**National Health Interview Survey**, 242

**National Institute of Nursing Research**, 335–336, 338

**National Institutes of Health (NIH)**, 255, 442

**National norms**, 210–211

**National Nursing Home Survey**, 242

**National Provider Identifier**, 246

**National Quality Forum (NQF)**, 422, 427, 428, 429, 430

**NCLEX-RN. See** National Council Licensure Examination

**Negatively skewed distributions**, 55, 57

**Net gain index**, 194–195

**NIH. See** National Institutes of Health

**No guessing assumption**, 78

**Nominal scales**, 51, 52

**Noncoverage**, 306

**Noninvasive biomedical instruments**, 337

**Nonmaleficence**, 409
Nonparticipant observers, 272
Nonresponse, 306–307
Nonstandardized interviews, 289–290, 291–292, 293, 296, 298
Nonstandardized measures, 204–206
Normal distributions, 54, 55, 57, 119
Normed Fit Index, 174
Norm-referenced measures, 91–123
administration, 105–106
blueprinting, 103–105
constructing, 105–123
criterion-referenced measures versus, 124
defined, 6, 91
described, 6–7
explicating objectives, 91–103
items, 106–116
scoring, 116–123
See also Standardized measures
Norm-referenced reliability procedures, 147–152
internal consistency procedure, 149–151
interrater reliability, 151–152
intrarater reliability, 152
parallel form procedure, 148–149
test–retest procedure, 147–148
Norm-referenced validity procedures, 165–186
content validity, 165–167
criterion-referenced validity, 176–183
item-analysis procedures, 183–186
Norms, 210–218
adequacy of, 217–218
communicating, 217
defined, 210
estimating, 211
local, 211
national, 210–211
norming administration and scoring, 207–208, 215–217
regional, 211
sample size, 215
selecting norming samples, 212–215
selecting standardization sample, 211–212
standards versus, 210
types, 210–211
updating, 217
Northern blotting, 362
NQF. See National Quality Forum
nth percentile, 122
Nucleic acids, 361–364
in situ hybridization, 362–363
molecular cloning, 361–362
Northern blotting, 362
polymerase chain reaction, 362
Southern blotting, 362
Western blotting, 363–364
Numerical rating scales, 319–320
See also Visual analog scales
Nursing concepts overview, 29–31
See also Operationalizing nursing concepts
Nursing home residents, influenza vaccination of, 418–420
Nursing practice, direct versus indirect, 4
Objective items, 107
Objective measures, 17
Objective-referenced tests, 124
Objectives
behavioral, 92–93, 102–103, 165
explicating, 91–103, 129
Observables, 28, 41–43
Observation
direct, 16–17, 271
indirect, 17, 271–272
molar approach to, 273
molecular approach to, 273
participant, 234–235
structured, 16, 275, 277
units of, 273
unstructured, 16, 275–276, 277
Observational methods, 271–278
advantages, 277
described, 16–17
disadvantages, 277
ethical issues, 277–278
event sampling, 274–275
observational approaches, 275–276
observer roles, 272–273
observing and recording, 273
reliability, 276–277
sampling, 273–275
time sampling, 274
validity, 276–277
Observed scores, 70–71, 371
Observed score variance, 71–73
Observed variables, 170–171
Observers
complete, 234
concealment of identity, 272, 277
nonparticipant, 272
participant, 234–235, 272
researchers as, 234–235
roles, 272–273
training of, 276
Ohm’s law, 340, 341, 349
Omission errors, 378
One-parameter logistic model, 78, 80
One-way translation, 454
Open-ended questions, 291–293, 297, 303, 307
Operational definitions, 31, 32, 418, 420, 423, 426–427
Operationalization of concepts, 28–29
Operationalizing nursing concepts, 33–44
developing measurement approaches, 43
developing theoretical definition, 34–40
evaluating theoretical and operational definitions, 43–44
identifying observable indicators, 41–43
overview, 33–34
specifying variable aspects of a concept, 40–41
Ordinal scales, 51, 52
Organizational characteristics/identifiers, 245–246
Oscillographs, 362
