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Abstract

Background

Validity is about the logic, meaningfulness, and evidence used to defend inferences made when interpreting results. Substruction is a heuristic or process that visually represent the hierarchical structure between theory and measures.

Purpose
To describe substruction as a method for assessing the toretical validity of research measures.

Methods
Using Fawcett's Conceptual-Theoretical-Empirical Structure. an exemplar is presented of substruction from the Individual and Family Self-Management Theory to the Striving to be strong study concepts and empirical measures.

Results
Substruction tables display evidence supporting theoretical validity of the instruments used in the study.

Conclusion
A high degree of congruence between theory and measure is critical to support the validity of the theory and to support attributions made about moderating, mediating, causal relationships, and intervention effects.

A primary purpose of nursing and healthcare research is the improvement of patient care and clinical outcomes. Results of studies focusing on the effectiveness of health behavior change provide evidence that interventions based on theory are more effective than atheoretical interventions (**Davis, Campbell, Hildon, Hobbs, & Michie, 2015**; **Glanz, 2017**; **Glanz & Bishop, 2010**). Theory provides the logical foundation for developing interventions and designing research to test the effectiveness of these interventions. Theory specifies key constructs and concepts to be studied and provides the logic linking the essential concepts to their respective measures. The theoretical validity is an indicator of the conceptual linkages of measures to theoretical concepts. High theoretical validity of measures is required to accurately interpret study results. However, there is widespread evidence that despite the emerging information about the importance of theory, the majority of published studies provide little evidence establishing a link between theory and the design, intervention, and measures (**Davis et al., 2015**; **Prestwich et al., 2014**).

Substruction is a strategy or heuristic that conceptually links a theory to research. Substruction tables are tools that aid researchers, educators, and clinicians to quickly visualize and comprehend the logic of the relationships among abstract theoretical constructs, practice-specific concepts, and the empirical (clinical) measures (**Dulock & Holzemer, 1991**; **Gibbs, 1972**; **Hinshaw, 1979**; **McQuiston & Campbell, 1997**; **Wolf & Heinzer, 1999**). Published examples of substruction provide evidence of its use as a process that makes transparent the logical underpinning of a theory to an intervention (**Bekhet & Zausziewski, 2008**; **Trego, 2009**) and as an educational tool to develop critical conceptual skills required to link theory to research (**Dulock & Holzemer, 1991**). **Fawcett (2013)** proposed extending use of substruction to aid researchers and clinicians to provide estimates of the theoretical validity of measures. Measures highly related to theory have high measurement validity and result in an increased confidence in judging the utility of the theory and the generalizability of study results.

This article focuses on the theoretical validity of measurs. Substruction tables are used as a tool linking theoretical concepts to measures. This linkage enables researchers and clinicians to evaluate the theoretical validity of measures for individual studies. In this article specific attention is paid to the quality of the linkage between theoretical concepts, how concepts are operationalized or measured, and how substruction tables can be used to evaluate the theoretical validity of measures. In responding to numerous requests received from researchers, educators, and clinicians, we provide examples of substruction charts. The substruction charts presented have been included in funded applications and in publications. Examples demonstrate how engaging in the substruction process supports the development of checklists and tools used to manage active studies and

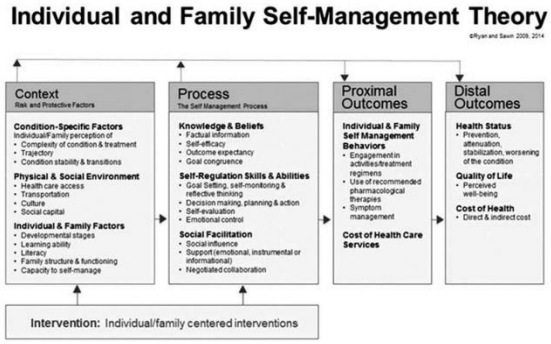
clinical programs, enhances team communication and decision-making, and supports development and use of study data bases.

Conceptual Framework and Background

Theoretical measurement validity is determined by evaluating the relationships between theory and measures—using the conceptual process of substruction. The Conceptual-Theoretical-Empirical (C-T-E) structure provides the framework that links the conceptual model constructs (C) with concepts from theory (T), and links the theoretical concepts to empirical (E) measures (**Fawcett, 1999**). The C-T-E structure outlines the relationship between abstract, theoretical ideas proposed in conceptual models, and theories to the measures chosen to represent these ideas. Abstract concepts are translated from generalized thinking into concrete, observable, and clinically meaningful measures. The C-T-E structure presents a three-tiered hierarchy approach to the relationship of theory to measurement. The conceptual level (C) consists of the most abstract information, containing constructs identified in conceptual models and some mid-range theories. The theoretical level (T) includes more specific concepts, often concepts familiar to practice settings. The C-T-E structure outlines the proposed connections among the constructs, concepts, and empirical (E) measures. Validation of theory propositions in research depends on using the concrete empirical measures that accurately represent the abstract ideas of the theory. The greater the congruence is between concepts and measures, the greater the theoretical validity of measures. A high degree of congruence between theory and measurement is critical to testing the validity of the theory. High congruence is a prerequisite to making attribution about how the theoretical concepts relate to moderation, mediation, or causation of outcomes of interest.

Some mid-range theories are more abstract than others and may include both constructs (conceptual level) and concepts (theoretical level). For example, in the mid-range Individual and Family Self-Management Theory (IFSMT), the conceptual level is represented by a number of abstract constructs organized within larger domains, or dimensions (**Ryan, 2009**; **Ryan & Sawin, 2009**) (**Figure 1**). Within each dimension, there are several abstract constructs. For example, in the process dimension, there are three abstract constructs condition-specific knowledge and beliefs, self-regulation skills and abilities, and social facilitation. Each construct has related concepts (theoretical level) that provide more detail about the construct and are more accessible to practice and for measurement (**Figure 1**). The empirical level (E) contains measurable indicators or concrete information which can be measured by observation, self-report, or by analysis of biologic samples. Measures or indicators, also termed "empirical referents," are designed to collect clinically appropriate data. Measures are chosen to be congruent with the definition and meaning embedded within the theoretical concepts—a characteristic referred to as "theoretical validity of measures" (**Adcock & Collier, 2001**; **Fawcett, 2013**; **Goodhue, 1998**).

