

SEVENTH EDITION

Using Multivariate Statistics

Barbara G. Tabachnick
California State University, Northridge

Linda S. Fidell
California State University, Northridge



330 Hudson Street, NY NY 10013

Portfolio Manager: *Tanimaa Mehra*
Content Producer: *Kani Kapoor*
Portfolio Manager Assistant: *Anna Austin*
Product Marketer: *Jessica Quazza*
Art/Designer: *Integra Software Services Pvt. Ltd.*
Full-Service Project Manager: *Integra Software Services Pvt. Ltd.*

Composer: *Integra Software Services Pvt. Ltd.*
Printer/Binder: *LSC Communications, Inc.*
Cover Printer: *Phoenix Color/Hagerstown*
Cover Design: *Lumina Datamatics, Inc.*
Cover Art: *Shutterstock*

Acknowledgments of third party content appear on pages within the text, which constitutes an extension of this copyright page.

Copyright © 2019, 2013, 2007 by Pearson Education, Inc. or its affiliates. All Rights Reserved. Printed in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms and the appropriate contacts within the Pearson Education Global Rights & Permissions department, please visit www.pearsoned.com/permissions/.

PEARSON and ALWAYS LEARNING are exclusive trademarks owned by Pearson Education, Inc. or its affiliates, in the U.S., and/or other countries.

Unless otherwise indicated herein, any third-party trademarks that may appear in this work are the property of their respective owners and any references to third-party trademarks, logos or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson's products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc. or its affiliates, authors, licensees or distributors.

Many of the designations by manufacturers and seller to distinguish their products are claimed as trademarks. Where those designations appear in this book, and the publisher was aware of a trademark claim, the designations have been printed in initial caps or all caps.

Library of Congress Cataloging-in-Publication Data

Names: Tabachnick, Barbara G., author. | Fidell, Linda S., author.
Title: Using multivariate statistics/Barbara G. Tabachnick, California State University, Northridge, Linda S. Fidell, California State University, Northridge.
Description: Seventh edition. | Boston: Pearson, [2019] | Chapter 14, by Jodie B. Ullman.
Identifiers: LCCN 2017040173 | ISBN 9780134790541 | ISBN 0134790545
Subjects: LCSH: Multivariate analysis. | Statistics.
Classification: LCC QA278 .T3 2019 | DDC 519.5/35—dc23
LC record available at <https://lcn.loc.gov/2017040173>



Contents

Preface	xiv	2.1.3 Prediction of Group Membership	20
1 Introduction	1	2.1.3.1 One-Way Discriminant Analysis	20
1.1 Multivariate Statistics: Why?	1	2.1.3.2 Sequential One-Way Discriminant Analysis	20
1.1.1 The Domain of Multivariate Statistics: Numbers of IVs and DVs	2	2.1.3.3 Multiway Frequency Analysis (Logit)	21
1.1.2 Experimental and Nonexperimental Research	2	2.1.3.4 Logistic Regression	21
1.1.3 Computers and Multivariate Statistics	3	2.1.3.5 Sequential Logistic Regression	21
1.1.4 Garbage In, Roses Out?	4	2.1.3.6 Factorial Discriminant Analysis	21
1.2 Some Useful Definitions	5	2.1.3.7 Sequential Factorial Discriminant Analysis	22
1.2.1 Continuous, Discrete, and Dichotomous Data	5	2.1.4 Structure	22
1.2.2 Samples and Populations	6	2.1.4.1 Principal Components	22
1.2.3 Descriptive and Inferential Statistics	7	2.1.4.2 Factor Analysis	22
1.2.4 Orthogonality: Standard and Sequential Analyses	7	2.1.4.3 Structural Equation Modeling	22
1.3 Linear Combinations of Variables	9	2.1.5 Time Course of Events	22
1.4 Number and Nature of Variables to Include	10	2.1.5.1 Survival/Failure Analysis	23
1.5 Statistical Power	10	2.1.5.2 Time-Series Analysis	23
1.6 Data Appropriate for Multivariate Statistics	11	2.2 Some Further Comparisons	23
1.6.1 The Data Matrix	11	2.3 A Decision Tree	24
1.6.2 The Correlation Matrix	12	2.4 Technique Chapters	27
1.6.3 The Variance–Covariance Matrix	12	2.5 Preliminary Check of the Data	28
1.6.4 The Sum-of-Squares and Cross-Products Matrix	13	3 Review of Univariate and Bivariate Statistics	29
1.6.5 Residuals	14	3.1 Hypothesis Testing	29
1.7 Organization of the Book	14	3.1.1 One-Sample z Test as Prototype	30
2 A Guide to Statistical Techniques: Using the Book	15	3.1.2 Power	32
2.1 Research Questions and Associated Techniques	15	3.1.3 Extensions of the Model	32
2.1.1 Degree of Relationship Among Variables	15	3.1.4 Controversy Surrounding Significance Testing	33
2.1.1.1 Bivariate r	16	3.2 Analysis of Variance	33
2.1.1.2 Multiple R	16	3.2.1 One-Way Between-Subjects ANOVA	34
2.1.1.3 Sequential R	16	3.2.2 Factorial Between-Subjects ANOVA	36
2.1.1.4 Canonical R	16	3.2.3 Within-Subjects ANOVA	38
2.1.1.5 Multiway Frequency Analysis	17	3.2.4 Mixed Between-Within-Subjects ANOVA	40
2.1.1.6 Multilevel Modeling	17	3.2.5 Design Complexity	41
2.1.2 Significance of Group Differences	17	3.2.5.1 Nesting	41
2.1.2.1 One-Way ANOVA and t Test	17	3.2.5.2 Latin-Square Designs	42
2.1.2.2 One-Way ANCOVA	17	3.2.5.3 Unequal n and Nonorthogonality	42
2.1.2.3 Factorial ANOVA	18	3.2.5.4 Fixed and Random Effects	43
2.1.2.4 Factorial ANCOVA	18	3.2.6 Specific Comparisons	43
2.1.2.5 Hotelling's T^2	18	3.2.6.1 Weighting Coefficients for Comparisons	43
2.1.2.6 One-Way MANOVA	18	3.2.6.2 Orthogonality of Weighting Coefficients	44
2.1.2.7 One-Way MANCOVA	19	3.2.6.3 Obtained F for Comparisons	44
2.1.2.8 Factorial MANOVA	19	3.2.6.4 Critical F for Planned Comparisons	45
2.1.2.9 Factorial MANCOVA	19	3.2.6.5 Critical F for Post Hoc Comparisons	45
2.1.2.10 Profile Analysis of Repeated Measures	19	3.3 Parameter Estimation	46
		3.4 Effect Size	47