Oscillometric (cuff) blood pressure monitoring, 349–350
Oscilloscopes, 342
Outcome criteria, 442
Outcome measures, 420, 425–426, 429, 441–443
See also Process/outcome measurement
Outcomes
clinical, 441–442
defined, 438
disease-oriented, 441
patient-oriented, 441
Outcome variables, 5
Outlining, 38
Overidentified models, 173
Overspecification, 439
Oxygen electrodes, 341, 342, 354
Oxygen saturation, 355–356
Paralingual cues, 280
Parallel form reliability
criterion-referenced, 156–157
norm-referenced, 148–149
Parallel measures model, 74, 75–76
Parameter estimation, in confirmatory factor analysis, 173–174
Parameter types, 172
Parents, as proxies for children, 69
Partially structured interviews, 289
Participant observers, 234–235, 272
Patient care goals, 442
Patient-centered health care, 417
Patient-centered interventions, 439–440
Patient-oriented outcomes, 441
Patient-Reported Outcomes Measurement Information System (PROMIS), 255–256, 257, 442
Patient’s Bill of Rights, 405
Pearson correlations, 378, 380
Pearson product-moment correlation coefficient, 60, 61–64, 148, 151, 152
Percentage of agreement, 148, 154, 159, 195–196, 374–375, 377
Percentage of explained variance, 62
Percentage scores, 121, 135
Percentile ranks, 121–122
Percentiles, 122
Percentile scores, 216
Performance gap, 422
Performance precision, 129
Performance quality, 129
Performance speed, 129
Personal influence theory, 116–117, 168–169
Person attributes, 78
Personnel selection, cut scores for, 190
 Phenomena
 defined, 3–4
 rhythmicity of, 274
Phenomenal sampling, 231
Phenomenology, 226, 232, 264
pH levels, 374, 377
Physical risks, 409–410, 412
Physical traces, 271–272
Physiological measurement
cellular products, 359–360
classification of, 338
described, 17
electrical potentials, 344–349
gases, 354–357
metabolism, 359
nucleic acids, 361–364
pressures, flow, and hemodynamics, 349–354
pulmonary volumes and gas flow, 357–358
temperature, 341, 358–359
See also Biomedical instrumentation
Pilot testing, 295, 423, 452
Platykurtic curves, 56
Polymerase chain reaction, 362
Positively skewed distributions, 55, 57
Pragmatic validity, 285
Pragmatist view of measurement rules, 52
Preamplifiers, 343
Precision
 accuracy versus, 374
defined, 373, 380
maximizing, 382
measuring, 374
measuring error in, 380–381
in operationalization, 43
performance, 129
statistics erroneously reported as measures of, 378, 380
Predictive validity, 176, 178, 285
Preliminary theoretical definitions, 35
Present on admission information, 245
Pressures, measurement of, 349–354
Pressure transducers, 340–341, 342
Pretesting, 145–146, 282–283, 305–306
Pretest/posttest difference index, 194
Pretreatment-posttreatment measures approach, 192, 193
Primary skin lesion classification, 126–127, 140
Privacy, 401, 402, 406–408, 412
Probability sampling, 212, 214–215
Probes, 288, 294
Procedure codes, 243
Process analysis, 280
Process criteria, 440–441
Process measures, 420, 425, 426, 438–441
Process/outcome evaluation, 438
Process/outcome measurement, 437–443
defined, 438
outcome measurement, 441–443
process measurement, 438–441
Process/outcome research, 438
Process variables, 5–6
Products of behavior, 271–272
Professional community, ethical issues related to, 412–413
Professional Standards Review Organization legislation, 438
Profile charts, 219
Profiles, 122–123
PROMIS. See Patient-Reported Outcomes Measurement Information System
Proportion of chance agreements, 154–155
Protected health information, 407, 408, 409
Proxy consent, 404
Proxy respondents, 464–465
Proxy responses, 68–69
Psychological risks, 410, 412
Psychometric testing, 455–456
Psychomotor domain taxonomy, 94, 103
Psychomotor measures, 15
Public Health Data Standards Consortium, 242
Pulmonary artery catheters, 350–352
Pulmonary volumes, 357–358
Pulse oximetry, 355–356
Purposeful samples, 215
Purposeful sampling, 231

