# Contents

Preface	xvi
Acknowledgments	xxi
About the Author	xii

### Section I: Introduction

Chapter 1 Structural Equation Modeling: The Basics	
Key Concepts	3
What Is Structural Equation Modeling?	
Basic Concepts	4
Latent versus Observed Variables	4
Exogenous versus Endogenous Latent Variables	5
The Factor Analytic Model	5
The Full Latent Variable Model	7
General Purpose and Process of Statistical Modeling	7
The General Structural Equation Model	9
Symbol Notation	9
The Path Diagram	10
Structural Equations	11
Nonvisible Components of a Model	12
Basic Composition	13
The Formulation of Covariance and Mean Structures	14
Notes	15
Chapter 2 Using the Amos Program	16
Key Concepts	16
Model Specification Using Amos Graphics (Example 1)	
Amos Modeling Tools	19
The Hypothesized Model	23
Drawing the Path Diagram	23
Model Specification Using Amos Tables View (Example 1)	
Understanding the Basic Components of Model 1	40
The Concept of Model Identification	40

Model Specification Using Amos Graphics (Example 2)	43
The Hypothesized Model	
Drawing the Path Diagram	
Model Specification Using Amos Tables View (Example 2)	51
Model Specification Using Amos Graphics (Example 3)	53
The Hypothesized Model	
Drawing the Path Diagram	
Changing the Amos Default Color for Constructed Models	
Model Specification Using Amos Tables View (Example 3)	61
Notes	63

#### Section II: Single-Group Analyses

#### Confirmatory Factor Analytic Models

Chapter 3 Application 1: Testing the Factorial Validity of a	
Theoretical Construct (First-Order CFA Model)	69
Key Concepts	69
The Hypothesized Model	70
Hypothesis 1: Self-concept is a 4-Factor Structure	
Modeling with Amos Graphics	75
Model Specification	75
Data Specification	75
Calculation of Estimates	78
Amos Text Output: Hypothesized 4-Factor Model	81
Model Summary	81
Model Variables and Parameters	82
Model Evaluation	82
Parameter Estimates	84
Model as a Whole	
Model Misspecification	102
Post Hoc Analyses	107
Hypothesis 2: Self-concept is a 2-Factor Structure	108
Selected Amos Text Output: Hypothesized 2-Factor Model	110
Hypothesis 3: Self-concept is a 1-Factor Structure	110
Modeling with Amos Tables View	111
Notes	113
·	
Chapter 4 Application 2: Testing the Factorial Validity of	
Scores from a Measurement Scale (First-Order	
CFA Model)	115
Key Concepts	115
Modeling with Amos Graphics	115

The Measuring Instrument under Study	116
The Hypothesized Model	110 117
Selected Amos Output: The Hypothesized Model	
Model Evaluation	
Post Hoc Analyses	120 131
Model 2	137
Selected Amos Output: Model 2	132
Model 3	136
Selected Amos Outnut: Model 3	136
Model 4	130 130
Selected Amos Output: Model 4	
Comparison with Robust Analyses Based on the	
Satorra-Bentler Scaled Statistic	145
Modeling with Amos Tables View	146
Notes	140
Chapter 5 Application 3: Testing the Factorial Validity of	
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order	140
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model)	
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model)	<b> 149</b> 149
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model	<b>149</b> 149 150
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics	<b>149</b> 149 150 152
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model	<b> 149</b> 
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model	<b> 149</b> 149 150 152 161
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model Model Evaluation	<b>149</b> 149 150 152 161 161
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model Model Evaluation Estimation Based on Continous Versus Categorical Data	<b>149</b> 149 150 152 161 161 163
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model Model Evaluation Estimation Based on Continous Versus Categorical Data Categorical Variables Analyzed as Continuous Variables	<b>149</b> 150 152 155 161 161 163 167
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model Model Evaluation Estimation Based on Continous Versus Categorical Data Categorical Variables Analyzed as Continuous Variables Categorical Variables Analyzed as Categorical Variables	<b>149</b> 150 152 155 161 161 163 167 168
<ul> <li>Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model)</li> <li>Key Concepts</li></ul>	<b>149</b> 150 152 155 161 163 163 167 168 170
<ul> <li>Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model)</li> <li>Key Concepts</li></ul>	<b>149</b> 149 150 152 161 163 163 167 168 170 171
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model) Key Concepts The Hypothesized Model Modeling with Amos Graphics Selected Amos Output File: Preliminary Model Selected Amos Output: The Hypothesized Model Selected Amos Output: The Hypothesized Model Model Evaluation Estimation Based on Continous Versus Categorical Data Categorical Variables Analyzed as Continuous Variables Categorical Variables Analyzed as Categorical Variables The Amos Approach to Analysis of Categorical Variables What is Bayesian Estimation? Application of Bayesian Estimation	<b>149</b> 149 150 152 161 161 163 167 168 170 171 171
Chapter 5 Application 3: Testing the Factorial Validity of Scores from a Measurement Scale (Second-Order CFA Model)	<b>149</b> 150 152 155 161 161 163 167 168 170 171 171 180 180

## Full Latent Variable Model

Chapter 6	Application 4: Testing the Validity of a	
~	Causal Structure	
Key Conce	pts	
The Hypot	hesized Model	
Modeling v	with Amos Graphics	
Formul	ation of Indicator Variables	
Confirm	natory Factor Analyses	

