## CONTENTS

## Preface

1

2

Introduction Chapter Objectives 1 Introduction 1 Providing a Conceptual Overview 2 Analysis of Multilevel Data Structures Contrasting Linear Models 6 Univariate Analysis 9 Multiple Regression 10 Analysis of Variance 10 Multivariate Analysis 11 Multivariate Analysis of Variance 11 Structural Equation Modeling 13 Multilevel Data Structures 15 Multilevel Multivariate Model 17 Multilevel Structural Model 18 Summary 20 References 21

5

Getting Started With Multilevel Analysis
Chapter Objectives 23
Introduction 23
From Single-Level to Multilevel Analysis 25
Summarizing Some Differences 29
Developing a General Multilevel Modeling Strategy

xiii

1

23

3

Step 1: Partitioning the Variance in an Outcome 33 Step 2: Adding Level-1 Predictors to Explain Intercept Variability 37 Step 3: Specifying Level-2 Predictors to Explain Intercept Variability 38 Step 4: Examining Possible Variation in Slopes 40 Step 5: Adding Predictors to Explain Variation in Slopes 41 Specifying Random Effects at Level 2 43 Methods for Estimating Model Parameters 44 Maximum Likelihood Estimation 45 48 Full Information ML Model Convergence 51 Considerations for ML Estimation 52 Other Model Estimation Approaches in Mplus 54 WLS Estimation 55 Bayesian Estimation 56 A Comparison of Estimation Approaches With Small Numbers of Level-2 Units 57 Summary 60 References 62 Multilevel Regression Models Chapter Objectives 67 Introduction 67 Overview of Multilevel Regression Models 69 70 Building a Model to Explain Employee Morale Model 1: One-Way ANOVA model 74 Model 1 Statements 75

Model 1 Output 77 79 Model 2: Level-1 Random-Intercept Model Model 2 Statements 81 Model 2 Output 82 Model 3: Specifying a Level-1 Random Slope 83 Model 3 Statements 83 Model 3 Output 84 Model 4: Explaining Variation in the Level-2 Intercept and Slope Model 4 Statements 85 Model 4 Output 86 **Centering Predictors** 87 Centering Predictors in Models With Random Slopes 91 Summary 93 References 94

4 Extending the Two-Level Regression Model
 Chapter Objectives 97
 Introduction 97

67

Three-Level Univariate Model 98 Developing a Three-Level Univariate Model 99 Research Questions 100 Data 100 Data 100 Model 1: Null (No Predictors) Model 101 Model 1 Statements 101 Model 1 Output 102 Model 2: Defining Predictors at Each Level 103 Grand-Mean Centering 103 Model 2 Statements 105 Model 2: Grand-Mean Centered Output 105 Group-Mean Centering 107 Model 2 Statements 107 Model 2: Group-Mean Centered Output 108 Model 3: Does the Slope Vary Randomly Across Schools? 109 Model 3 Statements 110 Model 3 Output 111 Model 4: Developing a Model to Explain Variability in Slopes 111 Model 4 Statements 112 Model 4 Output 112 Defining Path Models 113 Single-Level Path Model 114 Multilevel Path Model 115 Model 1: Two-Level Model With Multivariate Outcomes 117 Model 1 Statements 119 Model 1 Output 120 Model 2: Specifying a Mediating Variable Between Groups 122 Model 2 Statements 123 Model 2 Output 124 Model 3: Revised Model Removing Nonsignificant Paths 127 Examining an Indirect Effect 128 Model 3 Statements 128 Model 3 Output 129 Final R-Square Estimates 129 Summary 131 References 131 Defining Multilevel Latent Variables

Chapter Objectives 133 Introduction 133 Latent Variables 135 The Measurement Model 136 Structural Model 139 Proposing a CFA Model 140

5

Model Identification 143 Model Fit Indices 145 Model 1: Examining a Single-Level CFA Model 148 Model 1 Output 149 Model 2: Freeing an Error Covariance 153 Model 2 Output 153 Extending the Generalizability of a Model 154 Multilevel Measurement Models 155 Multilevel Factor Variance Components 158 Estimating ML-CFA Models 159 Model 3: Defining a Two-Level CFA Model 162 Examining the Fit Indices 166 Examining the Model Parameters 167 Model 4: Applying Equality Constraints on Factor Loadings 168 Model 4 Output 169 Standardized Estimates 171 Comparing Model 3 and Model 4 172 Extending the CFA Model to Three Levels 174 Model 5: Invariant Loadings at Levels 1 and 2 174 Model 5 Fit Indices 175 Model 6: Including Equality Constraints at Level 3 176 Model 6 Fit Indices 176 Model 7: Restricting Errors to Zero at Level 2 177 Model 7 Fit Indices 177 Comparing Models 6 and 7 177 Model 7 Parameter Estimates 178 Summary 179 References 179

6 Multilevel Structural Equation Models Chapter Objectives 183 Introduction 183 Multilevel Models With Latent Variables and Covariates 184 Model 1: Two-Level CFA With Observed Predictors 185 Model 1 Statements 187 Model 1 Output 189 Model 2: Specifying a Random Level-1 Slope 198 Model 2 Statements 199 Model 2 Output 200 Model 3: Specifying Female as Having Within- and Between-Group Components 200 Model 3 Statements 200 Model 3 Output 202 Model 4: Adding a Latent Factor Between Groups 202

Model 4 Statements 205 Model 4 Output 206 Model 5: Testing an Indirect Effect 206 Model 5 Statements 209 Model 5 Output 210 Model 6: Adding a Relationship Between the Latent Outcomes 211 Model 6 Statements 211 Model 6 Output 212 Model 7: Specifying a Reciprocal Relationship Between Outcomes 213 Model 7 Statements 216 Model 7 Output 218 Summary 219 References 220 Methods for Examining Individual and Organizational Change 221 Chapter Objectives 221 Introduction 221 Analyzing Longitudinal Data 223 Repeated-Measures ANOVA 223 Growth Modeling and Other Approaches 224 Random-Coefficients Growth Modeling 225 Defining the Level-1 Model 226 Defining the Level-2 Model 228 Extending the Model to Examine Changes Between Organizations 229 Defining the Level-3 Model 229 Examining Changes in Institutions' Graduation Rates 229 Model 1: Within-Individuals (Level-1) Model 231 Between-Individuals (Level-2) Model 232 Coding the Time Variable 232 Model 1 Statements 234 TECH1 Specification Output 235 Model 1 Output 236 Model 2: Explaining Differences in Random Growth Parameters Between Institutions 238 Model 2 Statements 238 TECH1 Output 239 Model 2 Output 240 Other Types of Random-Coefficients Models 241 Examining Individual Change With SEM 241 Intercept and Slope (IS) and Level and Shape (LS) Models 242 Defining the Latent Curve Model 244 The Measurement Model 244 The Structural Model 246

Model Output 361 Two-Level LGMM 364 Model Statements 366 Model Output 367 Summary 370 References 370

10 Data Considerations in Examining Multilevel Models Chapter Objectives 373 Introduction 373 Complex Samples, Design Effects, and Sample Weights 373 An Example Using Multilevel Weights 379 Model Statements 379 Model Output 382 Parameter Bias and Statistical Power 384 384 Bias Power 385 An Example 386 Anticipated Effect Size and Power 389 Mplus Monte Carlo Study 393 Model Statements 395 Model Output 396 Design Complexity 398 Missing Data 399 Missing Data at Level 2 404 Model Statements 404 Initial Summary Output 405 Imputation File 406 Model Estimates 407 Model Output 407 Concluding Thoughts 410 References 413

Glossary Author Index Subject Index