Qualitative data collection, 264–265
Qualitative measurement, 4, 9, 10, 443
Qualitative research, 264–265
content analysis, 279, 280, 282–283
data analysis, 235–236
data collection, 232–235
generalizability, 229
hallmarks, 226
interviews in, 233–234, 236, 298–299
overview, 225–227
reliability, 228–229
sample adequacy, 229–232
types, 226–227
validity, 227–228
Quality, performance, 129
Quality control, 228–229
Quality indicators, 418
Quality measurement, 417–430
attribute issues, 428–429
classical measurement theory applied to, 426–427
developing quality measures, 421–425
focus of measurement, 420–421
health care quality, 417–418
informational resources, 430
issues, 425–429
quality measures, 418–420
resources needed for, 429
rigor level, 427–428
what to measure, 425–426

Quality measures
analytical methods, 424
developing, 421–425
feasibility issues, 424–425
focus of measurement, 422–423
measure specifications, 423
overview, 418–420
pilot testing, 423
quality indicators versus, 418
reliability, 423–424, 426–427
scientific acceptability of, 423–424
usability testing, 424
validity, 424, 427
Quantitative data collection, 261–264
Quantitative measurement, 4, 9, 10
Quantitative research, 279, 280, 284
Quartiles, 122
Questionnaires, 301–308
administering, 306–307
advantages, 307–308
computer-administered, 304, 305, 306, 307–308
defined, 301
development procedure, 302–307
disadvantages, 308
distributing, 304–305
drafting, 304–305
information to be sought, 302
pretesting, 305–306
question/item development, 302–304
question/item sequence, 304
review of, 304
scoring, 307
software for, 301–302
Questions
closed-ended, 291–292, 294, 303, 307
developing, 293–294, 302–304
filter, 292, 294, 303
fixed-alternative, 291–292, 294
open-ended, 291–293, 297, 303, 307
semistructured, 291
sequence of, 294, 304
types, 291–293
See also Items
Race, as data collection category, 243
Radioimmunoassays, 360
Random errors, 66–67, 146–147, 371
See also Classical measurement theory
Randomized response technique (RRT), 387–389, 435
Randomly parallel tests, 82
Random probe approach, 455
Random sampling, 274, 282
Range, 58–59
Rasch one-parameter logistic model, 78, 80
Raters, defined, 374
Rating scales, in observational methods, 275
Ratio scales, 51, 52
Raw scores, 135
Reactivity, 272–273, 277
Real-time Internet data collection, 264–265
Recording devices, in observational methods, 272, 277–278
Refusal to participate by subjects, 385, 405–406
Regional carbon dioxide measurement, 356–357
Regional norms, 211
Regression modeling, 424
Related-question method, 387–388
Relative decisions, 76–77
Reliability, 145–161
case volume and, 426
categorical basis for, 147
categorization of, 146
content analysis, 284
criterion-referenced, 153–159
criterion-related validity and, 179
databases, 247–248
defined, 6
described, 19, 20–21
difference scores, 83
Reliability (continued)
  domain-sampling model and, 147
  external, 229
  indicator, 173
  internal, 228–229
  Internet data collection, 265
  interpretive, 282, 283, 284
  interrater, 151–152
  interviews, 296–297, 297–298
  intrarater, 152
  magnitude estimation scaling, 327
  measurement errors and, 146–147
  multiple-choice items, 330, 331
  norm-referenced, 147–152
  observational methods, 276–277
  operational definition and, 426–427
  in operationalization, 43
  pretests and, 145–146
  proxy respondents, 465
  qualitative research, 228–229
  quality measures, 423–424, 426–427
  random errors and, 66–67, 146
  split-half, 298
  state and trait attributes, 445, 446
  statistical definition of, 73–74
  systematic errors and, 146
  test length changes, 152–153
  unitizing, 281–282, 284
  validity and, 69
  visual analog scales, 320–321
See also Test-retest reliability; Validity; specific types of reliability
Reliability diagonal, 181, 183
Reliability index, 73
Research Data Assistance Center (ResDAC), 246
Researchers
  as interviewers, 233–234
  as observers, 234–235
  risk to, 411–412
Research interviews, 296
Residualized change scores, 83
Response attributes, 131
