CONTENTS

Preface *xv*
About the Authors *xix*

PART 1
Introduction **1**

1 Introduction 3
A Layout of Incrementally-Related SEMs: An Organizing Guide 3
Illustrative Example 1.1: Examining Alternative Growth Curve Models 4
Adolescents' Internalizing Symptoms (IS) Trajectories 9
Datasets used in Illustrations *9*
Measures *10*

2 Latent Growth Curves 13
Introduction 13
Growth Curve Modeling 13
Conventional Latent Growth Curve Models (LGCM) *14*
Illustrative Example 2.1: Examining the Longitudinal Covariance Pattern of Indicators 19
Estimating an Unconditional Linear Latent Growth Curve Model (LGCM) Using Mplus *20*
Illustrative Example 2.2: Estimating a Linear Latent Growth Curve Model (LGCM) 20

Curvilinear Growth Curve Modeling (i.e., A Quadratic Growth Curve Model) 20
Illustrative Example 2.3: Estimating a Quadratic Latent Growth Curve Model (LGCM) 24
Model Fit Indices *27*
Comparing Nested Models *30*
Illustrative Example 2.4: Nested Model Comparison Between Linear and Quadratic Models 30
Illustrative Example 2.5: Nested Model Comparison Between Models with and Without Correlated Errors 31
Illustrative Example 2.6: Non-nested Model Comparison Between Linear and Piecewise Models 31
Adding Covariates to an Unconditional Model 33
Illustrative Example 2.7: Adding a Predictor and Outcome to a Linear LGCM 35
Illustrative Example 2.8: Adding a Predictor and Outcome to a Quadratic LGCM 36
Methodological Concerns in Longitudinal Analysis: Why Growth Curves? 38
The Need to Preserve the Continuity of Change *38*
The Need to Investigate Different Growth Parameters *39*
The Need to Incorporate Growth Parameters as Either Predictors or Outcomes in the Same Model *39*
The Need to Incorporate Time-Varying Predictors *40*
Limitations 40
Beyond Latent Growth Curve Modeling 41
Revisiting the Layout of Models: Figures 1.1, 1.2, and 1.3 41
First-Order Structural Equation Models *42*
Second-Order Growth Curve Modeling *42*
Growth Mixture Modeling *42*
Chapter 2 Exercises 43

3 Longitudinal Confirmatory Factor Analysis and Curve-of-Factors Growth Curve Models 47
Introduction 47
Confirmatory Factor Analysis (CFA) (Step One) 47
Specification of a Simple CFA *48*
CFA Model Identification *50*
Scale Setting in a CFA *50*
Longitudinal Confirmatory Factor Analysis (LCFA): Model Specification (Step Two) 51

A Second-Order Growth Curve: A Curve-of-Factors Model (Step Three) 51
Specification of a Curve-of-Factors Model (CFM) *51*
Why Analyze a Curve-of-Factors Model? Improvements Over a Conventional LGCM *54*
Chapter 3 Exercises 57

4 Estimating Curve-of-Factors Growth Curve Models 59
Introduction 59
Steps for Estimating a Curve-of-Factors Model (CFM) 59
Investigating the Longitudinal Correlation Patterns of Subdomain Indicators (Step One) *60*
Illustrative Example 4.1: Examining the Longitudinal Correlation Patterns Among Indicators 60
Performing an Unconstrained Longitudinal Confirmatory Factor Analysis (LCFA) (Step Two) *62*
Illustrative Example 4.2: Longitudinal Confirmatory Factor Analysis (LCFA) Using Mplus 62
Measurement Invariance of the LCFA Model (Step Three) *70*
Illustrative Example 4.3: Systematic Incremental Testing Sequences for Assessing Measurement Invariance 71
Illustrative Example 4.4: Longitudinal Confirmatory Factor Analysis (LCFA) with "Trait" Factors (IT model) 81
Estimating a Second-Order Growth Curve: A Curve-of-Factors Model (CFM) (Step Four) *84*
Illustrative Example 4.5: Estimating a Curve-of-Factors Model (CFM) 85
Scale Setting Approaches and Second-Order Growth Model Parameters (Curve-of-Factors Model, CFM) 90
Marker Variable Approach *90*
Illustrative Example 4.6: Using the Marker Variable Approach for CFA Scale Setting 90
Fixed Factor Approach *94*
Illustrative Example 4.7: Using the Fixed Factor Scale Setting Approach in a CFA 94
Effect Coding Approach *96*
Illustrative Example 4.8: Using the Effect Coding Scale Setting Approach in a CFA 98
Adding Covariates to a Curve-of-Factors Model (CFM) 100
Time-Invariant Covariate (TIC) Model *100*
Illustrative Example 4.9: Adding a Time-Invariant Covariate (TIC) as a CFM Predictor 102

