

Preface xiii

# PART ONE: CONCEPTUAL BASES OF EXPERIMENTAL DESIGN AND ANALYSIS 1

#### Chapter 1: The Logic of Experimental Design 3

The Traditional View of Science, 4
Responses to the Criticisms of the Idea of Pure Science, 6
Threats to the Validity of Inferences from Experiments, 25
Exercises, 34

#### Chapter 2: Introduction to the Fisher Tradition 36

Interpretation and Its Reasoned Basis, 38 A Discrete Probability Example, 39

Randomization Test, 44

Toward Tests Based on Distributional Assumptions, 49

Exercises, 56

# PART TWO: MODEL COMPARISONS FOR BETWEEN-SUBJECTS DESIGNS 61

Chapter 3: Introduction to Model Comparisons: One-Way Between-Subjects Designs 63

The General Linear Model, 65

One-Group Situation, 67

Two-Group Situation, 77
The General Case of One-Way Designs, 85

On Tests of Significance and Measures of Effect, 95

Measures of Effect, 97

Statistical Assumptions, 107 Power of the F Test: One-Way ANOVA, 113

Extension: Regression, 120

Exercises, 116

#### Chapter 4: Individual Comparisons of Means 129

Chapter in Individual Company

A Model Comparison Approach for Testing Individual Comparisons, 131 Complex Comparisons, 136

170

The t-Test Formulation of Hypothesis Testing for Contrasts, 144 Testing More Than One Contrast, 150 Exercises, 160

Extension: Matrix Formulation, 164

### Chapter 5: Testing Several Contrasts:

The Multiple-Comparisons Problem

Multiple Comparisons, 171

Multiple Planned Comparisons, 175

Pairwise Comparisons, 180

Post Hoc Complex Comparisons, 186

Other Multiple-Comparison Procedures, 192 Simultaneous Confidence Intervals, 197

Choosing an Appropriate Procedure, 198

Exercises, 202

Chapter 6: Trend Analysis 207

Quantitative Factors, 208

Concluding Comments, 234

Statistical Treatment of Trend Analysis, 209

Hypothesis Test of Slope Parameter, 214

Testing for Nonlinearity, 217

Testing Individual Higher-Order Trends, 221

Further Examination of Nonlinear Trends, 227

Trend Analysis with Unequal Sample Sizes, 233

Exercises, 235

Chapter 7: Two-Way Between-Subjects Factorial Designs

The  $2 \times 2$  Design, 242

A Model Comparison Approach to the General Two-Factor Design, 247

Follow-Up Tests, 260 Statistical Power, 269

Advantages of Factorial Designs, 270

Nonorthogonal Designs, 271

Analysis of the General  $a \times b$  Nonorthogonal Design, 281

Chapter 8: Higher-Order Between-Subjects Factorial Designs

241

309

Exercises, 297

The  $2 \times 2 \times 2$  Design, 310

The General A  $\times$  B  $\times$  C Design, 319

Numerical Example, 325 Nonorthogonal Designs, 340

Higher-Order Designs, 343
Exercises, 344

Chapter 9: Designs with Concomitant Variables: ANCOVA and Blocking 353

ANCOVA, 356

Alternate Methods of Analyzing Designs with Concomitant Variables, 391

Extension: Heterogeneity of Regression, 403

#### Chapter 10: Designs with Random or Nested Factors 421

Designs with Random Factors, 422

Designs with Nested Factors, 433

Exercises, 448

# PART THREE: MODEL COMPARISONS FOR DESIGNS INVOLVING WITHIN-SUBJECTS FACTORS 453

# Chapter 11: One-Way Within-Subjects Designs: Univariate Approach 455

Prototypical Within-Subjects Designs, 456

Advantages of Within-Subjects Designs, 458

Analysis of Repeated-Measures Designs with Two Levels, 458

Analysis of Within-Subjects Designs with More Than Two Levels, 463

Traditional Univariate (Mixed-Model) Approach, 463

Assumptions in the Traditional Univariate (Mixed-Model) Approach, 471

Adjusted Univariate Tests, 475

Comparisons Among Individual Means, 479

Considerations in Designing Within-Subjects Experiments, 481

Relative Advantages of Between-Subjects and Within-Subjects Designs, 487

Exercises, 488

# Chapter 12: Higher-Order Designs with Within-Subjects Factors: Univariate Approach 495

Designs with Two Within-Subjects Factors, 496

One Within-Subjects Factor and One Between-Subjects Factor in the

Same Design, 516

More Complex Designs, 536

Exercises, 543

Chapter 13: One-Way Within-Subjects Designs: Multivariate Approach 552

A Brief Review of Analysis for Designs with Two Levels, 553

Multivariate Analysis of Within-Subjects Designs with Three Levels, 555

Multivariate Analysis of Within-Subjects Designs with a Levels, 563

Choosing an Appropriate Sample Size, 568

Choice of D Variables, 575

Tests of Individual Contrasts, 577

Multiple-Comparison Procedures: Determination of Critical Values, 581

The Relationship Between the Multivariate Approach and the Mixed-Model Approach, 585

Multivariate and Mixed-Model Approaches for Testing Contrasts, 593

A General Comparison of the Multivariate and Mixed-Model Approaches, 600

Exercises, 606

### Chapter 14: Higher-Order Designs with Within-Subjects Factors: Multivariate Approach 612

Two Within-Subjects Factors, Each with Two Levels, 613

Multivariate Analysis of Two-Way  $a \times b$  Within-Subjects Designs, 620

One Within-Subjects Factor and One Between-Subjects Factor in the Same Design, 635

Optional: The Relationship Between the Multivariate and the Mixed-Model Approaches, 672

Assumptions of the Multivariate Approach, 674

Multivariate and Mixed-Model Approaches for Testing

Within-Subjects Contrasts, 675

Optional: More Complex Designs, 676

Exercises, 683

### PART FOUR: ALTERNATIVE ANALYSIS STRATEGIES

#### Chapter 15: Robust ANOVA and ANCOVA 695

One-Way Between-Subjects Designs, 697

Two-Way Between-Subjects Designs, 715

693

Analysis of Covariance, 717

Repeated-Measures Designs, 718

Summary, 720

Exercises, 720

Extension: Why Does the Usual F Test Falter with Unequal ns When the Population Variances Are Unequal?, 723

#### Appendix A: Statistical Tables 725

A.1 Critical Values of t Distribution, 726

A.2 Critical Values of F Distribution, 727

A.3 Critical Values of Bonferroni F Distribution, 734

A.4 Critical Values of Studentized Range Distribution, 736

A.5 Critical Values of Studentized Maximum Modulus Distribution, 738

A.6 Critical Values of Dunnett's Two-Tailed Test for Comparing Treatments to a Control, 741

A.7 Critical Values of Dunnett's One-Tailed Test for Comparing Treatments to a Control, 742

A.8 Critical Values of Bryant-Paulson Generalized Studentized Range, 744

A.9 Critical Values of Chi-Square Distribution, 748

A.10 Coefficients of Orthogonal Polynomials, 749

A.11 Pearson-Hartley Power Charts, 751

Appendix B: Notes 759

Appendix C: References 781

Appendix D: Solutions to Selected Exercises 796

Name Index 887

Subject Index 892