Response error, 288, 295
Response rates, in Internet data collection, 261
Response sets, 433
Rhythmicity of phenomena, 274
Ribonucleic acid (RNA), 361, 362, 364
Right ventricular end-diastolic volume catheters, 351–352
Rigor level, in quality measurement, 427–428
Risk adjustment, 424, 428–429
Risk-benefit ratio, 409, 411
Risks
  defined, 409
  ethical issues, 409–411
  minimal, 409
  physical, 409–410, 412
  psychological, 410, 412
  to researchers, 411–412
RNA. See Ribonucleic acid
RRT. See Randomized response technique
Safety, in health care quality, 417
Sample items, 130
Samples
  adequacy of, 229–232
  cluster, 212–214
  convenience, 215
  criterion-related validity and, 178
  norming, 212–215
  purposeful, 215
  size of, 215, 232, 426
  standardization, 211–212
Sampling
  cross-cultural measurement, 451–452
  demographic, 231
  disproportionate, 215
  event, 274–275
  Internet data collection, 260–261
  mainstream, 356
  multistage, 282
  multistage cluster, 212, 214
  multistage stratified cluster, 212, 214
  observational methods, 273–275
  phenomenal, 231
  plan for, 282
  probability, 213, 214–215
  purposive, 231
  random, 213, 274, 282
  sidestream, 356
  stratified, 212–214
  systematic random, 213, 282
  theoretical, 231
  time, 274
  types, 231
  units, 231–232
Sampling validity, 285
Saturated models, 173
Scale of Egalitarian Sex Role Attitudes (SES-RA-S), 49
Scales, 12–14, 50–52
Scatterplots, 60–62
Scientific community, ethical issues related to, 412–413
Scores
  classes of, 118
  critical, 190
  cut, 134, 135–139, 190
  cutoff, 190
  defined, 374
  derived, 121
  deviation, 59
  difference, 83
  domain, 74–75, 135
  error, 70–71, 371
  estimated true-change, 83–84
  interpretation of, 218–220
  observed, 70–71, 371
  percentile, 216
  raw, 135
  residualized change, 83
  sources of variance in, 81–84
  standard, 119–120, 216
  standardized change, 84
stanine, 216
statistics for determining accuracy, 377–378
summative, 116–117
t, 120–121, 216
ture, 70–71, 371
universe, 76
Z, 120–121, 216
Score variance, 81
Scoring
criterion-referenced measure design, 133–134
dichotomous, 150
norm-referenced measure design, 116–123
questionnaires, 307
standardized measures, 209–210
visual analog scales, 320
Secondary data, 241–242
See also Databases
Second-order factors structure, 175
Selection-type items, 107
Self-care, 91–92, 126
Self-determination, 403, 404–405
Self-reported data, 298
Self-report measures, 12
Semantic differential scales, 13–14
Semantic validity, 284–285
Semistructured questions, 291
Sensitive information
collection issues, 385–386
collection strategies and techniques, 386–389
privacy and, 406
questionnaire distribution and, 305
social desirability and, 433–437
Sensitivity, defined, 373–374
Sequential model, 440
Sets, 433
Setting, 297, 395
Sidestream sampling, 356
Signal averaged electrocardiography, 347
Similarity error, 157
Skewed distributions, 54, 55
Skilled nursing facility residents, influenza vaccination of, 418–420
Skinfold measurements, 375
Social desirability, 433–437
defined, 433
in interviews, 294
measures of, 435–437
minimizing socially desirable responses, 434–435
questionnaires and, 304
Software, for questionnaires, 301–302
Source language, 448
Southern blotting, 362
Spearman–Brown formula, 152–153
Specification errors, 439
Specimens, 374
Spectral karyotyping, 363
Sphygmomanometers, 17
Spirometers, 357–358
Split-half reliability, 298
Stability, coefficient of, 148
Standard deviation, 59, 60, 119–120
Standard error of measurement, 71
Standardized change scores, 84
Standardized interviews, 288–289, 291, 293, 296, 298
Standardized measures, 203–222
administration, 207–209
constructing, 206–207
defined, 19, 203–204
nonstandardized measures versus, 204–206
norms, 210–218
score interpretation, 218–220
scoring, 209–210
selecting, 220–221
using, 221
See also Norm-referenced measures
Standardized Root Mean Squared Residual, 174
Standardized tests, 7
Standard Occupational Classification codes, 243
Standards
criterion-referenced scoring, 134, 135–139
error of, 157