Figure 1. Individual and family self-management theory.



The goal is to select measures with high theoretical validity relative to the constructs and concepts being studied. For example, the IFSMT states "the concepts of adherence, alliance, and compliance are perceived

contrary to self-management as they dismiss the notion that the primary responsibility and control lies with the individual or family" (**Ryan & Sawin, 2009**, p 225.e6). Inclusion of a measure of compliance in a study based in the IFSMT would have low theoretical validity as the concept of compliance is not congruent with the theory. Likewise, in the IFSMT, self-management is defined as a process people use to manage symptoms or to change a health behavior. Hence measures of actual engagement in the process need to be obtained. In this example, the number of steps walked daily would have greater theoretical validity of measures than a measure of intention to exercise.

Theoretical Validity of Measures

Validity is about logic, meaningfulness, and the ability to defend inferences made when interpreting results. Validity is defined as "the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests" (**American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999**, p.9). Traditional measures of validity (content, criterion, and construct) are no longer considered to be different types of validity but rather unique ways of obtaining evidence about validity (**Goodwin, 2002**). The inclusion of theoretical validity of measures requires researchers to demonstrate the linkages between theory and measures (empirical referents) by displaying the logical rationale for choosing each specific empirical measure, and requires researchers to interpret findings from the perspectives of theory.

The first step in determining theoretical validity of measures requires cognitive, discriminatory judgment resulting in an evaluation of the congruence among the constructs (conceptual level), concepts (theoretical level), and the measures (empirical level). The goal of the first step is to achieve clarity in the conceptual, theoretical, and operational definitions of the terms used for the three levels of abstraction. In the preparatory phase of a study, efforts to enhance validity depend on the judgment of persons with knowledge and expertise in the theory and familiarity with measures. These experts should deliberately evaluate the meaningfulness of the measure and the strength of the linkages from the theory to the measure. Once the active phase (data collection phase) of the study is completed, study results need to be analyzed and interpreted from the perspective of the theory: its constructs and concepts and their relationship to findings (**Adcock & Collier, 2001**). Similarly, evaluation of the effectiveness of clinical programs requires the use of clinically meaningful measures of the theoretical concepts underpinning the program.

Substruction

Scholars and researchers, practitioners, and students use substruction as a heuristic, or tool (**Wolf & Heinzer, 1999**), to illustrate the logical underpinnings of a study. Substruction tables make transparent the preliminary steps in determining theoretical validity of measures. This display makes visible the journey in the researcher's logic. The table links the abstract conceptual underpinnings of the research and clinical intervention program to the concepts to be measured by empirical indicators and collected as study/programatic data (**Bekhet & Zausziewski, 2008**; **Dulock & Holzemer, 1991**; **Hinshaw, 1979**; **McQuiston & Campbell, 1997**). Understanding and using substruction is a critical skill for persons aspiring to participate in the planning, conduct, and use of research. The value of substruction tables may go unrecognized because the content and the logic of the table appear intuitive. When done correctly, the substruction process results in a simple, concise, and clear description of the logical underpinnings of the research and the relationship between theoretical concepts and empirical variables. Despite the apparent simplicity of substruction tables, their preparation requires considerable knowledge about the research topic, relevant theories, and the mechanisms of research.

To represent the hierarchy of abstraction, substruction tables present the deductive process from the abstract to the concrete in a format of representing the layers of abstraction of the C-T-E structure: theory constructs, theory concepts, empirical measures, and description of measures. The table can be formatted to read from top

to bottom or left to right; the principle of progressing from the abstract to the concrete remains the same regardless of the vertical or horizontal orientation of the table. Abstract constructs are located first, and less abstract concepts are clustered under the parent concept and located second. Measurement tools or instruments are third, and information data format and specifications follow.

Substruction is a process similar to processes already used by researchers and practitioners. For example, consider the construct of body composition. Body composition is an abstract, complex, physical attribute that can be measured in a number of ways. Clinically body composition is commonly measured by calculating the relationship between height and weight, two physical concepts that are less abstract than the construct of body composition. Height and weight can be determined by using self-reported information, using data obtained from the health record, or by actual measurement using reliable and valid measures of height and weight such as stadiaometer and calibrated scale. This example demonstrates the abstract-to-concrete hierarchy of moving from the abstract construct of body composition to the less abstract concepts of height and weight. While height and weight are accepted clinical measures of body composition, increasingly accurate measures of body composition can also be determined (**Wells & Fewtrell, 2006**). Familiarity with the meaningfulness of the measure to the theoretical concept enables one to judge the theoretical validity of the measure.

Method: An Example of Substruction

The substruction approach provided a useful mechanism for preparing Striving to be Strong (StbS); a 12-month repeated measure randomized controlled trial (R01NR013913-01). This three-group study tested the effectiveness a smartphone app to enhance health behavior changes related to osteoporosis prevention. The study and the app were developed on the concepts of the IFSMT to enhance health behavior change, specifically calcium intake and exercise behaviors for osteoporosis prevention. Measures of process and outcome were selected to be theoretically congruent with the concepts of the IFSMT through the process of substruction. The substruction approach provided a useful mechanism for planning that ensured the theory-measure congruence to support the theoretical validity of measures. This exemplar of the use of substruction contains a brief description of the mid-range theory (IFSMT) and a table demonstrating one way of integrating information from the substruction process. This table expands on a commonly accepted method of presenting information about individual measures in study proposals, grant applications, and reports.

