
Contents

Preface ix

Chapter 1 Introduction to Multivariate Statistics

1.1 Definition of Multivariate Statistics 1
1.2 Relationship of Multivariate Statistics
to Univariate Statistics 5
1.3 Choice of Variables and Multivariate Method,
and the Concept of Optimal Linear Combination 7
1.4 Data for Multivariate Analyses 8
1.5 Three Fundamental Matrices in Multivariate Statistics 11
1.5.1 Covariance Matrix 12
1.5.2 Correlation Matrix 13
1.5.3 Sums-of-Squares and Cross-Products Matrix 15
1.6 Illustration Using Statistical Software 17

Chapter 2 Elements of Matrix Theory

2.1 Matrix Definition 31
2.2 Matrix Operations, Determinant, and Trace 33
2.3 Using SPSS and SAS for Matrix Operations 46
2.4 General Form of Matrix Multiplications With Vector,
and Representation of the Covariance, Correlation,
and Sum-of-Squares and Cross-Product Matrices 50
2.4.1 Linear Modeling and Matrix Multiplication 50
2.4.2 Three Fundamental Matrices of Multivariate Statistics
in Compact Form 51
2.5 Raw Data Points in Higher Dimensions, and Distance
Between Them 54

Chapter 3 Data Screening and Preliminary Analyses

3.1 Initial Data Exploration 61
3.2 Outliers and the Search for Them 69
3.2.1 Univariate Outliers 69
3.2.2 Multivariate Outliers 71
3.2.3 Handling Outliers: A Revisit 78
3.3 Checking of Variable Distribution Assumptions 80
3.4 Variable Transformations 83

Chapter 4	Multivariate Analysis of Group Differences	
4.1	A Start-Up Example	99
4.2	A Definition of the Multivariate Normal Distribution	101
4.3	Testing Hypotheses About a Multivariate Mean.....	102
4.3.1	The Case of Known Covariance Matrix.....	103
4.3.2	The Case of Unknown Covariance Matrix.....	107
4.4	Testing Hypotheses About Multivariate Means of Two Groups	110
4.4.1	Two Related or Matched Samples (Change Over Time)	110
4.4.2	Two Unrelated (Independent) Samples.....	113
4.5	Testing Hypotheses About Multivariate Means in One-Way and Higher Order Designs (Multivariate Analysis of Variance, MANOVA).....	116
4.5.1	Statistical Significance Versus Practical Importance	129
4.5.2	Higher Order MANOVA Designs.....	130
4.5.3	Other Test Criteria	132
4.6	MANOVA Follow-Up Analyses	143
4.7	Limitations and Assumptions of MANOVA.....	145
Chapter 5	Repeated Measure Analysis of Variance	
5.1	Between-Subject and Within-Subject Factors and Designs.....	148
5.2	Univariate Approach to Repeated Measure Analysis	150
5.3	Multivariate Approach to Repeated Measure Analysis	168
5.4	Comparison of Univariate and Multivariate Approaches to Repeated Measure Analysis.....	179
Chapter 6	Analysis of Covariance	
6.1	Logic of Analysis of Covariance.....	182
6.2	Multivariate Analysis of Covariance.....	192
6.3	Step-Down Analysis (Roy–Bargmann Analysis)	198
6.4	Assumptions of Analysis of Covariance	203
Chapter 7	Principal Component Analysis	
7.1	Introduction	211
7.2	Beginnings of Principal Component Analysis	213
7.3	How Does Principal Component Analysis Proceed?.....	220
7.4	Illustrations of Principal Component Analysis	224
7.4.1	Analysis of the Covariance Matrix Σ (S) of the Original Variables	224
7.4.2	Analysis of the Correlation Matrix P (R) of the Original Variables	224
7.5	Using Principal Component Analysis in Empirical Research.....	234

7.5.1	Multicollinearity Detection	234
7.5.2	PCA With Nearly Uncorrelated Variables Is Meaningless.....	235
7.5.3	Can PCA Be Used as a Method for Observed Variable Elimination?	236
7.5.4	Which Matrix Should Be Analyzed?.....	236
7.5.5	PCA as a Helpful Aid in Assessing Multinormality	237
7.5.6	PCA as “Orthogonal” Regression	237
7.5.7	PCA Is Conducted via Factor Analysis Routines in Some Software	237
7.5.8	PCA as a Rotation of Original Coordinate Axes.....	238
7.5.9	PCA as a Data Exploratory Technique.....	238

