# CONTENTS

Preface to the Fourth Edition xxiii  
Acknowledgments xxix

## PART One  
**DESCRIPTIVE STATISTICS**  
1

### Chapter 1  
**INTRODUCTION TO PSYCHOLOGICAL STATISTICS**  
1

#### A. Conceptual Foundation  
1  
What Is (Are) Statistics? 1  
Statistics and Research 2  
Variables and Constants 2  
Scales of Measurement 3  
Parametric Versus Nonparametric Statistics 6  
Likert Scales and the Measurement Controversy 7  
Continuous Versus Discrete Variables 8  
Scales Versus Variables Versus Underlying Constructs 8  
Independent Versus Dependent Variables 9  
Experimental Versus Observational Research 10  
Populations Versus Samples 11  
Statistical Formulas 12  
Summary 12  
Exercises 13

#### B. Basic Statistical Procedures  
14  
Variables With Subscripts 14  
The Summation Sign 15  
Properties of the Summation Sign 16  
Rounding Off Numbers 18  
Summary 19  
Exercises 20

#### C. Analysis by SPSS  
21  
Ihno’s Data 21  
Variable View 22  
Data Coding 23  
Missing Values 23  
Computing New Variables 24  
Reading Excel Files Into SPSS 24  
Exercises 25

### Chapter 2  
**FREQUENCY TABLES, GRAPHS, AND DISTRIBUTIONS**  
27

#### A. Conceptual Foundation  
27  
Frequency Distributions 27  
The Cumulative Frequency Distribution 28  
The Relative Frequency and Cumulative Relative Frequency Distributions 29
CONTENTS

The Cumulative Percentage Distribution 29
Percentiles 30
Graphs 30
Real Versus Theoretical Distributions 34
Summary 35
Exercises 37

B. Basic Statistical Procedures 38
Grouped Frequency Distributions 38
Apparent Versus Real Limits 39
Constructing Class Intervals 39
Choosing the Class Interval Width 39
Choosing the Limits of the Lowest Interval 40
Relative and Cumulative Frequency Distributions 41
Cumulative Percentage Distribution 41
Estimating Percentiles and Percentile Ranks
by Linear Interpolation 42
Graphing a Grouped Frequency Distribution 43
Guidelines for Drawing Graphs of Frequency Distributions 44
Summary 46
Exercises 47

C. Analysis by SPSS 48
Creating Frequency Distributions 48
Percentile Ranks and Missing Values 50
Graphing Your Distribution 50
Obtaining Percentiles 52
The Split File Function 52
Stem-and-Leaf Plots 53
Exercises 55

Chapter 3

MEASURES OF CENTRAL TENDENCY AND VARIABILITY 57

A. Conceptual Foundation 57
Measures of Central Tendency 57
Measures of Variability 61
Skewed Distributions 69
Summary 73
Exercises 75

B. Basic Statistical Procedures 76
Formulas for the Mean 76
Computational Formulas for the Variance and
Standard Deviation 77
Obtaining the Standard Deviation Directly From
Your Calculator 80
Properties of the Mean 81
Properties of the Standard Deviation 83
Measuring Skewness 84
Measuring Kurtosis 85
Summary 87
Exercises 88

C. Analysis by SPSS 89
Summary Statistics 89
Using Explore to Obtain Additional Statistics 90
Boxplots 91
Selecting Cases 94
Exercises 96

Key Formulas 96
Chapter 4

STANDARDIZED SCORES AND THE NORMAL DISTRIBUTION 99

A. Conceptual Foundation 99
   z Scores 99
   Finding a Raw Score From a z Score 101
   Sets of z Scores 101
   Properties of z Scores 102
   SAT, T, and IQ Scores 103
   The Normal Distribution 104
   Introducing Probability: Smooth Distributions Versus Discrete Events 106
   Real Distributions Versus the Normal Distribution 107
   z Scores as a Research Tool 108
   Sampling Distribution of the Mean 109
   Standard Error of the Mean 110
   Sampling Distribution Versus Population Distribution 111
   Summary 112
   Exercises 113