Individual and Family Self-Management Theory

The IFSMT (**Ryan, 2009**; **Ryan & Sawin, 2009**, **2014**) is a predictive mid-range theory containing three dimensions; context, process, and outcome. The theory purports that self-management takes place in the context of risk and protective factors specific to the condition, physical and social environment, and individual and family. The process dimension focuses on the behaviors used to initiate and maintain a health behavior change. These self-management behaviors are influenced by (a) knowledge and health beliefs, (b) self-regulation skills and abilities, and (c) social facilitation. Knowledge is the factual information about a specific condition, and beliefs include self-efficacy and goal congruence. Self-regulation includes the active processes of managing behaviors and consists of goal setting, self-monitoring and reflective thinking, decision-making, planning and action, self-evaluation, and emotional control. Social facilitation focuses on social influence, support, and collaboration with one's healthcare providers. Outcomes are both proximal and distal. Proximal outcomes focus on engagement in self-management behaviors which lead to distal (direct) outcomes or changes in the health condition. More detailed information is available in the online manuscript (**Ryan, 2009**, 2012) eliminate 2012 add 2018, including definitions of constructs and concepts, and the theoretical assumption for this mid-range theory.

The theory purports that the context dimensions have a direct effect on the process dimension, and that together context and process affect both the proximal and distal outcomes (with proximal outcomes having a

direct effect on distal outcomes). Intervention directly affects the context and the process, and it is through this direct effect that intervention affects the proximal and distal outcomes.

Summary of Striving to Be Strong Study Design

Applying the IRSMT to the StbS study, the Striving app used in the experimental group was designed to enhance knowledge and beliefs related to osteoporosis prevention, increase skills to self-regulate health behaviors of calcium and vitamin D, increase exercise and activity, improve balance, strengthen communication ability with healthcare providers, and understand monitoring and engagement in treatment modalities if and when necessary. It was hypothesized that women participating in StbS would have more positive health outcomes (i.e., bone density) than women in the other groups

Substruction Table Development

For the purposes of this article **Table 1** displays the C-T-E structure of the IFSMT-based StbS study, formatted in a horizontal (left to right) table to demonstrate the relationships of levels of abstraction, 1-3. The process dimension as presented in **Table 1** will be discussed in detail. The major constructs of the process dimension include the constructs of condition-specific knowledge and beliefs, self-regulation, and social facilitation. **Table 1** displays relationships between the theory construct, the theory concepts included in the study, and study measures, linking the foundational logic for the study to the theoretical validity of the measures. The first column contains the abstract constructs which are linked to the more concrete concepts to be investigated in the second column, characteristic of the data collected by these measures. The third column lists the measures, and the fourth column describes measures in detail.

The IFSMT proposes process is a major dimension of the self-management of health behavior change. Self-regulation is an abstract construct defined as an iterative process people engage in to achieve a change in health behaviors. Self-regulation contains less abstract concepts, including goal setting, self-monitoring, and so on. In this study, the Index of Self-Regulation (**Yeom et al., 2011**), Self-Management of Health Behavior Change Scale (**Brown & Author, 2013**), and app time use were the empirical measures of self-regulation, self-management, and engagement used to measure the components of the self-regulation process (**Table 1**). These constructs and concepts were taken directly from the theory and measures consistent with the definitions of the constructs used. Using the process of substruction, we are able to demonstrate the logic of the study and the congruence between the theory (constructs and concepts) and measures in all four dimensions of the IFSMT.

TABLE 1. Exemplar of Use of the Substruction Approach to Demonstrate the Relationship of Theory, Constructs, Concepts to Study Measures

Individual and Family Self-Management Theory			
Context: Risk and Protective Factors			
Construct	Concept	Empirical Indicator	Description
Individual and Family Factors	Socio-demographic characteristics	*All About You*	9 items: age, race/ethnicity, marital/living arrangement status, menopausal status (**Dennerstein, Lehert, Burger, & Guthrie, 2007**; **Harlow et al., 2007**; **Sowers et al., 2003**), Hollingshead Four-factor Index (Socio-economic status, occupation/education) (**Hollingshead, 2011**); risk

			for fracture (Henry et al., 2011; Kanis, 2011; World Health Organization Collaborating Centre for Metabolic Bone Disease, 2010).
Literacy	Health literacy	*REALM-R*	An eight-word test designed to identify persons with low health literacy. Administered in less than 2 minutes. Correlated with wide range of educational achievement tests including grade level (0.64) and Cronbach's α of 0.91 (Bass, Wilson, & Griffith, 2003).
	Computer literacy	*e-Heals*	An eight-items measure of knowledge, comfort, and skills using electronic health information. Cronbach's α = 0.88. Test-retest reliability stable (*r* = 0.68–0.40). Single factor solution (56% of variance) (Norman & Skinner, 2006).
		Surveying the Digital Future	A 22-items measure of perceived helpfulness and confidence finding and using health information on Internet: sub-categories include evaluate use of Internet for health (2 items), evaluate experience (2), assess experience (9), identify actions taken (5). Last 5 questions yes/no, 13 questions 5-choice response set ranging from strongly disagree to strongly agree. Question used as part of regularly conducted national survey (Ybarra & Suman, 2008).
	Capacity to self-manage	(PAM): Short Form	13 items assess knowledge, skill, and confidence for engagement in health behaviors. Interval level, unidimensional, Gutterman-like measure using a 0–100 scale (short scale remains reliable and valid) (Hibbard, Mahoney, Stockard, & Tusler, 2005; Hibbard, Stockard, Mahoney, & Tusler, 2004).
Processes: Self-management Processes			
Condition-Specific Knowledge	Osteoporosis and osteoporosis prevention	*Facts on Osteoporosis Quiz*	30 item true/false. Completion time 5 minutes. Content validity index .92, Cronbach's α was 0.90 general population and 0.84 in midlife women (Pande et al., 2000). Includes questions related to calcium from Osteoporosis Knowledge Test (Kim, Horan, Gendler, & Patel, 1991).
Beliefs	Self-efficacy	*Calcium and Physical Activity Self-Efficacy*	21-item visual analogue scale, including items about calcium (10 questions) and exercise (11 questions). Cronbach's α was 0.90 (Horan, Kim, Gendler, Froman, & Patel, 1998).
	Goal Congruence	*Goal Congruence: Calcium and Physical Activity*	20-item linear rating scale, measure of the extent of conflict among competing goals: calcium (10 items) with adaptation for exercise (10 items). Cronbach's α was 0.92–0.94 in women 40–60 years of age (Ryan, 2006).
Self-regulation	Activity self-regulation	*Index of Self-Regulation*	9 item measure of self-regulation of physical activity; response set 1 = strongly disagree to 6 = strongly agree.