Chapter 8 Exploratory Factor Analysis

8.1	Introduction	241
8.2	Model of Factor Analysis	242
8.3	How Does Factor Analysis Proceed?.....	248
8.3.1	Factor Extraction	248
8.3.1.1	Principal Component Method.....	248
8.3.1.2	Maximum Likelihood Factor Analysis.....	256
8.3.2	Factor Rotation	262
8.3.2.1	Orthogonal Rotation	266
8.3.2.2	Oblique Rotation	267
8.4	Heywood Cases	273
8.5	Factor Score Estimation.....	273
8.5.1	Weighted Least Squares Method (Generalized Least Squares Method)	274
8.5.2	Regression Method	274
8.6	Comparison of Factor Analysis and Principal Component Analysis	276

Chapter 9 Confirmatory Factor Analysis

9.1	Introduction	279
9.2	A Start-Up Example	279
9.3	Confirmatory Factor Analysis Model.....	281
9.4	Fitting Confirmatory Factor Analysis Models	284
9.5	A Brief Introduction to <i>Mplus</i> , and Fitting the Example Model.....	287
9.6	Testing Parameter Restrictions in Confirmatory Factor Analysis Models	298
9.7	Specification Search and Model Fit Improvement.....	300
9.8	Fitting Confirmatory Factor Analysis Models to the Mean and Covariance Structure	307
9.9	Examining Group Differences on Latent Variables.....	314

Chapter 10 Discriminant Function Analysis

10.1	Introduction	331
10.2	What Is Discriminant Function Analysis?.....	332
10.3	Relationship of Discriminant Function Analysis to Other Multivariate Statistical Methods.....	334
10.4	Discriminant Function Analysis With Two Groups	336
10.5	Relationship Between Discriminant Function and Regression Analysis With Two Groups	351
10.6	Discriminant Function Analysis With More Than Two Groups	353
10.7	Tests in Discriminant Function Analysis	355
10.8	Limitations of Discriminant Function Analysis.....	364

Chapter 11 Canonical Correlation Analysis

11.1	Introduction	367
11.2	How Does Canonical Correlation Analysis Proceed?	370
11.3	Tests and Interpretation of Canonical Variates	372
11.4	Canonical Correlation Approach to Discriminant Analysis.....	384
11.5	Generality of Canonical Correlation Analysis	389

**Chapter 12 An Introduction to the Analysis
of Missing Data**

12.1	Goals of Missing Data Analysis.....	391
12.2	Patterns of Missing Data	392
12.3	Mechanisms of Missing Data	394
12.3.1	Missing Completely at Random	396
12.3.2	Missing at Random.....	398
12.3.3	Ignorable Missingness and Nonignorable Missingness Mechanisms	400
12.4	Traditional Ways of Dealing With Missing Data	401
12.4.1	Listwise Deletion.....	402
12.4.2	Pairwise Deletion	402
12.4.3	Dummy Variable Adjustment.....	403
12.4.4	Simple Imputation Methods.....	403
12.4.5	Weighting Methods	405
12.5	Full Information Maximum Likelihood and Multiple Imputation.....	406
12.6	Examining Group Differences and Similarities in the Presence of Missing Data.....	407
12.6.1	Examining Group Mean Differences With Incomplete Data	410
12.6.2	Testing for Group Differences in the Covariance and Correlation Matrices With Missing Data.....	427

Chapter 13	Multivariate Analysis of Change Processes	
13.1	Introduction	433
13.2	Modeling Change Over Time With Time-Invariant and Time-Varying Covariates	434
13.2.1	Intercept-and-Slope Model	435
13.2.2	Inclusion of Time-Varying and Time-Invariant Covariates.....	436
13.2.3	An Example Application.....	437
13.2.4	Testing Parameter Restrictions.....	442
13.3	Modeling General Forms of Change Over Time.....	448
13.3.1	Level-and-Shape Model.....	448
13.3.2	Empirical Illustration	450
13.3.3	Testing Special Patterns of Growth or Decline.....	455
13.3.4	Possible Causes of Inadmissible Solutions	459
13.4	Modeling Change Over Time With Incomplete Data.....	461
Appendix:	Variable Naming and Order for Data Files.....	467
References		469
Author Index		473
Subject Index		477