B. Basic Statistical Procedures 115
   Finding Percentile Ranks 115
   Finding the Area Between Two z Scores 116
   Finding the Raw Scores Corresponding to a Given Area 118
   Areas in the Middle of a Distribution 119
   From Score to Proportion and Proportion to Score 119
   Describing Groups 120
   Probability Rules 122
   Summary 125
   Advanced Material: The Mathematics of the Normal Distribution 127
   Exercises 128

C. Analysis by SPSS 130
   Creating z Scores 130
   Obtaining Standard Errors 130
   Obtaining Areas of the Normal Distribution 131
   Data Transformations 131
   Exercises 132

Key Formulas 132

PART Two

ONE- AND TWO-SAMPLE HYPOTHESIS TESTS 135

Chapter 5

INTRODUCTION TO HYPOTHESIS TESTING: THE ONE-SAMPLE z TEST 135

A. Conceptual Foundation 135
   Selecting a Group of Subjects 135
   The Need for Hypothesis Testing 136
   The Logic of Null Hypothesis Testing 137
   The Null Hypothesis Distribution 137
   The Null Hypothesis Distribution for the One-Sample Case 138
   z Scores and the Null Hypothesis Distribution 139
   Statistical Decisions 140
Chapter 6

INTERVAL ESTIMATION AND THE $t$ DISTRIBUTION

A. Conceptual Foundation
   - The Mean of the Null Hypothesis Distribution
   - When the Population Standard Deviation Is Not Known
   - Calculating a Simple Example
   - The $t$ Distribution
   - Degrees of Freedom and the $t$ Distribution
   - Critical Values of the $t$ Distribution
   - Calculating the One-Sample $t$ Test
   - Sample Size and the One-Sample $t$ Test
   - Uses for the One-Sample $t$ Test
   - Cautions Concerning the One-Sample $t$ Test
   - Estimating the Population Mean
   - Summary
   - Exercises
   - Advanced Material: A Note About Estimators

B. Basic Statistical Procedures
   - Step 1: Select the Sample Size
   - Step 2: Select the Level of Confidence
   - Step 3: Select the Random Sample and Collect the Data
   - Step 4: Calculate the Limits of the Interval
   - Relationship Between Interval Estimation and Null Hypothesis Testing

Key Formulas
### Chapter 7: The t Test for Two Independent Sample Means

#### A. Conceptual Foundation
- Null Hypothesis Distribution for the Differences of Two Sample Means 204
- Standard Error of the Difference 205
- Formula for Comparing the Means of Two Samples 206
- Null Hypothesis for the Two-Sample Case 207
- The z Test for Two Large Samples 208
- Separate-Variances t Test 209
- The Pooled-Variances Estimate 209
- The Pooled-Variances t Test 210
- Formula for Equal Sample Sizes 211
- Calculating the Two-Sample t Test 211
- Interpreting the Calculated t 212
- Limitations of Statistical Conclusions 213
- Summary 213
- Exercises 214

#### B. Basic Statistical Procedures
- Step 1: State the Hypotheses 215
- Step 2: Select the Statistical Test and the Significance Level 216
- Step 3: Select the Samples and Collect the Data 216
- Step 4: Find the Region of Rejection 217
- Step 5: Calculate the Test Statistic 217
- Step 6: Make the Statistical Decision 218
- Interpreting the Results 218
- Confidence Intervals for the Difference Between Two Population Means 219
- Assumptions of the t Test for Two Independent Samples 221
- HOV Tests and the Separate-Variances t Test 223
- Random Assignment and the Separate-Variances t Test 224
- When to Use the Two-Sample t Test 225
- When to Construct Confidence Intervals 226
- Heterogeneity of Variance as an Experimental Result 226
- Publishing the Results of the Two-Sample t Test 226
- Summary 227
- Exercises 228
- Advanced Material: Finding the Degrees of Freedom for the Separate-Variances t Test 230
- Advanced Exercises 231
## CONTENTS

### C. Analysis by SPSS
- Performing the Two-Independent-Samples t Test
- Confidence Interval for the Difference of Two Population Means
- Bootstrapping
- Exercises