measurement terminology, 372–373
norms versus, 210
results interpretation, 134–139
Standard scores, 119–120, 216
Standard-setting methods
combination, 135, 138
empirical, 135
judgmental, 135, 136–138
Standards for Educational and Psychological Testing, 163–164
Standards-referenced assessment, 124
Stanine scores, 216
State attributes
defined, 443
described, 444–445
implications for measurement, 445–446
interpreting measurements, 446
State models, 134
Statham placement transducers, 340–341, 350
Statistical definition of reliability, 73–74
Statistical definition of unreliability, 73
Statistical principles and procedures, 52–65
dispersion, 58–60
distribution, 52–53
distribution shape, 53–56
measures of central tendency, 56–58
measures of correlation, 60–65
Statistical regression modeling, 424
Statistics
for determining score accuracy, 377–378
erroneously reported as measures of precision and accuracy, 378, 380
Stimulus, 340
Stimulus attributes, 130–131
Storytelling, 227, 232
Stow–Severinghaus–type electrodes, 354–355
Stratification, 424
Stratified sampling, 212, 214
Stress of Discharge Assessment Tool (SDAT-2), 6
Structural equation modeling, 171–172
Structured interviews, 288–289, 291, 293, 296, 298
Structured observation, 16, 275, 277
Structure measures, 420
Structure-process-outcome framework, 420, 425, 440
Students, and informed consent, 405
Subjective items, 107
Subjective measures, 17–18
Subjects
  animals as, 340
  biomedical instrumentation measurement schema, 340
  human, 401–412
  issues in collecting sensitive information, 385–386
  labeling, 410–411
  refusal to participate by, 385, 405–406
Sublingual capnometry, 357
Subobjectives, 130
Summated rating scales, 13
Summative scores, 116–117
Supply-type items, 107
Symmetrical distributions, 54, 119
Symmetrical translation, 452
Symmetrical weights, 158
Synchronous communication, 264–265
Systematic errors, 66, 67–69, 146, 371
Systematic random sampling, 282
Tables, 117–118, 217
Tape-recording equipment, 234
Target language, 448
Target population, 178
Tau-equivalent measure, 172
Taxonomies
  affective domain, 94
  Bloom’s taxonomy of the cognitive domain, 93–94, 103
  defined, 93
  psychomotor domain, 94, 103
  use in explicating and measuring objectives, 102–103
Technical error of measurement, 381
Telehealth initiatives, 338
Telephone interviews, 290–291, 297
Temperature measurement, 341, 358–359
Test calibration, in item response theory, 80
Test conditions, 82
Test information function, in item response theory, 80
Test-retest reliability
  criterion-referenced procedures, 153–156
  interviews, 297–298
  magnitude estimation scaling, 327
  norm-referenced procedures, 147–148
  visual analog scales, 320–321
Tests
  analysis-of-variance, 167–168
  aptitude, 19
  defined, 374
  diagnostic, 19
  domain-referenced, 124
  essay, 18
  evaluative, 455–456
  length of, 115–116, 129, 152–153
  mastery-referenced, 124, 127
  objective-referenced, 124
  psychometric, 455–456
  randomly parallel, 82
  restrictions and givens, 133
  specifications preparation, 129–133
  standardized, 7
  t, 167–168
  usability, 424
Themes, in content analysis, 281
Theoretical definitions
  defined, 31
  described, 31–32
  developing, 34–40
  evaluating, 43–44
  literature review and, 35–37
  mapping meaning, 37–39
  preliminary, 35
  stating, 39–40
Theoretical rationale, 3
Theoretical sampling, 231
Theoretical triangulation, 460
Theoretical validity, 228
Theories
  concepts in, 27–28
  defined, 3
See also specific theories
Theory-based measures, 3–6
Thermal pens, 343
Thermistors, 341, 358
Thoracic fluid measurement, 352
Three-parameter logistic model, 78, 80
Time domain analysis, 345
Timeliness, in health care quality, 417
Time perspective, for existing instruments, 395
Time restrictions, 133
Time sampling, 274
Traditional Chinese medicine, 316
Trait attributes
  defined, 443
  described, 443–444
  implications for measurement, 445–446
  interpreting measurements, 446
Trait variance, 180
Transcription of interviews, 236
Transcutaneous measurement of gases, 355