3.5 Bivariate Statistics: Correlation and Regression	48	5 Multiple Regression	99
3.5.1 Correlation	48	5.1 General Purpose and Description	99
3.5.2 Regression	49	5.2 Kinds of Research Questions	101
3.6 Chi-Square Analysis	50	5.2.1 Degree of Relationship	101
4 Cleaning Up Your Act: Screening Data Prior to Analysis	52	5.2.2 Importance of IVs	102
4.1 Important Issues in Data Screening	53	5.2.3 Adding IVs	102
4.1.1 Accuracy of Data File	53	5.2.4 Changing IVs	102
4.1.2 Honest Correlations	53	5.2.5 Contingencies Among IVs	102
4.1.2.1 Inflated Correlation	53	5.2.6 Comparing Sets of IVs	102
4.1.2.2 Deflated Correlation	53	5.2.7 Predicting DV Scores for Members of a New Sample	103
4.1.3 Missing Data	54	5.2.8 Parameter Estimates	103
4.1.3.1 Deleting Cases or Variables	57	5.3 Limitations to Regression Analyses	103
4.1.3.2 Estimating Missing Data	57	5.3.1 Theoretical Issues	103
4.1.3.3 Using a Missing Data Correlation Matrix	61	5.3.2 Practical Issues	104
4.1.3.4 Treating Missing Data as Data	61	5.3.2.1 Ratio of Cases to IVs	105
4.1.3.5 Repeating Analyses with and without Missing Data	61	5.3.2.2 Absence of Outliers Among the IVs and on the DV	105
4.1.3.6 Choosing Among Methods for Dealing with Missing Data	62	5.3.2.3 Absence of Multicollinearity and Singularity	106
4.1.4 Outliers	62	5.3.2.4 Normality, Linearity, and Homoscedasticity of Residuals	106
4.1.4.1 Detecting Univariate and Multivariate Outliers	63	5.3.2.5 Independence of Errors	108
4.1.4.2 Describing Outliers	66	5.3.2.6 Absence of Outliers in the Solution	109
4.1.4.3 Reducing the Influence of Outliers	66	5.4 Fundamental Equations for Multiple Regression	109
4.1.4.4 Outliers in a Solution	67	5.4.1 General Linear Equations	110
4.1.5 Normality, Linearity, and Homoscedasticity	67	5.4.2 Matrix Equations	111
4.1.5.1 Normality	68	5.4.3 Computer Analyses of Small-Sample Example	113
4.1.5.2 Linearity	72	5.5 Major Types of Multiple Regression	115
4.1.5.3 Homoscedasticity, Homogeneity of Variance, and Homogeneity of Variance–Covariance Matrices	73	5.5.1 Standard Multiple Regression	115
4.1.6 Common Data Transformations	75	5.5.2 Sequential Multiple Regression	116
4.1.7 Multicollinearity and Singularity	76	5.5.3 Statistical (Stepwise) Regression	117
4.1.8 A Checklist and Some Practical Recommendations	79	5.5.4 Choosing Among Regression Strategies	121
4.2 Complete Examples of Data Screening	79	5.6 Some Important Issues	121
4.2.1 Screening Ungrouped Data	80	5.6.1 Importance of IVs	121
4.2.1.1 Accuracy of Input, Missing Data, Distributions, and Univariate Outliers	81	5.6.1.1 Standard Multiple Regression	122
4.2.1.2 Linearity and Homoscedasticity	84	5.6.1.2 Sequential or Statistical Regression	123
4.2.1.3 Transformation	84	5.6.1.3 Commonality Analysis	123
4.2.1.4 Detecting Multivariate Outliers	84	5.6.1.4 Relative Importance Analysis	125
4.2.1.5 Variables Causing Cases to Be Outliers	86	5.6.2 Statistical Inference	128
4.2.1.6 Multicollinearity	88	5.6.2.1 Test for Multiple R	128
4.2.2 Screening Grouped Data	88	5.6.2.2 Test of Regression Components	129
4.2.2.1 Accuracy of Input, Missing Data, Distributions, Homogeneity of Variance, and Univariate Outliers	89	5.6.2.3 Test of Added Subset of IVs	130
4.2.2.2 Linearity	93	5.6.2.4 Confidence Limits	130
4.2.2.3 Multivariate Outliers	93	5.6.2.5 Comparing Two Sets of Predictors	131
4.2.2.4 Variables Causing Cases to Be Outliers	94	5.6.3 Adjustment of R^2	132
4.2.2.5 Multicollinearity	97	5.6.4 Suppressor Variables	133
		5.6.5 Regression Approach to ANOVA	134
		5.6.6 Centering When Interactions and Powers of IVs Are Included	135
		5.6.7 Mediation in Causal Sequence	137