			Cronbach's α = 91 (range 81–96) (Yeom, Choi, Belyea, & Fleury, 2011).
	Self-management	*Self-Management of Health Behavior Change*	Total of 16 items Newly developed general measure of the processes of behavior. 16 items with scores ranging from 1, not true for me to 5 very true for me (Brown & Author, 2013).
	Engagement in self-regulation process	*Utilization of App*	Time in minutes spent using app total, by month, by section.
Social facilitation	Support	*ENRICH*	7-item linear rating scale. Cronbach's α 0.86. High correlation with longer measures. Tested with midlife women
			Response set (1–5) ranging from none of the time to all of the time (Mitchell et al., 2003).
	Social influence	*Survey of Usual Care*	11 items. Frequency and percentage of each item. Questionnaire: 11 items, yes/no response set. Questions focus on additional care woman received from her healthcare provider related to osteoporosis prevention during the 12-month study period.
	Social Connectedness	*Connection to Other Study Participants*	Measure of connectedness to other women in study; 2 questions plus visual diagram measuring number of people you know in study and level of connectedness. Developed for study.
Proximal Outcomes: Engagement in Self-managements Behavior			
Behavior specific: engagement in self-regulation processes		*Ecological Momentary Assessments*	Self-reported assessments of self-regulation for the four health behaviors: calcium, balance, strength, and physical activity. yes/no response for seven behaviors. 248 notifications sent per cell phone over 12 months. Developed for study.
	General calcium intake Vitamin D intake	*3-day Food Diary Supplement*	21-item 3-day food diary containing calcium-rich foods. Adapted by Author. Dietary and supplement sub-totals. IU of Vitamin D in supplement and multi-vitamin questions 3-day food diary Adapted by author from Angus, Sambrook, Pocock, & Eisman, 1989; Blalock, Norton, Patel, Cabral, & Thomas, 2003; Block et al., 1986; Hertzler & Frary, 1994; Ryan, 2006.
	Physical Activity	6-*Minute Walk Test*	Performance test, measure of exercise capacity. Distance person walked over 6 minutes is measured in inches. Sensitive to change with exercise programs (Casanova et al., 2011).
		Physical Activity: Self-Assessment	Physical Activity Questionnaire is and internationally accepted 7-day self-report of time and intensity of 29 physical activities for which MET-minutes are calculated

			and totals are categorized for sedentary, low, medium, vigorous, and overall levels of activity (Hallal & Victoria, 2004).
		Stand Test	Researcher collected measure of core and leg strength. Time it takes to stand from and return to sitting position 10 times. Measured in seconds (Csuka & McCarty, 1985).
		Functional Movement Screen	Researcher collected performance test consisting of 4 activities from the Functional Movement Screen. Video-taped and scored by certified evaluator. Measure of balance and strength. Newly used in middle-aged healthy, nonathletic women (Beardsley & Contreras, 2014; Kraus, Schuetz, Taylor, & Doyscher, 2014).
		Balance	Researcher collected performance test: 4–45 second tests progressing from eyes open to closed; 2 feet on ground to one foot on ground. Sensitive to change resulting from exercise programs (Springer, Marin, Cyhan, Roberts, & Gill, 2007)
Distal Outcomes: Health Outcomes			
Long-term Outcomes	Bone Density	*DXA Trabecular Bone Score*	Measure of Bone Density. Sites measured include lower spine and hips. "A decrease of 1 SD in BMD represents a 10%–12% decrease in BMD and an increase in fracture risk by a factor of 1.5–2.6" (Picard et al., 2004)
		Body Composition	Using DXA-based technology measure of percent Fat/Fat lbs., Lean lbs., Fat free, Android, Gynoid, and A/G ratio (Wells & Fewtrell, 2006).
		FRAX	Fracture Risk Assessment: 10-year risk of hip fracture: includes gender, race, age, family history, medication history, prior fracture, and includes information from bone density obtain via DXA (Henry et al., 2011)
	Vitamin D	*Serum Vitamin D*	Serum D3, finger stick with serum saved to "Blood Spot Card" with special filter paper. Laboratory analysis via ZRT of Oregon, USA.

Note. BMD = bone mineral density; DXA = dual-energy x-ray absorptiometry; FRAX = Fracture Risk Assessment Tool; IU = international unit; MET = metabolic equivalent of time; PAM = Patient Activation Measure.

Value of Substruction Tables to the Research Process

Acquiring the knowledge and skills to develop substruction tables is a preliminary skill for novice researchers and practitioners developing clinical programs for care delivery (Goodhue, 1998). It enables these individuals to clearly articulate the logic of the study or clinical program, enhance decision-making, and defend their decisions related to design, intervention development or choice, and selection of measures.

Adaptation of the formative substruction table provides experienced researchers and clinicians with the foundation helpful to create a breadth of tools used in the conduct of a study or implementation of a program, management of data collection, building analytic databases, planning and conducting analysis, and dissemination of findings. For example, information from our substruction table was used as the organizing the framework for presentation of measures in our original funding application (Ryan, 2012). The major constructs from the IFSMT theory were used as organizational headings, concepts provided subheadings, and specific

descriptions of each measure were presented along with description of the measure, including information critical to an analytic database (e.g., level data, number and type items, and collection times).

Our substruction table was a valuable organizing tool during the research process for development of checklists to assist in the development of electronic measures, to monitor participant completion of measures, and to organize our analytic database. Information taken directly from the substruction table served as a communication and teaching tool. In the STBS study, we relied on simple versions of our substruction table when collaborating with the information technology members of our research team. Using these tools communicates clearly and precisely the organizational structure needed when developing systems to collect and report data obtained for all measures. The Striving App was developed to mirror the theoretical concepts so that the major sections in the intervention app directly corresponded to the concepts of the process dimension of the theory. When difficult decisions needed to be made during the operationalization of the study (e.g., adjustments in time line, budget constraints) we turned to the logic of the study and the potential impact of the decision to the purpose of the study and the organizing framework. Essentially, the substruction process contained the critical, essential information used in planning, conduct, analysis, and dissemination of results.

