

# PSYCHOMETRICS: FROM PRACTICE TO THEORY AND BACK

*15 Years of Nonparametric Multidimensional IRT,  
DIF/Test Equity, and Skills Diagnostic Assessment*

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Dedication: I want to dedicate this paper to my wife, Barbara Meihoefer, who was lost to illness in this year of my presidency. For, in addition to all the wonderful things she meant to me personally and the enormous support she gave concerning my career, she truly enjoyed and greatly appreciated my psychometric colleagues and indeed found psychometrics an important and fascinating intellectual endeavor, in particular finding the skills diagnosis area exciting and important: She often took time from her career as a business manager and entrepreneur to attend psychometric meetings with me and to discuss research projects with my colleagues and me. She would have enjoyed this paper.—William Stout

### Abstract

The paper surveys 15 years of progress in three psychometric research areas: latent dimensionality structure, test fairness, and skills diagnosis of educational tests. It is proposed that one effective model for selecting and carrying out research is to choose one's research questions from practical challenges facing educational testing, then bring to bear sophisticated probability modeling and statistical analyses to solve these questions, and finally to make effectiveness of the research answers in meeting the educational testing challenges be the ultimate criterion for judging the value of the research. The problem-solving power and the joy of working with a dedicated, focused, and collegial group of colleagues is emphasized. Finally, it is suggested that the summative assessment testing paradigm that has driven test measurement research for over half a century is giving way to a new paradigm that in addition embraces skills level formative assessment, opening up a plethora of challenging, exciting, and societally important research problems for psychometricians.

Key words: nonparametric IRT, NIRT, latent unidimensionality, latent multidimensionality, essential unidimensionality, monotone locally independent unidimensional IRT model, MLI1, item pair conditional covariances, DIMTEST, HCA/CCPROX, DETECT, CONCOV, Mokken scaling, generalized compensatory model, approximate simple structure, DIF, differential item functioning, differential bundle functioning DBF, valid subtest, multidimensional model for DIF, MMD, SIBTEST, MultiSIB, Mantel-Haenszel, PolySIB, CrossingSIB, skills diagnosis, formative assessment, Unified Model, reparameterized Bayes Unified Model, MCMC, evidence centered design, ECD, PSAT Score Report Plus.

## 1. Introduction

### 2. Nonparametric Latent Structure Assessment

*2.1. Unidimensionality from the Weak LI Conditional Covariance Perspective*

*2.2. Foundational Issues Facilitated by Infinite Test Length Unidimensional MLI1 Modeling*

*2.3. Interpreting Conditional Covariances Geometrically  
to Assess Latent Multidimensional Structure*

*2.4. NIRT-Based Statistical Procedures, Emphasizing Conditional Covariances*

FIGURE 1.

Projection of item discrimination vectors onto  $V_{\theta_T}$  hyperplane for a six item three-dimensional approximate sample structure.

### 3. Test Fairness

*3.1. Multidimensional Model for DIF (MMD)*

*3.2. Model-Based Parameterization of the amount of DIF in Various Settings*

*3.3. MMD- Inspired DIF Statistical Procedures*

FIGURE 2.

Comparison of  $\Theta_F$  and  $\Theta_R$  distribution with  $\Theta_F|X_V = k$  and  $\Theta_R|X_V = k$  distributions.

*3.4. Implementation of DIF/DBF Procedures*

FIGURE 3.

Item discrimination vectors of a 22 item validity sector.

### 4. Formative Assessment Skills Diagnosis: A New Test Paradigm

*4.1. A Brief Survey of Psychometric Skills Diagnostic Models*

*4.2. The Unified Model and Generalizations Making it Useful*

*4.3. Application of the Unified Model to PSAT Data*

*4.4. Skills Diagnosis: The New Paradigm?*

### 5. Dimensionality, Equity, and Diagnostic Software

### 6. Concluding Remarks

FIGURE 4.  
Panel index versus bundle DBF  $\hat{\beta}$ /item.

FIGURE 5.  
North Carolina End-of-Grade Math Skills Test Subscores.

FIGURE 6.  
PSAT Score Report *Plus* Skills Mastery Reporting.

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