5.7 Complete Examples of Regression Analysis	138	6.5.4.3 Specific Comparisons and Trend Analysis	185
5.7.1 Evaluation of Assumptions	139	6.5.4.4 Effect Size	187
5.7.1.1 Ratio of Cases to IVs	139	6.5.5 Alternatives to ANCOVA	187
5.7.1.2 Normality, Linearity, Homoscedasticity, and Independence of Residuals	139	6.6 Complete Example of Analysis of Covariance	189
5.7.1.3 Outliers	142	6.6.1 Evaluation of Assumptions	189
5.7.1.4 Multicollinearity and Singularity	144	6.6.1.1 Unequal n and Missing Data	189
5.7.2 Standard Multiple Regression	144	6.6.1.2 Normality	191
5.7.3 Sequential Regression	150	6.6.1.3 Linearity	191
5.7.4 Example of Standard Multiple Regression with Missing Values Multiply Imputed	154	6.6.1.4 Outliers	191
5.8 Comparison of Programs	162	6.6.1.5 Multicollinearity and Singularity	192
5.8.1 IBM SPSS Package	163	6.6.1.6 Homogeneity of Variance	192
5.8.2 SAS System	165	6.6.1.7 Homogeneity of Regression	193
5.8.3 SYSTAT System	166	6.6.1.8 Reliability of Covariates	193
6 Analysis of Covariance	167	6.6.2 Analysis of Covariance	193
6.1 General Purpose and Description	167	6.6.2.1 Main Analysis	193
6.2 Kinds of Research Questions	170	6.6.2.2 Evaluation of Covariates	196
6.2.1 Main Effects of IVs	170	6.6.2.3 Homogeneity of Regression Run	197
6.2.2 Interactions Among IVs	170	6.7 Comparison of Programs	200
6.2.3 Specific Comparisons and Trend Analysis	170	6.7.1 IBM SPSS Package	200
6.2.4 Effects of Covariates	170	6.7.2 SAS System	200
6.2.5 Effect Size	171	6.7.3 SYSTAT System	200
6.2.6 Parameter Estimates	171	7 Multivariate Analysis of Variance and Covariance	203
6.3 Limitations to Analysis of Covariance	171	7.1 General Purpose and Description	203
6.3.1 Theoretical Issues	171	7.2 Kinds of Research Questions	206
6.3.2 Practical Issues	172	7.2.1 Main Effects of IVs	206
6.3.2.1 Unequal Sample Sizes, Missing Data, and Ratio of Cases to IVs	172	7.2.2 Interactions Among IVs	207
6.3.2.2 Absence of Outliers	172	7.2.3 Importance of DVs	207
6.3.2.3 Absence of Multicollinearity and Singularity	172	7.2.4 Parameter Estimates	207
6.3.2.4 Normality of Sampling Distributions	173	7.2.5 Specific Comparisons and Trend Analysis	207
6.3.2.5 Homogeneity of Variance	173	7.2.6 Effect Size	208
6.3.2.6 Linearity	173	7.2.7 Effects of Covariates	208
6.3.2.7 Homogeneity of Regression	173	7.2.8 Repeated-Measures Analysis of Variance	208
6.3.2.8 Reliability of Covariates	174	7.3 Limitations to Multivariate Analysis of Variance and Covariance	208
6.4 Fundamental Equations for Analysis of Covariance	174	7.3.1 Theoretical Issues	208
6.4.1 Sums of Squares and Cross-Products	175	7.3.2 Practical Issues	209
6.4.2 Significance Test and Effect Size	177	7.3.2.1 Unequal Sample Sizes, Missing Data, and Power	209
6.4.3 Computer Analyses of Small-Sample Example	178	7.3.2.2 Multivariate Normality	210
6.5 Some Important Issues	179	7.3.2.3 Absence of Outliers	210
6.5.1 Choosing Covariates	179	7.3.2.4 Homogeneity of Variance–Covariance Matrices	210
6.5.2 Evaluation of Covariates	180	7.3.2.5 Linearity	211
6.5.3 Test for Homogeneity of Regression	180	7.3.2.6 Homogeneity of Regression	211
6.5.4 Design Complexity	181	7.3.2.7 Reliability of Covariates	211
6.5.4.1 Within-Subjects and Mixed Within-Between Designs	181	7.3.2.8 Absence of Multicollinearity and Singularity	211
6.5.4.2 Unequal Sample Sizes	182	7.4 Fundamental Equations for Multivariate Analysis of Variance and Covariance	212
		7.4.1 Multivariate Analysis of Variance	212

7.4.2 Computer Analyses of Small-Sample Example	218	8.3.2.2 Multivariate Normality	260
7.4.3 Multivariate Analysis of Covariance	221	8.3.2.3 Absence of Outliers	260
7.5 Some Important Issues	223	8.3.2.4 Homogeneity of Variance–Covariance Matrices	260
7.5.1 MANOVA Versus ANOVAs	223	8.3.2.5 Linearity	260
7.5.2 Criteria for Statistical Inference	223	8.3.2.6 Absence of Multicollinearity and Singularity	260
7.5.3 Assessing DVs	224	8.4 Fundamental Equations for Profile Analysis	260
7.5.3.1 Univariate F	224	8.4.1 Differences in Levels	262
7.5.3.2 Roy–Bargmann Stepdown Analysis	226	8.4.2 Parallelism	262
7.5.3.3 Using Discriminant Analysis	226	8.4.3 Flatness	265
7.5.3.4 Choosing Among Strategies for Assessing DVs	227	8.4.4 Computer Analyses of Small-Sample Example	266
7.5.4 Specific Comparisons and Trend Analysis	227	8.5 Some Important Issues	269
7.5.5 Design Complexity	228	8.5.1 Univariate Versus Multivariate Approach to Repeated Measures	269
7.5.5.1 Within-Subjects and Between-Within Designs	228	8.5.2 Contrasts in Profile Analysis	270
7.5.5.2 Unequal Sample Sizes	228	8.5.2.1 Parallelism and Flatness Significant, Levels Not Significant (Simple-Effects Analysis)	272
7.6 Complete Examples of Multivariate Analysis of Variance and Covariance	230	8.5.2.2 Parallelism and Levels Significant, Flatness Not Significant (Simple-Effects Analysis)	274
7.6.1 Evaluation of Assumptions	230	8.5.2.3 Parallelism, Levels, and Flatness Significant (Interaction Contrasts)	275
7.6.1.1 Unequal Sample Sizes and Missing Data	230	8.5.2.4 Only Parallelism Significant	276
7.6.1.2 Multivariate Normality	231	8.5.3 Doubly Multivariate Designs	277
7.6.1.3 Linearity	231	8.5.4 Classifying Profiles	279
7.6.1.4 Outliers	232	8.5.5 Imputation of Missing Values	279
7.6.1.5 Homogeneity of Variance–Covariance Matrices	233	8.6 Complete Examples of Profile Analysis	280
7.6.1.6 Homogeneity of Regression	233	8.6.1 Profile Analysis of Subscales of the WISC	280
7.6.1.7 Reliability of Covariates	235	8.6.1.1 Evaluation of Assumptions	280
7.6.1.8 Multicollinearity and Singularity	235	8.6.1.2 Profile Analysis	283
7.6.2 Multivariate Analysis of Variance	235	8.6.2 Doubly Multivariate Analysis of Reaction Time	288
7.6.3 Multivariate Analysis of Covariance	244	8.6.2.1 Evaluation of Assumptions	289
7.6.3.1 Assessing Covariates	244	8.6.2.2 Doubly Multivariate Analysis of Slope and Intercept	290
7.6.3.2 Assessing DVs	245	8.7 Comparison of Programs	297
7.7 Comparison of Programs	252	8.7.1 IBM SPSS Package	297
7.7.1 IBM SPSS Package	252	8.7.2 SAS System	298
7.7.2 SAS System	254	8.7.3 SYSTAT System	298
7.7.3 SYSTAT System	255	9 Discriminant Analysis	299
8 Profile Analysis: The Multivariate Approach to Repeated Measures	256	9.1 General Purpose and Description	299
8.1 General Purpose and Description	256	9.2 Kinds of Research Questions	302
8.2 Kinds of Research Questions	257	9.2.1 Significance of Prediction	302
8.2.1 Parallelism of Profiles	258	9.2.2 Number of Significant Discriminant Functions	302
8.2.2 Overall Difference Among Groups	258	9.2.3 Dimensions of Discrimination	302
8.2.3 Flatness of Profiles	258	9.2.4 Classification Functions	303
8.2.4 Contrasts Following Profile Analysis	258	9.2.5 Adequacy of Classification	303
8.2.5 Parameter Estimates	258	9.2.6 Effect Size	303
8.2.6 Effect Size	259	9.2.7 Importance of Predictor Variables	303
8.3 Limitations to Profile Analysis	259	9.2.8 Significance of Prediction with Covariates	304
8.3.1 Theoretical Issues	259	9.2.9 Estimation of Group Means	304
8.3.2 Practical Issues	259		
8.3.2.1 Sample Size, Missing Data, and Power	259		

