

Contents

<i>Preface</i>	<i>ix</i>
1 Introduction	1
1.1 Multilevel analysis	1
1.1.1 Probability models	2
1.2 This book	3
1.2.1 Prerequisites	5
1.2.2 Notation	5
2 Multilevel Theories, Multi-stage Sampling, and Multilevel Models	6
2.1 Dependence as a nuisance	6
2.2 Dependence as an interesting phenomenon	7
2.3 Macro-level, micro-level, and cross-level relations	9
3 Statistical Treatment of Clustered Data	13
3.1 Aggregation	13
3.2 Disaggregation	15
3.3 The intraclass correlation	16
3.3.1 Within-group and between-group variance	18
3.3.2 Testing for group differences	21
3.4 Design effects in two-stage samples	22
3.5 Reliability of aggregated variables	24
3.6 Within- and between-group relations	26
3.6.1 Regressions	27
3.6.2 Correlations	31
3.6.3 Estimation of within- and between-group correlations	33
3.7 Combination of within-group evidence	35
4 The Random Intercept Model	38
4.1 A regression model: fixed effects only	39
4.2 Variable intercepts: fixed or random parameters?	41
4.2.1 When to use random coefficient models?	43
4.3 Definition of the random intercept model	45
4.4 More explanatory variables	51
4.5 Within- and between-group regressions	52

4.6	Parameter estimation	56
4.7	'Estimating' random group effects: posterior means	58
4.7.1	Posterior confidence intervals	60
4.8	Three-level random intercept models	63
5	The Hierarchical Linear Model	67
5.1	Random slopes	67
5.1.1	Heteroscedasticity	68
5.1.2	Don't force τ_{01} to be 0!	69
5.1.3	Interpretation of random slope variances	70
5.2	Explanation of random intercepts and slopes	72
5.2.1	Cross-level interaction effects	73
5.2.2	A general formulation of fixed and random parts	79
5.3	Specification of random slope models	80
5.3.1	Centering variables with random slopes?	80
5.4	Estimation	82
5.5	Three and more levels	83
6	Testing and Model Specification	86
6.1	Tests for fixed parameters	86
6.1.1	Multi-parameter tests for fixed effects	88
6.2	Deviance tests	88
6.2.1	Halved p -values for variance parameters	90
6.3	Other tests for parameters in the random part	91
6.4	Model specification	91
6.4.1	Working upward from level one	94
6.4.2	Joint consideration of level-one and level-two variables	96
6.4.3	Concluding remarks about model specification	97
7	How Much Does the Model Explain?	99
7.1	Explained variance	99
7.1.1	Negative values of R^2 ?	99
7.1.2	Definitions of proportions of explained variance in two-level models	101
7.1.3	Explained variance in three-level models	104
7.1.4	Explained variance in models with random slopes	104
7.2	Components of variance	105
7.2.1	Random intercept models	106
7.2.2	Random slope models	108
8	Heteroscedasticity	110
8.1	Heteroscedasticity at level one	110
8.1.1	Linear variance functions	110
8.1.2	Quadratic variance functions	114
8.2	Heteroscedasticity at level two	119

9 Assumptions of the Hierarchical Linear Model	120
9.1 Assumptions of the hierarchical linear model	120
9.2 Following the logic of the hierarchical linear model	121
9.2.1 Include contextual effects	122
9.2.2 Check whether variables have random effects	122
9.2.3 Explained variance	123
9.3 Specification of the fixed part	124
9.4 Specification of the random part	125
9.4.1 Testing for heteroscedasticity	126
9.4.2 What to do in case of heteroscedasticity	128
9.5 Inspection of level-one residuals	128
9.6 Residuals and influence at level two	132
9.6.1 Empirical Bayes residuals	132
9.6.2 Influence of level-two units	134
9.7 More general distributional assumptions	139
10 Designing Multilevel Studies	140
10.1 Some introductory notes on power	141
10.2 Estimating a population mean	142
10.3 Measurement of subjects	143
10.4 Estimating association between variables	144
10.4.1 Cross-level interaction effects	148
10.5 Exploring the variance structure	151
10.5.1 The intraclass correlation	151
10.5.2 Variance parameters	154
11 Crossed Random Coefficients	155
11.1 A two-level model with a crossed random factor	155
11.1.1 Random slopes of dummy variables	156
11.2 Crossed random effects in three-level models	159
11.3 Correlated random coefficients of crossed factors	160
11.3.1 Random slopes in a crossed design	160
11.3.2 Multiple roles	161
11.3.3 Social networks	162
12 Longitudinal Data	166
12.1 Fixed occasions	167
12.1.1 The compound symmetry model	168
12.1.2 Random slopes	171
12.1.3 The fully multivariate model	173
12.1.4 Multivariate regression analysis	178
12.1.5 Explained variance	179
12.2 Variable occasion designs	181
12.2.1 Populations of curves	181
12.2.2 Random functions	182
12.2.3 Explaining the functions	193

12.2.4	Changing covariates	195
12.3	Autocorrelated residuals	199
13	Multivariate Multilevel Models	200
13.1	The multivariate random intercept model	201
13.2	Multivariate random slope models	206
14	Discrete Dependent Variables	207
14.1	Hierarchical generalized linear models	207
14.2	Introduction to multilevel logistic regression	208
14.2.1	Heterogeneous proportions	208
14.2.2	The logit function: Log-odds	211
14.2.3	The empty model	213
14.2.4	The random intercept model	215
14.2.5	Estimation	218
14.2.6	Aggregation	219
14.2.7	Testing the random intercept	220
14.3	Further topics about multilevel logistic regression	220
14.3.1	Random slope model	220
14.3.2	Representation as a threshold model	223
14.3.3	Residual intraclass correlation coefficient	224
14.3.4	Explained variance	225
14.3.5	Consequences of adding effects to the model	227
14.3.6	Bibliographic remarks	229
14.4	Ordered categorical variables	229
14.5	Multilevel Poisson regression	234
15	Software	239
15.1	Special software for multilevel modeling	239
15.1.1	HLM	240
15.1.2	MLn / MLwiN	243
15.1.3	VARCL	245
15.1.4	MIXREG, MIXOR, MIXNO, MIXPREG	247
15.2	Modules in general purpose software packages	248
15.2.1	SAS, procedure MIXED	248
15.2.2	SPSS, command VARCOMP	249
15.2.3	BMDP-V modules	250
15.2.4	Stata	250
15.3	Other multilevel software	251
15.3.1	PinT	251
15.3.2	Mplus	251
15.3.3	MLA	251
15.3.4	BUGS	251
	References	252
	Index	261