Digital Module 02: Scale Reliability in Structural Equation Models

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Available in the ITEMS portal at https://ncme.elevate.commpartners.com

Module Overview

In this ITEMS module we frame the topic of scale reliability within a *confirmatory factor analysis* and *structural equation modeling* (SEM) context and address some of the limitations of Cronbach's α. This modeling approach has two major advantages: (1) it allows researchers to make explicit the relation between their items and the latent variables representing the constructs those items intend to measure, and (2) it facilitates a more principled and formal practice of scale reliability evaluation. Specifically, we begin the module by discussing key conceptual and statistical foundations of the *classical test theory* (CTT) model and then framing it within an SEM context; we do so first with a single item and then expand this approach to a multi-item scale. This allows us to set the stage for presenting different measurement structures that might underlie a scale and, more importantly, for assessing and comparing those structures formally within the SEM context. We then make explicit the connection between measurement model parameters and different measures of reliability, emphasizing the challenges and benefits of key measures while ultimately endorsing the flexible McDonald's ω over Cronbach's α. We then demonstrate how to estimate key measures in both a commercial software program (*Mplus*) and three packages within an open-source environment (*R*). In closing, we make recommendations for practitioners about best practices in reliability estimation based on the ideas presented in the module.

Key words: scale reliability; structural equation modeling; Cronbach's α; McDonald's ω

Prerequisite Knowledge

This ITEMS module assumes that readers have had some exposure to basic principles of CTT and reliability even though we provide a brief treatment of such concepts specifically within the SEM framework. Specifically, we assume that learners are familiar with the basic definitions of:

- true scores and error scores
- reliability
- Cronbach's α

Specific prior computational experience with specifying structural models in *Mplus* or *R*, while helpful in working through examples, is not critical as we provide instructional scaffolds throughout.

Learning Objectives

Upon completion of this ITEMS module, learners should be able to:

A. Conceptual Understanding

- Express a unidimensional scale graphically as a structural model
- Express parallel, tau-equivalent, and congeneric structures within an SEM framework
- Express the assumptions of Cronbach's α in terms of a structural model
- Determine, for any given unidimensional scale, which parameters would have to be estimated for a parallel model, tau-equivalent model, and congeneric model

B. Working with Software

- Specify a unidimensional congeneric model within the SEM framework
- Compute the necessary summary statistics to obtain the traditional estimate of Cronbach's α
- Compute an estimate of Cronbach's α using parameter estimates from SEM output
- Compute an estimate of McDonald's ω using parameter estimates from SEM output
- Compute a 95% confidence interval for McDonald's ω using the asymptotic standard error (software permitting) from SEM output
- Compute a 95% bootstrap confidence interval for McDonald's ω (software permitting) from SEM output
- Conduct absolute model-data fit evaluations using suitable indices (e.g., SRMR, RMSEA, CFI) for parallel, tau-equivalent, and congeneric models from SEM output
- Conduct relative model-data fit comparisons among the parallel, tau-equivalent, and congeneric models using information criteria (e.g., AIC, BIC) as well as χ^2 difference tests from SEM output

After completion of this module, learners might take additional ITEMS modules on CTT, generalizability theory, validity, item response theory, bi-factor models. Check the NCME or ITEMS Portal webpages for up-to-date information on ITEMS modules!

Module Structure

The module is divided into the following sections, which can be reviewed sequentially or independently [*approximate completion times in parentheses*].

- Module Introduction [*5 Minutes*]
- Section 1: Sneak Peek [*10 Minutes*]
- Section 2: Issues [*25 Minutes*]
- Section 3: Practice [*20 Minutes*]
- Section 4: Quizzes [*15 Minutes*]
- Section 5: Refreshers [*50 Minutes*]
- Section 6: Shiny R App [*30 Minutes*]

Module Components

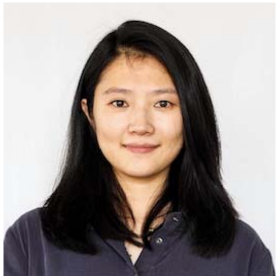
This ITEMS module includes the following components, which are delivered within a unified design shell created with modern course development software:

- integrated content slides that provide a structured walk-through of the content and computational examples with suitable voice-over or video components;
- simulated sample data that are used for worked examples throughout the module;
- Mplus code for estimating McDonald's ω for different data structures as well as simulating data for different measurement models;
- R code for estimating McDonald's ω for different data structures in three packages [MBESS (Kelley, 2015), semTools (Pornprasertmanit, Miller, Schoemann, & Rosseel, 2013), and coefficientalpha (Zhang & Yuan, 2015)] as well as simulating data for different measurement models;
- Shiny R application for specifying basic measurement models and inspecting basic model-data fit and reliability indices;
- a didactic overview article on the key concepts discussed in the module;
- self-assessment questions with diagnostic feedback covering the conceptual, computational, and modeling aspects of the module;
- performance-based exercises that require data manipulation and interpretation with video walk-throughs;
- a glossary of key terms used in the module;
- a small library of online resources that have been vetted for general scientific accuracy and instructional utility.

Additional materials may be added over time so check back periodically!

Module Developers

Gregory R. Hancock Gregory R. Hancock is Professor, Distinguished Scholar-Teacher, and Director of the *Measurement, Statistics and Evaluation* program in the *Department of Human Development and Quantitative Methodology* at the University of Maryland, College Park, and Director of the *Center for Integrated Latent Variable Research* (CILVR). His research interests include structural equation modeling and latent growth models, and the use of latent variables in (quasi)experimental design. His research has appeared in a wide variety of prestigious peer-reviewed journals. He also co-edited the volumes *Structural Equation Modeling: A Second Course* (2006; 2013), *The Reviewer's Guide to Quantitative Methods in the Social Sciences* (2010), and *Advances in Longitudinal Methods in the Social and Behavioral Sciences* (2012). He has taught dozens of methodological workshops in the United States, Canada, and outside North America and has received the 2011 *Jacob Cohen Award for Distinguished Contributions to Teaching and Mentoring* by the APA.



Ji An is a Ph.D. candidate in the *Measurement, Statistics and Evaluation* program in the *Department of Human Development and Quantitative Methodology* at the University of Maryland, College Park. Her research interests include propensity score methods, analysis of survey data with complex sampling designs, structural equation modeling, and multilevel modeling. Before her time at College Park she had earned an M.A. in Teaching and Curriculum from Michigan State University. She has subsequently worked as an instructor for introductory courses in educational statistics and as a graduate assistant for various courses at the undergraduate and graduate level.

Associate Editor / Lead Portal Developer

André A. Rupp is a Research Director at the Educational Testing Service (ETS) in Princeton, New Jersey. He is the co-author and co-editor of two award-winning interdisciplinary books entitled *Diagnostic Measurement: Theory, Methods, and Applications* (2010) and *The Handbook of Cognition and Assessment: Frameworks, Methodologies, and Applications* (2016). His research synthesis- and framework-oriented work has appeared in a wide variety of prestigious peer-reviewed journals. Among other things, he is passionate about improving processes for interdisciplinary collaborations during the development and implementation of scoring solutions for digitally-delivered assessments. Consequently, he is very excited to serve a three-year term as the associate editor / lead instructional designer of the emerging ITEMS portal for NCME that will provide various digital resources for members to support self-directed learning and professional development.

This is the pre-peer reviewed version of the following article:

Hancock, G., & An, J. (2018). Digital ITEMS module 02: Scale reliability in structural equation modeling. Educational Measurement: Issues and Practice, 37(2), 73-74.

It has been published in final form at https://doi.org/10.1111/emip.12210. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Use of Self-Archived Versions.