9.3	Limitations to Discriminant Analysis	304	10	Logistic Regression	346
9.3.1	Theoretical Issues	304	10.1	General Purpose and Description	346
9.3.2	Practical Issues	304	10.2	Kinds of Research Questions	348
9.3.2.1	Unequal Sample Sizes, Missing Data, and Power	304	10.2.1	Prediction of Group Membership or Outcome	348
9.3.2.2	Multivariate Normality	305	10.2.2	Importance of Predictors	348
9.3.2.3	Absence of Outliers	305	10.2.3	Interactions Among Predictors	349
9.3.2.4	Homogeneity of Variance–Covariance Matrices	305	10.2.4	Parameter Estimates	349
9.3.2.5	Linearity	306	10.2.5	Classification of Cases	349
9.3.2.6	Absence of Multicollinearity and Singularity	306	10.2.6	Significance of Prediction with Covariates	349
9.4	Fundamental Equations for Discriminant Analysis	306	10.2.7	Effect Size	349
9.4.1	Derivation and Test of Discriminant Functions	307	10.3	Limitations to Logistic Regression Analysis	350
9.4.2	Classification	309	10.3.1	Theoretical Issues	350
9.4.3	Computer Analyses of Small-Sample Example	311	10.3.2	Practical Issues	350
9.5	Types of Discriminant Analyses	315	10.3.2.1	Ratio of Cases to Variables	350
9.5.1	Direct Discriminant Analysis	315	10.3.2.2	Adequacy of Expected Frequencies and Power	351
9.5.2	Sequential Discriminant Analysis	315	10.3.2.3	Linearity in the Logit	351
9.5.3	Stepwise (Statistical) Discriminant Analysis	316	10.3.2.4	Absence of Multicollinearity	351
9.6	Some Important Issues	316	10.3.2.5	Absence of Outliers in the Solution	351
9.6.1	Statistical Inference	316	10.3.2.6	Independence of Errors	352
9.6.1.1	Criteria for Overall Statistical Significance	317	10.4	Fundamental Equations for Logistic Regression	352
9.6.1.2	Stepping Methods	317	10.4.1	Testing and Interpreting Coefficients	353
9.6.2	Number of Discriminant Functions	317	10.4.2	Goodness of Fit	354
9.6.3	Interpreting Discriminant Functions	318	10.4.3	Comparing Models	355
9.6.3.1	Discriminant Function Plots	318	10.4.4	Interpretation and Analysis of Residuals	355
9.6.3.2	Structure Matrix of Loadings	318	10.4.5	Computer Analyses of Small-Sample Example	356
9.6.4	Evaluating Predictor Variables	320	10.5	Types of Logistic Regression	360
9.6.5	Effect Size	321	10.5.1	Direct Logistic Regression	360
9.6.6	Design Complexity: Factorial Designs	321	10.5.2	Sequential Logistic Regression	360
9.6.7	Use of Classification Procedures	322	10.5.3	Statistical (Stepwise) Logistic Regression	362
9.6.7.1	Cross-Validation and New Cases	322	10.5.4	Probit and Other Analyses	362
9.6.7.2	Jackknifed Classification	323	10.6	Some Important Issues	363
9.6.7.3	Evaluating Improvement in Classification	323	10.6.1	Statistical Inference	363
9.7	Complete Example of Discriminant Analysis	324	10.6.1.1	Assessing Goodness of Fit of Models	363
9.7.1	Evaluation of Assumptions	325	10.6.1.2	Tests of Individual Predictors	365
9.7.1.1	Unequal Sample Sizes and Missing Data	325	10.6.2	Effect Sizes	365
9.7.1.2	Multivariate Normality	325	10.6.2.1	Effect Size for a Model	365
9.7.1.3	Linearity	325	10.6.2.2	Effect Sizes for Predictors	366
9.7.1.4	Outliers	325	10.6.3	Interpretation of Coefficients Using Odds	367
9.7.1.5	Homogeneity of Variance–Covariance Matrices	326	10.6.4	Coding Outcome and Predictor Categories	368
9.7.1.6	Multicollinearity and Singularity	327	10.6.5	Number and Type of Outcome Categories	369
9.7.2	Direct Discriminant Analysis	327	10.6.6	Classification of Cases	372
9.8	Comparison of Programs	340	10.6.7	Hierarchical and Nonhierarchical Analysis	372
9.8.1	IBM SPSS Package	344			
9.8.2	SAS System	344			
9.8.3	SYSTAT System	345			