Transducers, 340–342, 350
Transferability, 228, 229, 447
Translation
  approaches, 452–454
  asymmetrical, 452
  in cross-cultural measurement, 448, 451
  decentered, 452, 454
  double, 452, 454–455
  focus group, 454
  forward, 454
  methodologies, 454–455
  one-way, 454
  symmetrical, 452
  unicentered, 452
Translation by committee, 454
Translators, in interviews, 233
Triangulation, 458–464
   across-method, 461–462
   analysis of data from, 462–463
   between-method, 461–462
   contextual, 461–462
data, 276, 459–460
data-analysis, 462
defined, 11, 458
holistic, 461–462
investigator, 460
methodological, 460–462
mixed-method, 460–462
multi method, 460–462
multiple, 462
multitrait-multimethod, 180–183, 461, 462–463
in observational methods, 276
principles, 459
theoretical, 460
types, 459–462
within-method, 461
True scores, 70–71, 371
t-rule, 173
t scores, 120–121, 216
t test, 167–168
Two-parameter logistic model, 78, 80
Two-sample approach, 388
Typical performance measures, 19
Underidentified models, 173
Underspecification, 439
Ungrouped frequency distribution, 117
Uncentered translation, 452
Unidimensionality, in item response theory, 78
Uninstructed-instructed group difference index, 194, 195
Uninstructed-instructed groups approach, 192–193
Unitizing reliability, 281–282, 284
Unit nonresponse, 306–307
Unit normal curve, 120–121
Unit of analysis, 50, 281–282
Unit of measurement, 50, 371
Units of observation, 273
Universe of content, 281
Universe of generalization, 76
Universe score, 76
Unobserved variables, 170–171
Unrelated-question method, 388
Unreliability, 72, 146
See also Reliability
Unstructured interviews, 289–290, 291–292, 293, 296, 298
Unstructured observation, 16, 275–276, 277
Usability criteria, 422
Usability testing, 424
Utility, in operationalization, 43–44
Vaginal pH levels, 374, 377
Validity, 163–197
   assessment by content specialists, 187
   concurrent, 176, 177–178
   content, 140, 165–167, 187–189
   content analysis, 284–285
   convergent, 180, 181
   criterion-referenced, 176–183, 186–197
   cross-cultural measurement, 447–448
   databases, 248–249
data-related, 284
dependence, 189–190
defined, 6, 163
described, 19–11
descriptive, 228
discriminant, 180, 321
descriptive, 228
evidence types, 163–164
evaluation, 228
external, 228, 229
facets, 166–167, 427
internal, 228
Internet data collection, 265
interpretive, 228
interviews, 292, 298–299
magnitude estimation scaling, 327
measurement errors and, 146–147
norm-referenced, 165–186
observational methods, 276–277
in operationalization, 44
pragmatic, 285
predictive, 176, 178, 285
pretests and, 145–146
proxy respondents, 464–465
qualitative research, 227–228
quality measures, 424, 427
random errors and, 146–147
reliability and, 69
sampling, 285
semantic, 284–285
state and trait attributes, 446
systematic error and, 67–69
theoretical, 228
visual analog scales, 321
See also Construct validity; Reliability; specific types of validity
Validity coefficient, 173
Validity diagonals, 181, 183
Validity generalization, 179–180
Values, 12
Variable errors, 66–67, 146–147, 371
Variables
   defined, 4
   latent, 170–171
   manifest, 170–171
   observed, 170–171
   outcome, 5
   process, 5–6
   unobserved, 170–171
Variance
   dispersion and, 59–60
   method, 180
   in norm-referenced measures, 7
   observed score, 71–73
   percentage of explained, 62
Variance (continued)
    score, 81
    trait, 180
Variance ratio, 73
VAS. See Visual analog scales
Vectors, 361–362
Videotaping, 234, 235
Virtual focus groups, 264
Visual analog scales (VAS), 319–322
    administration, 320
    advantages, 320, 321–322
    constructing, 320
    defined, 319
    disadvantages, 322
    reliability, 320–321
    scoring, 320
    uses, 319, 322
    validity, 321
Voice recording, of interviews, 297
Voltage change measurement, 340–341, 345
Waveform changes, 352–353
Weighted kappa ($K_w$), 158–159
Western blotting, 363–364
Withdrawal, from research study, 405–406
Within-method triangulation, 461
Zip code information, 246
Z scores, 120–121, 216