Results: Evaluation of Theoretical Validity

Assessing the theoretical validity of study measures by using substruction provided evidence that, for this study, the measures had theoretical validity and use of all measures could be justified. Measuring all of the concepts provided us with data to evaluate the utility of the theoretical concepts and their proposed relationship, in addition to analysis of hypothesis and research questions. The substruction process proved to be pragmatic as it provides a quick guide to select measures and made visible the link to the conceptual outline of the study. The chart enabled us initially to quickly determine whether or not a tool had been obtained and at the end of the study served as a reference for planned analysis.

This exemplar provided a schema of a predictive mid-range theory that purports that engagement in self-management processes resulted in changing and maintaining health behaviors. The figure provided a visual display of the constructs, their related concepts, and information about the measurement tools. Comparing **Figure 1** with **Table 1** provided evidence that the constructs and concepts identified in the conceptual model have been measured in this study. Concepts have been measured with at least one instrument. Inclusion and measurement of concepts strengthened one's judgment that the key components of the theory were used and were represented in this study—indicating the study adequately represented the theory. The information in **Table 1** also provided evidence that measurements of the concepts “fit with” or that there was a high degree of congruence between the theoretical concepts and the measures—providing evidence of a high level of theoretical validity of measures.

In this study, linking the selection of measures directly to theoretical concepts enabled us to limit our selection of measures, to justify or provide the logic for the measures included or excluded, and to have a comprehensive template to aid in planning and collecting data and communicating results. Our theory provided the framework or logic for what needed to be measured and interpretation of findings.

Discussion

Researchers benefit directly from engaging in the substruction process. Creating tables requires the researcher to reflect on the assumptions of the theory of choice and the implication of these assumptions to the research questions, eligibility criteria, measures, procedure, and planned analysis. Decisions must be made about which concepts will be manipulated and which will be held constant and the congruence of that decision with the theory. Many theories, including many mid-range theories, contain more variables than can be measured in any single study. Should all theoretical concepts be included? If not, what are the potential outcomes of including or

excluding them? Abstract constructs and the more clinically relevant concepts must be understood. Concepts must be operationally defined with respect to the current study and measures with high theoeretical validity selected. The intervention being tested must be congruent with the theory and reflect the major theoretical beliefs and assumptions. Research proposals and manuscripts reporting study results need to express the congruence between theory and research.

The application of research finding to clinical nursing practice is advantaged by clinician's having the skills and abilities to interpret substruction tables. Substruction tables quickly and simply aid the clinician to identify major concepts, the instruments included in a study, and the results. These tables can help clinicians think about clinical phenomenon from a more abstract perspective and to use this information to develop clinical programs and to contribute to enhancement of clinical delivery systems.

The expansion of criteria or expectations for explicit consideration of theoretical validity of measures requires that the congruence between theory and measures be evaluated for all studies. Researchers need to make available the information consumers and reviewers of research need to judge the congruence between the theory and measures. Likewise attributions about the helpfulness of a theory to understanding a clinical phenomenon require a high degree of congruence of the measures to the theory. Substruction is a tool that results in a table visually displaying the “theoretical blocks,” “links,” and “measures” that are the logical building blocks of a study or practice protocol. It provides a simple explanation of how measures are related to the theory—hence validating or providing evidence that measures are directly connected to the theory.

At times researchers and clinicians elect to merge constructs from two theories (**Campbell et al., 2007**). Use of a substruction table enables the researcher to demonstrate the proposed relationship between the mid-range theories. Expanding this table enables researcher to maintain the logical foundation for the study while maintaining conceptual clarity as they merge theories for use under differing conditions and circumstances. It allows researchers and clinicians to make explicit the different origins and new relationships of the concepts, measures, and outcomes being measured. For example, Author and colleagues (**Weiss, Yakusheva, & Bobay, 2019**) demonstrated the integration a quality and a transition theory to provide the theoretical framework for studies of readiness for hospital discharge. They propose that the merger of these mid-range theories provide a more comprehensive understanding of the complexity of patients' experiences and requirements for care delivery systems (**Table 2**).

Making explicit the links between the theoretical constructs and measures enhances theory testing as it provides a visual display to determine which concepts have been included in studies and which have not—a finding often not available when only positive findings of statistically significant differences between groups are reported. Combining the findings across studies will provide the empirical data needed to identify the key theoretical constructs and concepts and to discard or modify concepts that fail to make a significant contribution. Evaluation across populations will contribute to identification of the differential effects of the theory across population, conditions, and outcomes.

It has been proposed that substruction is foundational to theoretical validity of measures, with an invitation extended by Fawcett to researchers to advance the process of substruction (**Fawcett, 2013**). To this end, substruction has been discussed from a number of perspectives in the literature, including a number of studies ranging from learned resourcefulness (**Bekhet & Zausziewski, 2008**), military attitudes toward menstrual suppression (**Trego, 2009**), chronic pain (**Dunn, 2004**), self-care agency (**McQuiston & Campbell, 1997**), social support and health (**Dulock & Holzemer, 1991**), and weight management (**Pickett, Peters, & Jarosz, 2014**).

TABLE 2. Exemplar of Integration of Two Mid-Range Theories (**Ryan, Weiss, Traxel, & Brondino, 2011**)

Meleis' Transitions Theory				
Nature of Transition	Transition Conditions	Nursing Therapeutics		Patterns of Response
		Donabedian's Quality Model		
		Structure	Process	Outcome
Patient level control variables	Patient and unit level control variables	Nurse Staffing	Discharge Readiness Assessment	Postdischarge Outcomes
Measures				
PATIENT APR-DRG with severity and mortality indices, and type of admission (medical/surgical), discharge disposition (home, home with home health), length of stay, ICU stay, Payor.	*PATIENT Age* Sex Race/ethnicity Living alone Prior hospitalization	*UNIT* RN HPPD Skill mix (%RN, %BSN) RN experience	*NURSE* RN-RHDS NDAG *PATIENT* PT-RHDS	*PATIENT* Emergency (ED) visits Hospital Readmission
		Cost Measures		
	UNIT Unit size Discharge Model of Care	Costs associated with nurse staffing variables		ED and readmission costs and net revenue/loss

Note. APR-DRG = all patients refined diagnosis related group; BSN = Bachelor of Science in Nursing; ED = emergency department; ICU = intensive care unit; RN = registered nurse; RN HPPD = registered nurse hours per patient day; RN-RHDS = Registered Nurse-Readiness for Hospital Discharge Survey; NDAG = Nurse Discharge Action Guide; PT-RHDS = Patient – Readiness for Hospital Discharge Scale.