10.6.8	Importance of Predictors	373	11.4.2	Standard Error of Cumulative Proportion Surviving	408
10.6.9	Logistic Regression for Matched Groups	374	11.4.3	Hazard and Density Functions	408
10.7	Complete Examples of Logistic Regression	374	11.4.4	Plot of Life Tables	409
10.7.1	Evaluation of Limitations	374	11.4.5	Test for Group Differences	410
10.7.1.1	Ratio of Cases to Variables and Missing Data	374	11.4.6	Computer Analyses of Small-Sample Example	411
10.7.1.2	Multicollinearity	376	11.5	Types of Survival Analyses	415
10.7.1.3	Outliers in the Solution	376	11.5.1	Actuarial and Product-Limit Life Tables and Survivor Functions	415
10.7.2	Direct Logistic Regression with Two-Category Outcome and Continuous Predictors	377	11.5.2	Prediction of Group Survival Times from Covariates	417
10.7.2.1	Limitation: Linearity in the Logit	377	11.5.2.1	Direct, Sequential, and Statistical Analysis	417
10.7.2.2	Direct Logistic Regression with Two-Category Outcome	377	11.5.2.2	Cox Proportional-Hazards Model	417
10.7.3	Sequential Logistic Regression with Three Categories of Outcome	384	11.5.2.3	Accelerated Failure-Time Models	419
10.7.3.1	Limitations of Multinomial Logistic Regression	384	11.5.2.4	Choosing a Method	423
10.7.3.2	Sequential Multinomial Logistic Regression	387	11.6	Some Important Issues	423
10.8	Comparison of Programs	396	11.6.1	Proportionality of Hazards	423
10.8.1	IBM SPSS Package	396	11.6.2	Censored Data	424
10.8.2	SAS System	399	11.6.2.1	Right-Censored Data	425
10.8.3	SYSTAT System	400	11.6.2.2	Other Forms of Censoring	425
11	Survival/Failure Analysis	401	11.6.3	Effect Size and Power	425
11.1	General Purpose and Description	401	11.6.4	Statistical Criteria	426
11.2	Kinds of Research Questions	403	11.6.4.1	Test Statistics for Group Differences in Survival Functions	426
11.2.1	Proportions Surviving at Various Times	403	11.6.4.2	Test Statistics for Prediction from Covariates	427
11.2.2	Group Differences in Survival	403	11.6.5	Predicting Survival Rate	427
11.2.3	Survival Time with Covariates	403	11.6.5.1	Regression Coefficients (Parameter Estimates)	427
11.2.3.1	Treatment Effects	403	11.6.5.2	Hazard Ratios	427
11.2.3.2	Importance of Covariates	403	11.6.5.3	Expected Survival Rates	428
11.2.3.3	Parameter Estimates	404	11.7	Complete Example of Survival Analysis	429
11.2.3.4	Contingencies Among Covariates	404	11.7.1	Evaluation of Assumptions	430
11.2.3.5	Effect Size and Power	404	11.7.1.1	Accuracy of Input, Adequacy of Sample Size, Missing Data, and Distributions	430
11.3	Limitations to Survival Analysis	404	11.7.1.2	Outliers	430
11.3.1	Theoretical Issues	404	11.7.1.3	Differences Between Withdrawn and Remaining Cases	433
11.3.2	Practical Issues	404	11.7.1.4	Change in Survival Experience over Time	433
11.3.2.1	Sample Size and Missing Data	404	11.7.1.5	Proportionality of Hazards	433
11.3.2.2	Normality of Sampling Distributions, Linearity, and Homoscedasticity	405	11.7.1.6	Multicollinearity	434
11.3.2.3	Absence of Outliers	405	11.7.2	Cox Regression Survival Analysis	436
11.3.2.4	Differences Between Withdrawn and Remaining Cases	405	11.7.2.1	Effect of Drug Treatment	436
11.3.2.5	Change in Survival Conditions over Time	405	11.7.2.2	Evaluation of Other Covariates	436
11.3.2.6	Proportionality of Hazards	405	11.8	Comparison of Programs	440
11.3.2.7	Absence of Multicollinearity	405	11.8.1	SAS System	444
11.4	Fundamental Equations for Survival Analysis	405	11.8.2	IBM SPSS Package	445
11.4.1	Life Tables	406	11.8.3	SYSTAT System	445
			12	Canonical Correlation	446
			12.1	General Purpose and Description	446
			12.2	Kinds of Research Questions	448

12.2.1	Number of Canonical Variate Pairs	448	13.3.2.5	Absence of Multicollinearity and Singularity	482
12.2.2	Interpretation of Canonical Variates	448	13.3.2.6	Factorability of R	482
12.2.3	Importance of Canonical Variates and Predictors	448	13.3.2.7	Absence of Outliers Among Variables	483
12.2.4	Canonical Variate Scores	449	13.4	Fundamental Equations for Factor Analysis	483
12.3	Limitations	449	13.4.1	Extraction	485
12.3.1	Theoretical Limitations	449	13.4.2	Orthogonal Rotation	487
12.3.2	Practical Issues	450	13.4.3	Communalities, Variance, and Covariance	488
12.3.2.1	Ratio of Cases to IVs	450	13.4.4	Factor Scores	489
12.3.2.2	Normality, Linearity, and Homoscedasticity	450	13.4.5	Oblique Rotation	491
12.3.2.3	Missing Data	451	13.4.6	Computer Analyses of Small-Sample Example	493
12.3.2.4	Absence of Outliers	451	13.5	Major Types of Factor Analyses	496
12.3.2.5	Absence of Multicollinearity and Singularity	451	13.5.1	Factor Extraction Techniques	496
12.4	Fundamental Equations for Canonical Correlation	451	13.5.1.1	PCA Versus FA	496
12.4.1	Eigenvalues and Eigenvectors	452	13.5.1.2	Principal Components	498
12.4.2	Matrix Equations	454	13.5.1.3	Principal Factors	498
12.4.3	Proportions of Variance Extracted	457	13.5.1.4	Image Factor Extraction	498
12.4.4	Computer Analyses of Small-Sample Example	458	13.5.1.5	Maximum Likelihood Factor Extraction	499
12.5	Some Important Issues	462	13.5.1.6	Unweighted Least Squares Factoring	499
12.5.1	Importance of Canonical Variates	462	13.5.1.7	Generalized (Weighted) Least Squares Factoring	499
12.5.2	Interpretation of Canonical Variates	463	13.5.1.8	Alpha Factoring	499
12.6	Complete Example of Canonical Correlation	463	13.5.2	Rotation	500
12.6.1	Evaluation of Assumptions	463	13.5.2.1	Orthogonal Rotation	500
12.6.1.1	Missing Data	463	13.5.2.2	Oblique Rotation	501
12.6.1.2	Normality, Linearity, and Homoscedasticity	463	13.5.2.3	Geometric Interpretation	502
12.6.1.3	Outliers	466	13.5.3	Some Practical Recommendations	503
12.6.1.4	Multicollinearity and Singularity	467	13.6	Some Important Issues	504
12.6.2	Canonical Correlation	467	13.6.1	Estimates of Communalities	504
12.7	Comparison of Programs	473	13.6.2	Adequacy of Extraction and Number of Factors	504
12.7.1	SAS System	473	13.6.3	Adequacy of Rotation and Simple Structure	507
12.7.2	IBM SPSS Package	474	13.6.4	Importance and Internal Consistency of Factors	508
12.7.3	SYSTAT System	475	13.6.5	Interpretation of Factors	509
			13.6.6	Factor Scores	510
			13.6.7	Comparisons Among Solutions and Groups	511
13	Principal Components and Factor Analysis	476	13.7	Complete Example of FA	511
13.1	General Purpose and Description	476	13.7.1	Evaluation of Limitations	511
13.2	Kinds of Research Questions	479	13.7.1.1	Sample Size and Missing Data	512
13.2.1	Number of Factors	479	13.7.1.2	Normality	512
13.2.2	Nature of Factors	479	13.7.1.3	Linearity	512
13.2.3	Importance of Solutions and Factors	480	13.7.1.4	Outliers	513
13.2.4	Testing Theory in FA	480	13.7.1.5	Multicollinearity and Singularity	514
13.2.5	Estimating Scores on Factors	480	13.7.1.6	Factorability of R	514
13.3	Limitations	480	13.7.1.7	Outliers Among Variables	515
13.3.1	Theoretical Issues	480	13.7.2	Principal Factors Extraction with Varimax Rotation	515
13.3.2	Practical Issues	481			
13.3.2.1	Sample Size and Missing Data	481			
13.3.2.2	Normality	482			
13.3.2.3	Linearity	482			
13.3.2.4	Absence of Outliers Among Cases	482			