### Key Formulas

### Chapter 8

**Statistical Power and Effect Size**

### A. Conceptual Foundation
- The Alternative Hypothesis Distribution
- The Expected t Value (Delta)
- The Effect Size
- Power Analysis
- The Interpretation of t Values
- Estimating Effect Size
- Manipulating Power
- Summary
- Exercises

### B. Basic Statistical Procedures
- Using Power Tables
- The Relationship Between Alpha and Power
- Power Analysis With Fixed Sample Sizes
- Sample Size Determination
- The Case of Unequal Sample Sizes
- The Power of a One-Sample Test
- Constructing Confidence Intervals for Effect Sizes
- Calculating Power Retrospectively
- Meta-Analysis
- Summary
- Exercises

### Advanced Material: When Is Null Hypothesis Testing Useful?

### C. Analysis by SPSS
- Power Calculations in SPSS
- G^Power 3
- Exercises

### Key Formulas

### Part Three

**Hypothesis Tests Involving Two Measures on Each Subject**

### Chapter 9

**Linear Correlation**

### A. Conceptual Foundation
- Perfect Correlation
- Negative Correlation
- The Correlation Coefficient
- Linear Transformations
Graphing the Correlation 274
Dealing With Curvilinear Relationships 275
Problems in Generalizing From Sample Correlations 277
Correlation Does Not Imply Causation 279
True Experiments Involving Correlation 280
Summary 280
Exercises 281

B. Basic Statistical Procedures 283
The Covariance 283
The Unbiased Covariance 284
An Example of Calculating Pearson’s $r$ 284
Which Formula to Use 285
Testing Pearson’s $r$ for Significance 285
Understanding the Degrees of Freedom 287
Assumptions Associated With Pearson’s $r$ 288
Uses of the Pearson Correlation Coefficient 289
Publishing the Results of Correlational Studies 290
The Power Associated With Correlational Tests 291
Summary 293
Exercises 294

C. Analysis by SPSS 296
Creating Scatterplots 296
Computing Pearson’s $r$ 296
The Listwise Option 298
Using the Syntax Window for More Options 298
Using the Keyword “With” to Reduce the Size of Your Correlation Matrix 299
Bootstrapping 300
Exercises 301

Key Formulas 302

Chapter 10

LINEAR REGRESSION 303

A. Conceptual Foundation 303
Perfect Predictions 303
Predicting With $z$ Scores 304
Calculating an Example 304
Regression Toward the Mean 305
Graphing Regression in Terms of $z$ Scores 305
The Raw-Score Regression Formula 306
The Slope and the $Y$ Intercept 307
Predictions Based on Raw Scores 308
Interpreting the $Y$ Intercept 309
Quantifying the Errors Around the Regression Line 309
The Variance of the Estimate 310
Explained and Unexplained Variance 311
The Coefficient of Determination 312
The Coefficient of Nondetermination 312
Calculating the Variance of the Estimate 312
Summary 313
Exercises 313

B. Basic Statistical Procedures 314
Life Insurance Rates 314
Regression in Terms of Sample Statistics 315
CONTENTS

Finding the Regression Equation 315
Making Predictions 316
Using Sample Statistics to Estimate the Variance of the Estimate 316
Standard Error of the Estimate 317
Testing the Regression Slope for Significance 318
Assumptions Underlying Linear Regression 319
Regressing X on Y 319
Alternative Formula for the Regression Slope 320
When to Use Linear Regression 320
The Point-Biserial Correlation Coefficient 322
Calculating \( r_{pb} \) 323
Deriving \( r_{pb} \) From a \( t \) Value 324
Interpreting \( r_{pb} \) 324
Strength of Association in the Population (Omega Squared) 325
Biserial \( r \) 327
Summary 327
Exercises 328

C. Analysis by SPSS 330
Computing a Linear Regression Analysis 330
Bootstrapping 333
Point-Biserial Correlations 333
Exercises 333

Key Formulas 334

Chapter 11

The Matched \( t \) Test 337

A. Conceptual Foundation 337
Before-After Design 337
The Direct-Difference Method 338
The Matched \( t \) Test as a Function of Linear Correlation 339
Reduction in Degrees of Freedom 341
Drawback of the Before-After Design 341
Other Repeated-Measures Designs 341
Matched-Pairs Design 342
Correlated or Dependent Samples 343
When Not to Use the Matched \( t \) Test 343
Summary 344
Exercises 345