Including the thoughts and opinions of persons from lay advisory boards who serve as consultants to research can be a powerful mechanism to identifying the extent to which persons actually experiencing a condition or testing an intervention identify with the meaningfulness of the measures used to measure efficacy and effectiveness. In addition, study participants need to be queried poststudy about their experience as participants and their perceptions of the meaningfulness of measures to them.

Relevance for Practice, Education, and Research

Research

Substruction tables provide an excellent tool for seasoned researchers to quickly and systematically inform reviewers, readers, and members of their research team of the foundational building blocks for the study and the logic of relationships between the theoretical basis for the study and the measures selected. The substruction process has been supported for use in both quantitative and qualitative studies (**Adcock & Collier, 2001**; **Dulock & Holzemer, 1991**; **Wolf & Heinzer, 1999**).

Using substruction can provide evidence for the need to develop new measures congruent with the theoretical framework (**Fawcett, 2013**; **Goodhue, 1998**). Preparing to conduct a new study provides an opportunity to consider the development and testing of new measures. Coupling the testing of new measures to high theoretical measurement validity to the collection of established measures can be advantageous to evaluating

both the established and the new measure and result in theory-specific measures and enhanced measurement validity.

There are situations in which knowledge development requires the use of measures that may not be congruent with the mid-range theory foundational to the study. For example, in order to create a body of knowledge about a construct such as self-management, researchers want to develop a collection of standardized measures and tools common to the phenomenon of self-management to evaluate the effectiveness of different theories, interventions, or treatments used across different conditions and different populations. Current standards for National Institutes of Health/National Institute of Nursing Research funded studies recommend the collection of Common Data Elements to be used across all self-management studies (and other phenomena) to build data repositories (**Moore et al., 2016**). Core data elements currently recommended for self-management studies have been selected, in part, because they reflect examples of common concepts across theories—supporting the critical importance of theoretical validity of measures.

Education: Formal and Experiential

Substruction can be used as an educational tool providing direction to students and novice researchers to reach a higher level of conceptual clarity by schematically laying out the mid-range theory that provides the logic for the study matched with the measures used to assess participant outcomes and experiences. Educators have found that assignments which include the critical thinking skills required to create substruction tables enable students to gain the confidence necessary to defend their projects both in writing and verbally (**Dulock & Holzemer, 1991**; **Wolf & Heinzer, 1999**).

The substruction process can assist students and novice researchers in building programs of research which contribute to knowledge development within their discipline (**Feetham & Doering, 2015**). Most mid-range theories contain more constructs than can reasonably be tested in any single study. Substruction tables enable students and novice researchers to thoughtfully select those constructs and concepts that build the foundation on which to plan and conduct more advanced studies. Thoughtfully and sequentially across studies, researchers can include information from the substruction table to identify how to add to and complement their program of research, including activities and studies designed to test theory, the efficacy and efficiency of interventions, and conceptually valid measures.

Practice

Substruction-based tables help to “demystify” research, which increases the usability of the findings for clinical practice. Making visible the logic of a study and the relationship among the study components gives practitioners a tool to understand the meaning of research and the potential applicability of the findings of a study to clinical practice. These tables help practitioners put all the pieces together, providing a method to quickly evaluate the applicability of measures to clinical practice. Substruction tables assists clinicians' engagement with the integration of findings into evidence-based practice protocols by providing categories common across studies, a tool that would assist practitioners in evidence-based practice reviews. Likewise, use of the substruction process can be useful in the development of new clinical program initiatives based on theory.

Conclusion

Substruction is a critical thinking skill helpful to researchers, educators, and practitioners. The substruction process assures attention to design of research and selection of measures to assure that the theoretical conceptualization is translated into the reality of intervention and measurement. Tables resulting from the substruction process are easily integrated into research applications and reports, and in synthesis of information for evidence-based practice reviews and clinical practice protocols.

References

Adcock, R., & Collier, D. (2001). Measurement validity: A shared standard for qualitative and quantitative research. *The American Political Science Review*, 95(3), 529–546. doi:10.1017/S0003055401003100

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (1999). *Standards for educational and psychological testing*. Washington, DC.

Angus, R. M., Sambrook, P. N., Pocock, N. A., & Eisman, J. A. (1989). A simple method for assessing calcium intake in Caucasian women. *Journal of the American Dietetic Association*, 89(2), 209–214.

Bass, P. F., Wilson, J. F., & Griffith, C. H. (2003). A shortened instrument for literacy screening. *Journal of General Internal Medicine*, 18(12), 1036–1038.

Beardsley, C., & Contreras, B. (2014). The functional movement screen: A review. *Strength and Conditioning Journal*, 36(5), 72–80. doi:10.1519/SSC.0000000000000074

Bekhet, A. K., & Zausziewski, J. A. (2008). Theoretical substruction illustrated by the theory of learned resourcefulness. *Research and Theory for Nursing Practice: An International Journal*, 22(3), 205–214. doi:10.1891/0889-7182.22.3.205

Blalock, S. J., Norton, L. L., Patel, R. A., Cabral, K., & Thomas, C. L. (2003). Development and assessment of a short instrument for assessing dietary intakes of calcium and vitamin D. *Journal of the American Pharmacists Association: JAPhA*, 43(6), 685–693.

Block, G., Hartman, A. M., Dresser, C. M., Carroll, M. D., Gannon, J., & Gardner, L. (1986). A data-based approach to diet questionnaire design and testing. *American Journal of Epidemiology*, 124(3), 453–469.

Brown, M. E., & Author, P. (2013). *Self-management of health behavior change: Instrument development*. Unpublished manuscript, College of Nursing, University of Wisconsin-Milwaukee, Milwaukee, WI.