13.8 Comparison of Programs	525
13.8.1 IBM SPSS Package	527
13.8.2 SAS System	527
13.8.3 SYSTAT System	527

14 Structural Equation Modeling by Jodie B. Ullman 528

14.1 General Purpose and Description	528
14.2 Kinds of Research Questions	531
14.2.1 Adequacy of the Model	531
14.2.2 Testing Theory	531
14.2.3 Amount of Variance in the Variables Accounted for by the Factors	532
14.2.4 Reliability of the Indicators	532
14.2.5 Parameter Estimates	532
14.2.6 Intervening Variables	532
14.2.7 Group Differences	532
14.2.8 Longitudinal Differences	532
14.2.9 Multilevel Modeling	533
14.2.10 Latent Class Analysis	533
14.3 Limitations to Structural Equation Modeling	533
14.3.1 Theoretical Issues	533
14.3.2 Practical Issues	534
14.3.2.1 Sample Size and Missing Data	534
14.3.2.2 Multivariate Normality and Outliers	534
14.3.2.3 Linearity	534
14.3.2.4 Absence of Multicollinearity and Singularity	535
14.3.2.5 Residuals	535
14.4 Fundamental Equations for Structural Equations Modeling	535
14.4.1 Covariance Algebra	535
14.4.2 Model Hypotheses	537
14.4.3 Model Specification	538
14.4.4 Model Estimation	540
14.4.5 Model Evaluation	543
14.4.6 Computer Analysis of Small-Sample Example	545
14.5 Some Important Issues	555
14.5.1 Model Identification	555
14.5.2 Estimation Techniques	557
14.5.2.1 Estimation Methods and Sample Size	559
14.5.2.2 Estimation Methods and Nonnormality	559
14.5.2.3 Estimation Methods and Dependence	559
14.5.2.4 Some Recommendations for Choice of Estimation Method	560
14.5.3 Assessing the Fit of the Model	560
14.5.3.1 Comparative Fit Indices	560
14.5.3.2 Absolute Fit Index	562

14.5.3.3 Indices of Proportion of Variance Accounted	562
14.5.3.4 Degree of Parsimony Fit Indices	563
14.5.3.5 Residual-Based Fit Indices	563
14.5.3.6 Choosing Among Fit Indices	564
14.5.4 Model Modification	564
14.5.4.1 Chi-Square Difference Test	564
14.5.4.2 Lagrange Multiplier (LM) Test	565
14.5.4.3 Wald Test	569
14.5.4.4 Some Caveats and Hints on Model Modification	570
14.5.5 Reliability and Proportion of Variance	570
14.5.6 Discrete and Ordinal Data	571
14.5.7 Multiple Group Models	572
14.5.8 Mean and Covariance Structure Models	573
14.6 Complete Examples of Structural Equation Modeling Analysis	574
14.6.1 Confirmatory Factor Analysis of the WISC	574
14.6.1.1 Model Specification for CFA	574
14.6.1.2 Evaluation of Assumptions for CFA	574
14.6.1.3 CFA Model Estimation and Preliminary Evaluation	576
14.6.1.4 Model Modification	583
14.6.2 SEM of Health Data	589
14.6.2.1 SEM Model Specification	589
14.6.2.2 Evaluation of Assumptions for SEM	591
14.6.2.3 SEM Model Estimation and Preliminary Evaluation	593
14.6.2.4 Model Modification	596
14.7 Comparison of Programs	607
14.7.1 EQS	607
14.7.2 LISREL	607
14.7.3 AMOS	612
14.7.4 SAS System	612

15 Multilevel Linear Modeling 613

15.1 General Purpose and Description	613
15.2 Kinds of Research Questions	616
15.2.1 Group Differences in Means	616
15.2.2 Group Differences in Slopes	616
15.2.3 Cross-Level Interactions	616
15.2.4 Meta-Analysis	616
15.2.5 Relative Strength of Predictors at Various Levels	617
15.2.6 Individual and Group Structure	617
15.2.7 Effect Size	617
15.2.8 Path Analysis at Individual and Group Levels	617
15.2.9 Analysis of Longitudinal Data	617
15.2.10 Multilevel Logistic Regression	618
15.2.11 Multiple Response Analysis	618