Selected Amos Output: Hypothesized Model	
Model Assessment	
Post Hoc Analyses	
Selected Amos Output: Model 2	
Model Assessment	
Selected Amos Output: Model 3	
Model Assessment	
Selected Amos Output: Model 4	
Model Assessment	
Selected Amos Output: Model 5	
Model Assessment	
Selected Amos Output: Model 6	
Model Assessment	
The Issue of Model Parsimony	
Selected Amos Output: Model 7 (Final Model)	
Model Assessment	210
Parameter Estimates	
Modeling with Amos Tables View	
Notes	221

#### Section III: Multiple-Group Analyses

Confirmatory Factor Analytic Models

Scales from a Measurement Scale (First-Order	
CFA Model)	227
Key Concepts	227
Testing For Multigroup Invariance	229
The General Notion	229
The Testing Strategy	230
The Hypothesized Model	230
Establishing Baseline Models: The General Notion	231
Establishing the Baseline Models: Elementary and	
Secondary Teachers	231
Modeling with Amos Graphics	235
Hierarchy of Steps in Testing Multigroup Invariance	238
I. Testing for Configural Invariance	238
Selected Amos Output: The Configural Model	
(No Equality Constraints Imposed)	240
II. Testing for Measurement and Structural Invariance: The	
Specification Process	244

III. Testing for Measurement and Structural Invariance:	
Model Assessment	252
Testing For Multigroup Invariance: The Measurement	
Model	
Model Assessment	
Testing For Multigroup Invariance: The Structural	
Model	
Notes	
Chapter 8 Application 6: Testing Invariance of Latent Mean	า
Structures (First-Order CFA Model)	
Key Concepts	
Basic Concepts Underlying Tests of Latent Mean Structures	
Estimation of Latent Variable Means	
The Hypothesized Model	
The Baseline Models	
Modeling with Amos Graphics	
The Structured Means Model	
Testing for Latent Mean Differences	
The Hypothesized Multigroup Model	
Steps in the Testing Process	
Selected Amos Output: Model Summary	
Selected Amos Output: Goodness-of-fit Statistics	
Selected Amos Output: Parameter Estimates	
Notes	

## Full Latent Variable Model

Chapter 9 Application 7: Testing Invariance of a Causal	
Structure (Full Structural Equation Model)	
Key Concepts	
Cross-Validation in Covariance Structure Modeling	
Testing for Invariance across Calibration/Validation Samples	
The Hypothesized Model	
Establishing a Baseline Model	
Modeling with Amos Graphics	
Testing for the Invariance of Causal Structure Using the	
Automated Multigroup Approach	
Selected Amos Output: Goodness-of-fit Statistics	
for Comparative Tests of Multigroup Invariance	

#### Section IV: Other Important Applications

Chapter 10 Application 8: Testing Evidence of Construct	
Validity: The Multitrait-Multimethod Model	11
Key Concepts	11
The Correlated Traits-Correlated Methods Approach to	
MTMM Analyses	13
Model 1: Correlated Traits-Correlated Methods	15
Model 2: No Traits-Correlated Methods 32	20
Model 3: Perfectly Correlated Traits-Freely Correlated Methods32	22
Model 4: Freely Correlated Traits-Uncorrelated Methods	26
Testing for Evidence of Convergent and Discriminant	
Validity: MTMM Matrix-level Analyses	27
Comparison of Models	27
Evidence of Convergent Validity	27
Evidence of Discriminant Validity	27
Testing for Evidence of Convergent and Discriminant Validity:	
MTMM Parameter-level Analyses	28
Examination of Parameters	28
Evidence of Convergent Validity	29
Evidence of Discriminant Validity	31
The Correlated Uniquenesses Approach to MTMM Analyses	31
Model 5: Correlated Uniqueness Model	35
Notes 3'	38
	50
Chapter 11 Application 9: Testing Change Over Time:	
The Latent Growth Curve Model	39
Key Concepts	39
Measuring Change in Individual Growth over Time: The General	
Notion 34	41
The Hypothesized Dual-domain LGC Model	41
Modeling Intraindividual Change	41
Modeling Interindividual Differences in Change	45
Testing Latent Crowth Curve Models: A Dual-Domain Model	16 16
The Hypothesized Model 3/	16
Selected Amos Output: Hypothesized Model 25	50
Testing Latent Growth Curve Models: Gender as a Time-invariant	

## Section V: Other Important Topics

Chapter 12 Application 10: Use of Bootstrapping in	
Addressing Nonnormal Data	.365
Key Concepts	. 365
Basic Principles Underlying the Bootstrap Procedure	. 368
Benefits and Limitations of the Bootstrap Procedure	.369
Caveats Regarding the Use of Bootstrapping in SEM	.369
Modeling with Amos Graphics	.370
The Hypothesized Model	371
Characteristics of the Sample	371
Applying the Bootstrap Procedure	373
Selected Amos Output	.375
Parameter Summary	375
Assessment of Normality	376
Parameter Estimates and Standard Errors	378
Note	392
Chapter 13 Application 11: Addressing the Issues	
of Missing Data	.393
Kev Concepts	393
Basic Patterns of Missing Data	394
Common Approaches to Handling Incomplete Data	396
Ad Hoc Approaches to Handling Missing Data	070
(Not recommended)	396
Theory-based Approaches to Handling Missing Data	070
(Recommended)	399
The Amos Approach to Handling Missing Data	400
Modeling with Amos Granhics	401
The Hypothesized Model	401
Selected Amos Output: Parameter and Model Summary	101
Information	404
Selected Amos Output: Parameter Estimates	405
Selected Amos Output: Coodness-of-fit Statistics	405
Note	400
1000	400
References	407
Author Index	428
Subject Index	433