B. Basic Statistical Procedures 346
Step 1: State the Hypotheses 346
Step 2: Select the Statistical Test and the Significance Level 346
Step 3: Select the Samples and Collect the Data 346
Step 4: Find the Region of Rejection 347
Step 5: Calculate the Test Statistic 347
Step 6: Make the Statistical Decision 348
Using the Correlation Formula for the Matched \( t \) Test 348
The Confidence Interval for the Difference of Two Population Means 349
Effect Size for the Matched \( t \) Test 350
Power of the Matched \( t \) Test 352
Assumptions of the Matched \( t \) Test 353
The Varieties of Designs Calling for the Matched \( t \) Test 353
Publishing the Results of a Matched \( t \) Test 355
Summary 356
Exercises 357
Advanced Material: Displaying the Results From a Matched \( t \) Test 359
C. Analysis by SPSS 360
   Performing a Matched-Pairs \( t \) Test 360
   Bootstrapping 362
   Exercises 362
Key Formulas 362

PART Four
ANALYSIS OF VARIANCE WITHOUT REPEATED MEASURES 365

Chapter 12
ONE-WAY INDEPENDENT ANOVA 365

A. Conceptual Foundation 365
   Transforming the \( t \) Test Into ANOVA 366
   Expanding the Denominator 367
   Expanding the Numerator 368
   The \( F \) Ratio 368
   The \( F \) Ratio as a Ratio of Two Population Variance Estimates 368
   Degrees of Freedom and the \( F \) Distribution 369
   The Shape of the \( F \) Distribution 370
   ANOVA as a One-Tailed Test 371
   Using Tables of \( F \) Values 371
   An Example With Three Equal-Sized Groups 371
   Calculating a Simple ANOVA 372
   Interpreting the \( F \) Ratio 373
   Advantages of the One-Way ANOVA 375
   Summary 375
   Exercises 376

B. Basic Statistical Procedures 377
   An ANOVA Example With Unequal Sample Sizes 377
   Step 1: State the Hypotheses 377
   Step 2: Select the Statistical Test and the Significance Level 378
   Step 3: Select the Samples and Collect the Data 378
   Step 4: Find the Region of Rejection 378
   Step 5: Calculate the Test Statistic 379
   Step 6: Make the Statistical Decision 380
   Interpreting Significant Results 381
   The Sums of Squares Approach 381
   The Proportion of Variance Accounted for in an ANOVA 383
   Assumptions of the One-Way ANOVA for Independent Groups 385
   Testing Homogeneity of Variance 386
   The Brown-Forsythe and Welch Tests 388
   Power and Effect Size for ANOVA 388
   Varieties of the One-Way ANOVA 392
   Publishing the Results of a One-Way ANOVA 394
   Summary 396
   Exercises 398
CONTENTS

Calculating the Two-Way ANOVA 454
Calculating MSW 455
Calculating the Main Effect of the Drug Treatment Factor 455
Calculating the Main Effect of the Gender Factor 455
Graphing the Cell Means 456
The General Linear Model 457
Calculating the Variability Due to Interaction 458
Types of Interactions 459
Separating Interactions From Cell Means 462
The F Ratio in a Two-Way ANOVA 463
Advantages of the Two-Way Design 463
Summary 465
Exercises 466

B. Basic Statistical Procedures 467
Step 1: State the Null Hypothesis 467
Step 2: Select the Statistical Test and the Significance Level 467
Step 3: Select the Samples and Collect the Data 468
Step 4: Find the Regions of Rejection 468
Step 5: Calculate the Test Statistics 469
Step 6: Make the Statistical Decisions 472
The Summary Table for a Two-Way ANOVA 472
Interpreting the Results 473
Post Hoc Comparisons for the Significant Main Effects 474
Effect Sizes in the Two-Way ANOVA 475
Post Hoc Comparisons for a Significant Interaction 477
Interaction of Trend Components 481
Assumptions of the Two-Way ANOVA 481
Advantages of the Two-Way ANOVA With Two Experimental Factors 482
Advantages of the Two-Way ANOVA With One Grouping Factor 483
Advantages of the Two-Way ANOVA With Two Grouping Factors 483
Publishing the Results of a Two-Way ANOVA 484
The Two-Way ANOVA for Unbalanced Designs 485
Summary 487
Exercises 489