15.3	Limitations to Multilevel Linear Modeling	618	15.7.1.1	Sample Sizes, Missing Data, and Distributions	656
15.3.1	Theoretical Issues	618	15.7.1.2	Outliers	659
15.3.2	Practical Issues	618	15.7.1.3	Multicollinearity and Singularity	659
15.3.2.1	Sample Size, Unequal- <i>n</i> , and Missing Data	619	15.7.1.4	Independence of Errors: Intraclass Correlations	659
15.3.2.2	Independence of Errors	619	15.7.2	Multilevel Modeling	661
15.3.2.3	Absence of Multicollinearity and Singularity	620	15.8	Comparison of Programs	668
15.4	Fundamental Equations	620	15.8.1	SAS System	668
15.4.1	Intercepts-Only Model	623	15.8.2	IBM SPSS Package	670
15.4.1.1	The Intercepts-Only Model: Level-1 Equation	623	15.8.3	HLM Program	671
15.4.1.2	The Intercepts-Only Model: Level-2 Equation	623	15.8.4	MLwiN Program	671
15.4.1.3	Computer Analyses of Intercepts-Only Model	624	15.8.5	SYSTAT System	671
15.4.2	Model with a First-Level Predictor	627	16	Multway Frequency Analysis	672
15.4.2.1	Level-1 Equation for a Model with a Level-1 Predictor	627	16.1	General Purpose and Description	672
15.4.2.2	Level-2 Equations for a Model with a Level-1 Predictor	628	16.2	Kinds of Research Questions	673
15.4.2.3	Computer Analysis of a Model with a Level-1 Predictor	630	16.2.1	Associations Among Variables	673
15.4.3	Model with Predictors at First and Second Levels	633	16.2.2	Effect on a Dependent Variable	674
15.4.3.1	Level-1 Equation for Model with Predictors at Both Levels	633	16.2.3	Parameter Estimates	674
15.4.3.2	Level-2 Equations for Model with Predictors at Both Levels	633	16.2.4	Importance of Effects	674
15.4.3.3	Computer Analyses of Model with Predictors at First and Second Levels	634	16.2.5	Effect Size	674
15.5	Types of MLM	638	16.2.6	Specific Comparisons and Trend Analysis	674
15.5.1	Repeated Measures	638	16.3	Limitations to Multiway Frequency Analysis	675
15.5.2	Higher-Order MLM	642	16.3.1	Theoretical Issues	675
15.5.3	Latent Variables	642	16.3.2	Practical Issues	675
15.5.4	Nonnormal Outcome Variables	643	16.3.2.1	Independence	675
15.5.5	Multiple Response Models	644	16.3.2.2	Ratio of Cases to Variables	675
15.6	Some Important Issues	644	16.3.2.3	Adequacy of Expected Frequencies	675
15.6.1	Intraclass Correlation	644	16.3.2.4	Absence of Outliers in the Solution	676
15.6.2	Centering Predictors and Changes in Their Interpretations	646	16.4	Fundamental Equations for Multiway Frequency Analysis	676
15.6.3	Interactions	648	16.4.1	Screening for Effects	678
15.6.4	Random and Fixed Intercepts and Slopes	648	16.4.1.1	Total Effect	678
15.6.5	Statistical Inference	651	16.4.1.2	First-Order Effects	679
15.6.5.1	Assessing Models	651	16.4.1.3	Second-Order Effects	679
15.6.5.2	Tests of Individual Effects	652	16.4.1.4	Third-Order Effect	683
15.6.6	Effect Size	653	16.4.2	Modeling	683
15.6.7	Estimation Techniques and Convergence Problems	653	16.4.3	Evaluation and Interpretation	685
15.6.8	Exploratory Model Building	654	16.4.3.1	Residuals	685
15.7	Complete Example of MLM	655	16.4.3.2	Parameter Estimates	686
15.7.1	Evaluation of Assumptions	656	16.4.4	Computer Analyses of Small-Sample Example	690
			16.5	Some Important Issues	695
			16.5.1	Hierarchical and Nonhierarchical Models	695
			16.5.2	Statistical Criteria	696
			16.5.2.1	Tests of Models	696
			16.5.2.2	Tests of Individual Effects	696
			16.5.3	Strategies for Choosing a Model	696
			16.5.3.1	IBM SPSS HILOGLINEAR (Hierarchical)	697

16.5.3.2 IBM SPSS GENLOG (General Log-Linear)	697	17.5.2.1 Abrupt, Permanent Effects	741
16.5.3.3 SAS CATMOD and IBM SPSS LOGLINEAR (General Log-Linear)	697	17.5.2.2 Abrupt, Temporary Effects	742
16.6 Complete Example of Multiway Frequency Analysis	698	17.5.2.3 Gradual, Permanent Effects	745
16.6.1 Evaluation of Assumptions: Adequacy of Expected Frequencies	698	17.5.2.4 Models with Multiple Interventions	746
16.6.2 Hierarchical Log-Linear Analysis	700	17.5.3 Adding Continuous Variables	747
16.6.2.1 Preliminary Model Screening	700	17.6 Some Important Issues	748
16.6.2.2 Stepwise Model Selection	702	17.6.1 Patterns of ACFs and PACFs	748
16.6.2.3 Adequacy of Fit	702	17.6.2 Effect Size	751
16.6.2.4 Interpretation of the Selected Model	705	17.6.3 Forecasting	752
16.7 Comparison of Programs	710	17.6.4 Statistical Methods for Comparing Two Models	752
16.7.1 IBM SPSS Package	710	17.7 Complete Examples of Time-Series Analysis	753
16.7.2 SAS System	712	17.7.1 Time-Series Analysis of Introduction of Seat Belt Law	753
16.7.3 SYSTAT System	713	17.7.1.1 Evaluation of Assumptions	754
17 Time-Series Analysis	714	17.7.1.2 Baseline Model Identification and Estimation	755
17.1 General Purpose and Description	714	17.7.1.3 Baseline Model Diagnosis	758
17.2 Kinds of Research Questions	716	17.7.1.4 Intervention Analysis	758
17.2.1 Pattern of Autocorrelation	717	17.7.2. Time-Series Analysis of Introduction of a Dashboard to an Educational Computer Game	762
17.2.2 Seasonal Cycles and Trends	717	17.7.2.1 Evaluation of Assumptions	763
17.2.3 Forecasting	717	17.7.2.2 Baseline Model Identification and Diagnosis	765
17.2.4 Effect of an Intervention	718	17.7.2.3 Intervention Analysis	766
17.2.5 Comparing Time Series	718	17.8 Comparison of Programs	771
17.2.6 Time Series with Covariates	718	17.8.1 IBM SPSS Package	771
17.2.7 Effect Size and Power	718	17.8.2 SAS System	774
17.3 Assumptions of Time-Series Analysis	718	17.8.3 SYSTAT System	774
17.3.1 Theoretical Issues	718	18 An Overview of the General Linear Model	775
17.3.2 Practical Issues	718	18.1 Linearity and the General Linear Model	775
17.3.2.1 Normality of Distributions of Residuals	719	18.2 Bivariate to Multivariate Statistics and Overview of Techniques	775
17.3.2.2 Homogeneity of Variance and Zero Mean of Residuals	719	18.2.1 Bivariate Form	775
17.3.2.3 Independence of Residuals	719	18.2.2 Simple Multivariate Form	777
17.3.2.4 Absence of Outliers	719	18.2.3 Full Multivariate Form	778
17.3.2.5 Sample Size and Missing Data	719	18.3 Alternative Research Strategies	782
17.4 Fundamental Equations for Time-Series ARIMA Models	720	Appendix A	
17.4.1 Identification of ARIMA (p, d, q) Models	720	A Skippy Introduction to Matrix Algebra	783
17.4.1.1 Trend Components, d : Making the Process Stationary	721	A.1 The Trace of a Matrix	784
17.4.1.2 Auto-Regressive Components	722	A.2 Addition or Subtraction of a Constant to a Matrix	784
17.4.1.3 Moving Average Components	724	A.3 Multiplication or Division of a Matrix by a Constant	784
17.4.1.4 Mixed Models	724	A.4 Addition and Subtraction of Two Matrices	785
17.4.1.5 ACFs and PACFs	724	A.5 Multiplication, Transposes, and Square Roots of Matrice	785
17.4.2 Estimating Model Parameters	729		
17.4.3 Diagnosing a Model	729		
17.4.4 Computer Analysis of Small-Sample Time-Series Example	734		
17.5 Types of Time-Series Analyses	737		
17.5.1 Models with Seasonal Components	737		
17.5.2 Models with Interventions	738		