Casanova, C., Celli, B. R., Barria, P., Casas, A., Cote, C., de Torres, J. P., … Aguirre-Jaime, A. (2011). The 6-min walk distance in health subjects: Reference standards from seven countries. *European Respiratory Journal*, 37(1), 150–156.

Campbell, N. C., Murray, E., Darbyshire, J., Emery, J., Farmer, A., Griffiths, F., … Kinmonth, A. L. (2007). Designing and evaluating complex interventions to improve health care. *British Medical Journal*, 334, 455–459. doi:10.1136/bmj.39108.379965.BE

Csuka, M., & McCarty, D. J. (1985). Simple method for measurement of lower-extremity muscle strength. *American Journal of Medicine*, 78(1), 77–81. doi:10.1016/0002-9343(85)90465-6

Davis, R., Campbell, R., Hildon, Z., Hobbs, L., & Michie, S. (2015). Theories of behavior and behavior change across the social and behavioral sciences: A scoping review. *Health Psychology Review*, 9(3), 323–3344. doi:10.1080/17437199.2014.941722

Dennerstein, L., Lehert, P., Burger, H. G., & Guthrie, J. R. (2007). New findings from non-linear longitudinal modelling of menopausal hormone changes. *Human Reproduction Update*, 13(6), 551–557. doi:10.1093/humupd/dmm022

Dulock, H. L., & Holzemer, W. L. (1991). Substruction: Improving the linkage from theory to method. *Nursing Science Quarterly*, 4(2), 83–87. doi:10.1177/089431849100400209

Dunn, K. S. (2004). Toward a middle-range theory of adaptation to chronic pain. *Nursing Science Quarterly*, 17(1), 78–84. doi:10.1177/0894318403260474

Fawcett, J. (1999). *Relationship of theory and research* (3rd ed.). Philadelphia, PA.

Fawcett, J. (2013). Thoughts about conceptual models and measurement validity. *Nursing Science Quarterly*, 26(2), 189–191. doi:10.1177/0894318413477143

Feetham, S., & Doering, J. J. (2015). Career cartography: A conceptualization of career development to advance health and policy. *Journal of Nursing Scholarship*, 47(1), 70–77. doi:10.1111/jnu.12103

Gibbs, J. (1972). *Sociological theory construction*. Hinsdale, IL

Glanz, K. (2017). Chapter 2: Social & behavioral theories. *e-Source Social and Behavioral Theories*. Retrieved from **www.esourceresearch.org**

Glanz, K., & Bishop, D. B. (2010). The role of behavioral science theory in development and implementation of public health interventions. *Annual Review of Public Health*, 31, 399–418. doi:10.1146/annurev.publhealth.012809.103604

Goodhue, D. L. (1998). Development and measurement validity of a task-technology fit instrument for user evaluations of information systems. *Decision Science*, 29(1), 105–138. doi:10.1111/j.1540-5915.1998.tb01346.x

Goodwin, L. D. (2002). Changing conception of measurement validity: An update on the new standards. *Journal of Nursing Education*, 41(3), 100–106.

Hallal, P. C., & Victoria, C. G. (2004). Reliability and validity of International Physical Activity Questionnaire (IPAQ). *Med Sci Sports Exercise*, 36(556), 1381–1395. doi:10.1249/01.M550000078924.61435.FB

Hinshaw, A. S. (1979). Theoretical substruction: An assessment process. *Western Journal of Nursing Research*, 1(3), 3019–3024.

Harlow, S. D., Crawford, S., Dennerstein, L., Burger, H. G., Mitchell, E. S., Sowers, M. F., & Re, S. C. (2007). Recommendations from a multi-study evaluation of proposed criteria for staging reproductive aging. *Climacteric: The Journal of the International Menopause Society*, 10(2), 112–119. doi:10.1080/13697130701258838

Henry, M. J., Pasco, J. A., Merriman, E. N., Zhang, Y., Sanders, K. M., Kotowicz, M. A., & Nicholson, G. C. (2011). Fracture risk score and absolute risk of fracture. *Radiology*, 259(2), 495–501. doi:10.1148/radiol.10101406

Hertzler, A. A., & Frary, R. B. (1994). A dietary calcium rapid assessment method (RAM). *Top Clinical Nutrition*, 9(3), 76–85.

Hibbard, J., Stockard, J., Mahoney, E., & Tusler, M. (2004). Development of the Patient Activation Measure (PAM): Conceptualizing and measuring activation in patients and consumers. *Health Services Research*, 39(4), 1005–1026.

Hibbard, J. H., Mahoney, E. R., Stockard, J., & Tusler, M. (2005). Development and testing of a short form of the patient activation measure. *Health Services Research*, 40(6), 1918–1930. doi:10.1111/j.1475-6773.2005.00438.x

Hollingshead, A. B. (2011). Four factor index of social status. *Yale Journal of Sociology*, 8, 21–53.

Horan, M. L., Kim, K. K., Gendler, P., Froman, R. D., & Patel, M. D. (1998). Development and evaluation of the osteoporosis self-efficacy scale. *Research in Nursing & Health*, 21(5), 395–403.

Kanis, J. A. (2011). Welcome to FRAX. Retrieved from **http://www.shef.ac.uk/FRAX/**

Kim, K. K., Horan, M. L., Gendler, P., & Patel, M. K. (1991). Development and evaluation of the Osteoporosis Health Belief Scale. *Research in Nursing & Health*, 14(2), 155–163. doi:10.1002/nur.4770140210

Kraus, K., Schuetz, E., Taylor, W. R., & Doyscher, R. (2014). Efficacy of the functional movement screen: A review. *Journal of Strength and Conditioning Research*, 28(12), 3571–3584.

McQuiston, C. M., & Campbell, J. C. (1997). Theoretical substruction: A guide for theory testing research. *Nursing Science Quarterly*, 10(3), 117–123.

Mitchell, P. H., Powell, L., Blumenthal, J., Norten, J., Ironson, G., Pitula, C. R., … Berkman, L. F. (2003). A short social support measure for patients recovering from myocardial infarction: The ENRICHD Social Support Inventory. *Journal of Cardiopulmonary Rehabilitation*, 23(6), 398–403.