Illustrative Example 4.10: Adding a Multiple-Indicator Latent Factor as a CFM Predictor 104
Illustrative Example 4.11: Predicting Both Second-Order Growth Parameters and First-Order Latent Factors 106
Illustrative Example 4.12: Predicting Distal Outcomes of Second-order Growth Factors 108
Time-Varying Covariate (TVC) Model 110
Illustrative Example 4.13: Incorporating a Time-Varying Covariate as a Direct Predictor of Manifest Indicators 111
Illustrative Example 4.14: Incorporating a Time-Varying Covariate as a Parallel Process 115
Chapter 4 Exercises 118

5 Extending a Parallel Process Latent Growth Curve Model (PPM) to a Factor-of-Curves Model (FCM) 122
Introduction 122
Parallel Process Latent Growth Curve Model (PPM) 122
Estimating a Parallel Process Model (PPM) 124
Correlation of Measurement Errors in a PPM 126
Influence of Growth Factors of One Subdomain on the Growth Factors of Other Subdomains 128
Modeling Sequentially Contingent Processes over Time 132
Extending a Parallel Process Latent Growth Curve Model (PPM) to a Factor-of-Curves Growth Curve Model (FCM) 134
Second-Order Growth Factors 136
Chapter 5 Exercises 141

6 Estimating a Factor-of-Curves Model (FCM) and Adding Covariates 142
Introduction 142
Estimating a Factor-of-Curves Model (FCM) 142
Investigating the Longitudinal Correlation Patterns Among Repeated Measures of Each Subdomain (Step One) 143
Illustrative Example 6.1: Investigating the Longitudinal Correlation Patterns Among Repeated Measures of Each Subdomain 144
Estimating a Parallel Process Growth Curve Model (PPM) (Step Two) 144
Illustrative Example 6.2: Estimating a Parallel Process Growth Curve Model (PPM) 144
Estimating a Factor-of-Curves Model (FCM) (Step Three) 146

Illustrative Example 6.3: Estimating a Factor-of-Curves Model (FCM) 148
Illustrative Example 6.4: Comparing Two Competing Models Empirically 152
Estimating a Conditional FCM (Step Four) *153*
Illustrative Example 6.5: Adding Time-Invariant Covariates (TIC) to a FCM 154
Illustrative Example 6.6: Incorporating a Latent Distal Outcome into a FCM 156
Illustrative Example 6.7: Incorporating a Time-Varying Covariate (TVC) as a Direct Predictor 160
Illustrative Example 6.8: Incorporating a Time-Varying Predictor as a Parallel Process 164
A Multiple-Group FCM (Multi-Group Longitudinal Modeling) 165
Illustrative Example 6.9: Estimating a FCM for Multiple Groups 167
Multivariate FCM 172
Illustrative Example 6.10: Estimating a Multivariate FCM 174
Model Selection: Factor-of-Curves vs. Curve-of-Factors 177
Illustrative Example 6.11: Empirically Comparing CFM and FCM Approaches 179
Combining a CFM and a FCM: A Factor-of-Curves-of-Factors (FCF) Model 182
Illustrative Example 6.12: Estimating a Factor-of-Curves-of-Factors (FCF) Model 183
Chapter 6 Exercises 185