A.6 Matrix “Division” (Inverses and Determinants)	786
A.7 Eigenvalues and Eigenvectors: Procedures for Consolidating Variance from a Matrix	788

Appendix B

Research Designs for Complete Examples	791
B.1 Women’s Health and Drug Study	791
B.2 Sexual Attraction Study	793
B.3 Learning Disabilities Data Bank	794
B.4 Reaction Time to Identify Figures	794
B.5 Field Studies of Noise-Induced Sleep Disturbance	795
B.6 Clinical Trial for Primary Biliary Cirrhosis	795

B.7 Impact of Seat Belt Law	795
B.8 The Selene Online Educational Game	796

Appendix C

Statistical Tables	797
C.1 Normal Curve Areas	798
C.2 Critical Values of the t Distribution for $\alpha = .05$ and $.01$, Two-Tailed Test	799
C.3 Critical Values of the F Distribution	800
C.4 Critical Values of Chi Square (χ^2)	804
C.5 Critical Values for Squares Multiple Correlation (R^2) in Forward Stepwise Selection: $\alpha = .05$	805
C.6 Critical Values for $F_{MAX} (S^2_{MAX}/S^2_{MIN})$ Distribution for $\alpha = .05$ and $.01$	807
References	808
Index	815

Preface

Some good things seem to go on forever: friendship and updating this book. It is difficult to believe that the first edition manuscript was typewritten, with real cutting and pasting. The publisher required a paper manuscript with numbered pages—that was almost our downfall. We could write a book on multivariate statistics, but we couldn't get the same number of pages (about 1200, double-spaced) twice in a row. SPSS was in release 9.0, and the other program we demonstrated was BMDP. There were a mere 11 chapters, of which 6 of them were describing techniques. Multilevel and structural equation modeling were not yet ready for prime time. Logistic regression and survival analysis were not yet popular.

Material new to this edition includes a redo of all SAS examples, with a pretty new output format and replacement of interactive analyses that are no longer available. We've also re-run the IBM SPSS examples to show the new output format. We've tried to update the references in all chapters, including only classic citations if they date prior to 2000. New work on relative importance has been incorporated in multiple regression, canonical correlation, and logistic regression analysis—complete with demonstrations. Multiple imputation procedures for dealing with missing data have been updated, and we've added a new time-series example, taking advantage of an IBM SPSS expert modeler that replaces previous tea-leaf reading aspects of the analysis.

Our goals in writing the book remain the same as in all previous editions—to present complex statistical procedures in a way that is maximally useful and accessible to researchers who are not necessarily statisticians. We strive to be short on theory but long on conceptual understanding. The statistical packages have become increasingly easy to use, making it all the more critical to make sure that they are applied with a good understanding of what they can and cannot do. But above all else—what does it all mean?

We have not changed the basic format underlying all of the technique chapters, now 14 of them. We start with an overview of the technique, followed by the types of research questions the techniques are designed to answer. We then provide the cautionary tale—what you need to worry about and how to deal with those worries. Then come the fundamental equations underlying the technique, which some readers truly enjoy working through (we know because they helpfully point out any errors and/or inconsistencies they find); but other readers discover they can skim (or skip) the section without any loss to their ability to conduct meaningful analysis of their research. The fundamental equations are in the context of a small, made-up, usually silly data set for which computer analyses are provided—usually IBM SPSS and SAS. Next, we delve into issues surrounding the technique (such as different types of the analysis, follow-up procedures to the main analysis, and effect size, if it is not amply covered elsewhere). Finally, we provide one or two full-bore analyses of an actual real-life data set together with a Results section appropriate for a journal. Data sets for these examples are available at www.pearsonhighered.com in IBM SPSS, SAS, and ASCII formats. We end each technique chapter with a comparison of features available in IBM SPSS, SAS, SYSTAT and sometimes other specialized programs. SYSTAT is a statistical package that we reluctantly had to drop a few editions ago for lack of space.

We apologize in advance for the heft of the book; it is not our intention to line the coffers of chiropractors, physical therapists, acupuncturists, and the like, but there's really just so much to say. As to our friendship, it's still going strong despite living in different cities. Art has taken the place of creating belly dance costumes for both of us, but we remain silly in outlook, although serious in our analysis of research.

The lineup of people to thank grows with each edition, far too extensive to list: students, reviewers, editors, and readers who send us corrections and point out areas of confusion. As always, we take full responsibility for remaining errors and lack of clarity.

*Barbara G. Tabachnick
Linda S. Fidell*

To locate your representative, use the Rep Locator tool. These are data files for the complete examples of Chapters 4 through 16 and 18, Using Multivariate Statistics, 6th edition. File names are referred to generically in the book, for example, SCREEN.*, and files are in two formats. Formats are as follows