C. Analysis by SPSS 493
Performing a Two-Way ANOVA 493
Options for Univariate ANOVA 495
Simple Main Effects 496
Exercises 498

Key Formulas 498

PART Five
Analysis of Variance With Repeated Measures 501

Chapter 15
Repeated Measures ANOVA 501

A. Conceptual Foundation 501
Calculation of an Independent-Groups ANOVA 501
The One-Way RM ANOVA as a Two-Way Independent ANOVA 502
Calculating the SS Components of the RM ANOVA 503
CONTENTS

Step 3: Select the Samples and Collect the Data 556
Step 4: Find the Regions of Rejection 557
Step 5: Calculate the Test Statistics 558
Step 6: Make the Statistical Decisions 561
Interpreting the Results 561
Alternative Breakdown of the SS Components of a Mixed-Design ANOVA 562
Estimating Effect Sizes for a Mixed Design 563
Publishing the Results of a Mixed ANOVA 563
Assumptions of the Mixed-Design ANOVA 564
A Special Case: The Before-After Mixed Design 565
Post Hoc Comparisons 566
An Excerpt From the Psychological Literature 569
Interactions Involving Trends 570
Removing Error Variance From Counterbalanced Designs 571
Summary 572
Exercises 574

C. Analysis by SPSS 578
Performing a Two-Way Mixed-Design ANOVA 578
Plots 579
Post Hoc Tests 580
Options: Homogeneity Tests 580
Simple Main Effects 581
Exercises 582

Key Formulas 582

PART Six
MULTIPLE REGRESSION AND ITS CONNECTION TO ANOVA 585

Chapter 17
MULTIPLE REGRESSION 585

A. Conceptual Foundation 585
Uncorrelated Predictors 586
The Standardized Regression Equation 587
More Than Two Mutually Uncorrelated Predictors 587
The Sign of Correlations 588
Two Correlated Predictors 588
The Beta Weights 589
Completely Redundant Predictors 591
Partial Regression Slopes 591
Degrees of Freedom 593
Semipartial Correlations 593
Calculating the Semipartial Correlation 594
Suppressor Variables 595
Complementary Variables 596
The Raw-Score Prediction Formula 597
Partial Correlation 598
Finding the Best Prediction Equation 600
Hierarchical (Theory-Based) Regression 601
Summary 602
Exercises 603
B. Basic Statistical Procedures 605
The Significance Test for Multiple R 605
Tests for the Significance of Individual Predictors 606
Methods for Variable Selection 607
Problems Associated With Having Many Predictors 611
Too Few Predictors 615
Minimal Sample Size 615
Basic Assumptions of Multiple Regression 616
Regression With Dichotomous Predictors 618
Multiple Regression as a Research Tool: Variable Ordering 619
Publishing the Results of Multiple Regression 621
Summary 622
Exercises 623
Optional Exercise 626
Advanced Material 626
C. Analysis by SPSS 632
Performing a Multiple Regression Analysis 632
Statistics, Plots, Save, and Options 634
Stepwise Regression 635
Hierarchical Regression 636
Exercises 636
Key Formulas 637

Chapter 18
THE REGRESSION APPROACH TO ANOVA 639
A. Conceptual Foundation 639
Dummy Coding 640
The Regression Plane 640
Effect Coding 641
The General Linear Model 642
Equivalence of Testing ANOVA and R² 642
Two-Way ANOVA as Regression 643
The GLM for Higher-Order ANOVA 645
Analyzing Unbalanced Designs 646
Methods for Controlling Error Variance 649
Summary 650
Exercises 652
B. Basic Statistical Procedures 653
Simple ANCOVA as Multiple Regression 653
The Linear Regression Approach to ANCOVA 656
Post Hoc Comparisons 663
Performing ANCOVA by Multiple Regression 664
Power and Effect Size 665
The Assumptions of ANCOVA 665
Additional Considerations 666
Factorial ANCOVA 667
Using Two or More Covariates 668
Alternatives to ANCOVA 668
Using ANCOVA With Intact Groups 670
Summary 671
Exercises 673
C. Analysis by SPSS 675
Dummy Coding 675
Effect Coding 677
CONTENTS