Moore, S. M., Schiffman, R., Waldrop-Valverde, D., Redeker, N. S., McCloskey, D. J., Kim, M. T., … Grady, P. (2016). Recommendations of common data elements to advance the science of self-management of chronic conditions. *Journal of Nursing Scholarship*, 48(5), 437–447. doi:10.1111/jnu.12233

Norman, C. D., & Skinner, H. A. (2006). eHEALS: The eHealth literacy scale. *Journal of Medical Internet Research*, 8(4), e27. doi:10.2196/jmir.8.4.e27

Pande, K. C., DeTakats, D., Kandis, J. A., Edwards, V., Slade, P., & McCloskey, E. V. (2000). Development of a questionnaire (OPQ) to assess patient's knowledge about osteoporosis. *Maturitas*, 237, 75–81.

Pickett, S., Peters, R. M., & Jarosz, P. A. (2014). Toward a middle-range theory of weight management. *Nursing Science Quarterly*, 27(3), 242–247. doi:10.1177/0894318414534486

Picard, D., Brown, J. P., Rosenthall, L., Couturier, M., Levesque, J., Dumont, M., … Dodin, S. (2004). Ability of peripheral DXA measurement to diagnose osteoporosis as assessed by central DXA measurement. *Journal of Clinical Densitometry: The Official Journal of the International Society for Clinical Densitometry*, 7(1), 111–118.

Prestwich, A., Sniehotta, F. F., Whittington, G., Dombrowski, S. U., Rogers, L., & Michie, S. (2014). Does theory influence the effectiveness of health behavior interventions? Meta-analysis. *Health Psychology*, 33(5), 465–474. doi:10.1037/a0032853

Ryan, P. (2006). Tailored Computerized Intervention for Behavior Change, 1R15NR00 9021-01A2. In (Vol. 1R15NR00 9021-01A2).

Ryan, P. (2009). Integrated theory of health behavior change: Background and intervention development. *Clinical Nurse Specialist*, 23(3), 161–170; quiz 171–172. doi:10.1097/NUR.0b013e3181a42373

Ryan, P., Weiss, M., Traxel, N., & Brondino, M. (2011). Testing the integrated theory of health behaviour change for postpartum weight management. *Journal of Advanced Nursing*, 67(9), 2047–2059. doi:10.1111/j.1365-2648.2011.05648.x

Ryan, P., Papanek, P., Csuka, M. E., Brown, M. E., Hopkins, S., Lynch, S., Scheer, V., Schlidt, A., Yan, K., Simpson, P., Hoffman, R., & Striving to be Strong Team. 2018. Background and method of the Striving to be Strong study: A RCT testing the efficacy of a m-health self-management intervention. Contemporary Clinical Trial. doi.org/10.1016/j.cct.2018.06.006.

Ryan, P., & Sawin, K. J. (2009). The individual and family self-management theory: Background and perspectives on context, process, and outcomes. *Nursing Outlook*, 57(4), 217–225.e216. doi:10.1016/j.outlook.2008.10.004

Ryan, P., & Sawin, K. (2014). *Individual and family self-management theory (Revised figure)*. Retrieved from **http://www4.uwm.edu/nursing/about/centers-institute/self-management/theory/cfm**

Sowers, M. F. R., Greendale, G. A., Bondarenko, I., Finkelstein, J. S., Cauley, J. A., Neer, R. M., & Ettinger, B. (2003). Endogenous hormones and bone turnover markers in pre- and perimenopausal women: SWAN. *Osteoporosis Iternational: A Journal Established as Result of Cooperation Between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA*, 14(3), 191–197. doi:10.1007/s00198-002-1329-4

Springer, B. A., Marin, R., Cyhan, T., Roberts, H., & Gill, N. W. (2007). Normative values for the unipedal stance test with eyes open and closed. *Journal of Geriatric Physical Therapy (2001)*, 30(1), 8–15.

Trego, L. L. (2009). Theoretical substruction: Establishing links between theory and measurement of military women's attitudes towards menstrual suppression during military operations. *Journal of Advanced Nursing*, 65(7), 1548–1558. doi:10.1111/j.1365-2648.2009.05010

Weiss, M., Yakusheva, O., & Bobay, K. L. (2011). Quality and cost analysis of nurse staffing, discharge preparation, and postdischarge utilization. *Health Services Research*, 46(5), 1473–1494. doi:10.1111/j.1475-6773.2011.01267.x

Weiss, M. E., Yakusheva, O., & Bobay, K. L. (2011). Quality and cost analysis of nurse staffing, discharge preparation, and postdischarge utilization. *Health Services Research*, 46(5), 1473–1494. doi:10.1111/j.1475-6773.2011.01267.x

Weiss, M. E., Yakusheva, O., Bobay, K. B., Costa, L., Hughes, R. G., Nuccio, S., Hamilton, M., Bahr, S., Siclovan, D., & Bang, J. (2019). Effect of a discharge readiness assessment on return to hospital in adult medical-

surgical patients: The READI randomized clinical trial. *JAMA Network Open*, (2), e187387. doi:10:1001/Jamanetworkopen.2018.7387

Wells, J. C. K., & Fewtrell, M. S. (2006). Measuring body composition. *Archives Disease in Childhood*, 91, 612–617. doi:10.1136/adc.2005.085522

Wolf, Z. R., & Heinzer, M. M. (1999). Substruction: Illustrating the connections from research question to analysis. *Journal of Professional Nursing*, 15(1), 33–37. doi:10.1016/S8755-7223(99)80023-4

World Health Organization Collaborating Centre for Metabolic Bone Disease. (2010). FRAX WHO Fracture Risk Assessment Tool. Retrieved from **http://www.shef.ac.uk/FRAX/tool.jsp?locationValue=9**

Yeom, H. A., Choi, M., Belyea, M., & Fleury, J. (2011). Psychometric evaluation of the index of self-regulation. *Western Journal of Nursing Research*, 33(2), 268–285. doi:10.1177/0193945910378854

Ybarra, M. L., & Suman, M. (2008). Reasons, assessments and actions taken: Sex and age differences in uses of Internet health information. *Health Education Research*, 23(3), 512–521. doi:10.1093/her/cyl062

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