PART 2
Growth Mixture Modeling **189**

7 An Introduction to Growth Mixture Models (GMMs) 191
Introduction 191
A Conventional Latent Growth Curve Model (LGCM) 192
Potential Heterogeneity in Individual Trajectories 192
Growth Mixture Modeling (GMM) 195
Latent Class Growth Analysis (LCGA): A Simplified GMM 196
Specifying a Growth Mixture Model (GMM) 197
Specifying Trajectory Classes: Class-Specific Equations *199*
Specifying a Latent Class Growth Analysis (LCGA) *199*
Building A Growth Mixture Model (GMM) Using M*plus* 201
Specify a Traditional Growth Curve Model (LGCM) (Step One) *201*

Estimating a Latent Class Growth Analysis (LCGA) (Step Two) 202
Illustrative Example 7.1: M*plus* Syntax for a Latent Class Growth Analysis (LCGA) 204
Specifying a Growth Mixture Model (GMM) (Step Three) 204
Illustrative Example 7.2: M*plus* Syntax for a Growth Mixture Model (GMM) 205
Addressing Estimation Problems (Step Four) 206
Illustrative Example 7.3: A Non-Normal Distribution 207
Selecting the Optimal Class Model (Enumeration Indices) (Step Five) 213
Illustrative Example 7.4: Identifying the Optimal Model 216
Summary of a Model Building Strategy 221
Chapter 7 Exercises 223

8 Estimating a Conditional Growth Mixture Model (GMM) 227
Introduction 227
Growth Mixture Models: Predictors and Distal Outcomes 228
The One-Step Approach to Incorporating Covariates into a GMM 229
Predictors of Latent Classes (Multinomial Regression) 229
Illustrative Example 8.1: Incorporating a Time-Invariant Predictor into a GMM 230
Predictors of Latent Growth Factors Within Classes 230
Illustrative Example 8.2: Adding Within-Class Effects of Predictors to a GMM 232
Adding Distal Outcomes of Latent Classes (Categorical and Continuous) 234
Illustrative Example 8.3: Incorporating a Binary Distal Outcome into a GMM 234
Illustrative Example 8.4: Incorporating a Continuous Distal Outcome into a GMM 236
Uncertainty of Latent Class Membership With the Addition of Covariates 237
The Three-Step Approach: The "Manual" Method 238
Illustrative Example 8.5: The Three-Step Procedure for Incorporating Predictor(s) 239
Illustrative Example 8.6: The Three-Step Procedure for Incorporating Distal Outcome(s) 243
AUXILIARY Option for the Three-Step Approach 247
Illustrative Example 8.7: Utilizing the Auxiliary Option with the 3-Step Approach 247
Illustrative Example 8.8: Utilizing the Auxiliary Option with "Lanza Commands" 249
Chapter 8 Exercises 253

9 Second-Order Growth Mixture Models (SOGMMs) 256
Introduction 256
Estimating a Second-Order Growth Mixture Model:
A Curve-of-Factors Model (SOGMM of a CFM) 257
Illustrative Example 9.1: A Second-Order Growth
Mixture Model of a CFM (SOGMM-CF) 259
Illustrative Example 9.2: Avoiding Convergence Problems 265
Estimating a Second-Order Growth Mixture Model:
A Factor-of-Curves Model (SOGMM of a FCM) 272
Illustrative Example 9.3: A Second-Order Growth
Mixture Model of a FCM (SOGMM-FC) 273
Comparison of Classification Between a First-Order GMM With
Composite Measures and Second-Order GMMs 277
Estimating a Conditional Model (Conditional SOGMM) 279
The Three-Step Approach (Using the AUXILIARY Option) to
Add Predictors of Second-Order Trajectory Classes *281*
Illustrative Example 9.4: Estimating a Conditional SOGMM
with Predictors 281
The Three-Step Approach (Using the AUXILIARY Option) to
Add Outcomes of Second-Order Trajectory Classes *285*
Illustrative Example 9.5: Estimating a Conditional
SOGMM with Outcomes 285
Estimating a Multidimensional Growth Mixture Model
(MGMM) 287
Illustrative Example 9.6: Estimating a Multidimensional
Growth Mixture Model 289
Conclusion 291
Chapter 9 Exercises 293

Answers to Chapter Exercises *297*
Author Index *320*
Subject Index *323*