Two-Way ANOVA by Regression 677
Analysis of Covariance 678
Analysis of Covariance by Multiple Regression 681
Exercises 682
Key Formulas 682

PART Seven

NONPARAMETRIC STATISTICS 685

Chapter 19

THE BINOMIAL DISTRIBUTION 685

A. Conceptual Foundation 685
The Origin of the Binomial Distribution 686
The Binomial Distribution With N = 4 687
The Binomial Distribution With N = 12 688
When the Binomial Distribution Is Not Symmetrical 689
The z Test for Proportions 691
The Classical Approach to Probability 692
The Rules of Probability Applied to Discrete Variables 693
The Empirical Approach to Probability 694
Summary 695
Exercises 696

B. Basic Statistical Procedures 697
Step 1: State the Hypotheses 697
Step 2: Select the Statistical Test and the Significance Level 697
Step 3: Select the Samples and Collect the Data 698
Step 4: Find the Region of Rejection 698
Step 5: Calculate the Test Statistic 698
Step 6: Make the Statistical Decision 699
Interpreting the Results 699
Assumptions of the Sign Test 699
The Gambler’s Fallacy 700
When to Use the Binomial Distribution for Null Hypothesis Testing 700
Summary 702
Exercises 703
Advanced Material: Permutations and Combinations 704
Constructing the Binomial Distribution 705

C. Analysis by SPSS 706
Performing a Binomial Test 706
Options for the Binomial Test 708
The Sign Test 709
Exercises 710
Key Formulas 711

Chapter 20

CHI-SQUARE TESTS 713

A. Conceptual Foundation 713
The Multinomial Distribution 713
The Chi-Square Distribution 714
Expected and Observed Frequencies 714
CONTENTS

The Chi-Square Statistic 715
Critical Values of Chi-Square 715
Tails of the Chi-Square Distribution 716
Expected Frequencies Based on No Preference 717
The Varieties of One-Way Chi-Square Tests 718
Summary 720
Exercises 720

B. Basic Statistical Procedures 721
Two-Variable Contingency Tables 721
Pearson’s Chi-Square Test of Association 722
An Example of Hypothesis Testing With Categorical Data 722
The Simplest Case: 2 × 2 Tables 726
Measuring Strength of Association 726
Assumptions of the Chi-Square Test 729
Some Uses for the Chi-Square Test for Independence 730
Publishing the Results of a Chi-Square Test 731
Summary 732
Exercises 733
Advanced Material 735

C. Analysis by SPSS 737
Performing a One-Way Chi-Square Test 737
Performing a Two-Way Chi-Square Test 739
Exercises 741

Key Formulas 741

Appendix A

Statistical Tables 743
A.1. Areas Under the Standard Normal Distribution 743
A.2. Critical Values of the t Distribution 746
A.3. Power as a Function of δ and Significance Criterion (α) 747
A.4. δ as a Function of Significance Criterion (α) and Power 748
A.5. Critical Values of Pearson’s r (df = N − 2) 749
A.6. Table of Fisher’s Transformation of r to Z 750
A.7. Critical Values of the F Distribution for α = .05 751
A.8. Critical Values of the F Distribution for α = .025 752
A.9. Critical Values of the F Distribution for α = .01 753
A.10. Power of ANOVA (α = .05) 754
A.11. Critical Values of the Studentized Range Statistic (q) for α = .05 755
A.12. Orthogonal Polynomial Trend Coefficients 756
A.13. Probabilities of the Binomial Distribution for P = .5 757
A.14. Critical Values of the χ2 Distribution 758

Appendix B

Answers to Selected Exercises in Sections A and B 759

Appendix C

Data From Inho’s Experiment 777

References 781
Index 787