Contents

Preface xiii

1 Introduction 2

Meaning of Statistics 2
Role of Statistics 3
Variables 4
A Hierarchy of Measurement Scales 5
Nominal Scale 6
Ordinal Scale 7
Interval Scale 7
Ratio Scale 8
Populations and Samples 8

Descriptive Statistics and Inferential Statistics 9
Summary 11

2 Organizing Data for Meaningful Representation 12

Frequency Distributions 12
Graphic Representation of Frequency Distributions 18
Differences in the Shapes of Frequency Distributions 20
Percentiles 21

Cumulative Frequency Distribution and Percentiles 23 Percentile Rank 25

Summary 29 Exercises 30

3 Describing Distributions: Measures of Central Tendency and Dispersion 32

Summation Notation and Operation 33
Measures of Central Tendency 34
Mode 35

٧ĺ

Median 36 Mean 37

Comparison of the Mode, the Median, and the Mean 39

The Mean of Combined Groups 41

Measures of Dispersion 42

Range 42

The Semi-Interquartile Range 43

Standard Deviation 46

Summary 47

Exercises 47

4 Standard Scores and the Normal Curve 50

Standard Scores **50**

Computing Standard Scores **52**

Properties of Standard Scores 53

The Normal Curve 57

The Standard Normal Curve 60

Using the Standard Normal Curve 61

Summary 66

Exercises 67

5 Correlation: The Measure of Relationship 70

The Correlation Coefficient and the Meaning of Correlation 71

Direction and Magnitude of the Relationship 72

Computing the Correlation Coefficient 75

Computational Formula for r 77

Factors Affecting the Size of the Pearson r 79

Linearity 79

Homogeneity of the Group 82

Size of the Group 84

Interpretation of the Correlation Coefficient 84

The Scale of r 84

Interpreting r in Terms of Variance 85

Correlation and Causality 87

Summary 88

Exercises 88

6 Types of Correlation Coefficients 92

Scales of Measurement 92

Nominal—Discrete Dichotomy 92

Nominal—Continuous Dichotomy 93

Ordinal 93

Interval or Ratio 94

Appropriate Correlation Coefficients for Various Combinations

of Scales 95

vii

Pearson Product-Moment Correlation Coefficients 96
Point-Biserial 97
Phi 99
Spearman Rho (ρ) 101
Non-Product-Moment Coefficient 104
The Contingency Coefficient (C) 104
Kendall's Tau (τ) 104
Biserial Coefficient 105
Tetrachoric Coefficient 108
Rank-Biserial Coefficient 110
Undefined Correlation Coefficients 111
Coefficient of Nonlinear Relationship Between Two Variables 112
Eta (η) or Correlation Ratio 112
Summary 116

7 Introduction to Inferential Statistics: Part 1 120

Exercises 117

Role of Sampling in Inferential Statistics 120 Random Sampling Methods 121 Role of Probability in Inferential Statistics 125 Probability and the Concept of the Underlying Distribution 127 The Normal Curve as an Underlying Distribution 128 The Underlying Distribution of the Sample Mean 130 Hypothesis Testing 132 Testing Hypotheses When Population Characteristics Are Unknown 132 The Underlying Distribution of Sample Means When σ is Unknown 133 Stating Hypotheses 137 Testing the Example Hypotheses ($\mu = 90$ and $\mu = 68$) 138 Level of Significance 142 Estimation of a Parameter 142 Point Estimation 143 Interval Estimation 144 Summary 147 Exercises 148

8 Introduction to Inferential Statistics: Part II 150

Testing Hypotheses 150
Hypotheses: One-Sample and Two-Sample Case 152
Nondirectional Alternative Hypotheses 152
Directional Alternative Hypotheses 153
Errors in Hypothesis Testing and Interval Estimation 154
Type I and Type II Errors 154
Level of Significance 156
Region of Rejection: Nondirectional Alternative Hypotheses 159
Region of Rejection: Directional Alternative Hypotheses 163
Level of Confidence 165

Data Needed for Hypothesis Testing and Interval Estimation 167 Summary 169 Exercises 169

9 Hypothesis Testing: One-Sample Case 172

Testing H_0 : $\mu=\alpha$ 173
Testing H_0 : $\rho=\alpha$ 176
Testing H_0 : $\rho=0$ 187
Testing H_0 : $P=\alpha$ 183
Testing H_0 : $\sigma^2=\alpha$ 187
The Chi-square (χ^2) Distribution 188
Statistical Precision 191
Statistical Significance versus Practical Importance 192

Summary **194** Exercises **195**

10 Hypothesis Testing: Two-Sample Case 198

Assumptions for the Two-Sample Case **199**Assumption of Independent Samples **199**Assumption of Homogeneity of Variance **202**Testing H_0 : $\mu_1 = \mu_2$ **202**Testing H_0 : $\mu_1 = \mu_2$ When $\sigma_1^2 = \sigma_2^2$ **209**

Testing H_0 : $\mu_1 = \mu_2$ When $\theta_1 = \theta_2$ 207 Testing H_0 : $\mu_1 = \mu_2$ —Dependent Samples 211

Testing H_0 : $P_1 = P_2$ —Independent Samples **216** Testing H_0 : $P_1 = P_2$ —Dependent Samples **219**

Testing H_0 : $\rho_1 = \rho_2$ —Independent Samples 223

Testing H_0 : $\rho_1 = \rho_2$ —Dependent Samples **226**

Testing H_0 : $\sigma_1^2 = \sigma_2^2$ —Independent Samples **228**

One-Tailed Test 232

Testing H_0 : $\sigma_1^2 = \sigma_2^2$ —Dependent Samples **232**

Statistical Significance vs. Practical Importance: A Return

to Reality **234** Summary **235**

Exercises 239

11 Hypothesis Testing: k—Sample Case Analysis of Variance—One-Way Classification 242

Problems with Multiple *t*-Tests **242**The Variables in ANOVA **244**Concepts Underlying ANOVA **245**Intuitive Approach to Partitioning the Variation **245**The Linear Model **249**Partitioning the Sum of Squares **250**Two Estimates of The Population Variance **252**

Testing the Null Hypothesis 254

Expected Mean Square Between: $E(MS_B)$ **254** Expected Mean Square Within: $E(MS_W)$ **255**

The F-Ratio 255

Summary Table for ANOVA 256

Computational Formulas for Sums of Squares 256

Assumptions Underlying the Analysis of Variance 260

Consequence of Violating the Assumptions 261

The Relationship of ANOVA to the t-Test 262

Summary 264

Exercises 265

12 Multiple Comparison Procedures 268

Post Hoc Multiple Comparison Tests 269

Type | Error Rates 270

The Tukev Method 272

The Newman-Keuls Method 273

Comparison of the Tukev and Newman-Keuls Methods 275

Post Hoc Test for Unequal n 275

The Scheffé Method 276

The Scheffé Method for Pair-Wise Comparisons 276

A Priori Planned Tests 280

Planned Orthogonal Contrasts 280

Relationship of Orthogonal Contrasts and the Between Sum

of Squares (SS_R) 283

One-Tailed Test Using Orthogonal Contrasts 285

Trend Analysis 285

Orthogonal Polynomials: Contrasts Used in Trend Analysis 288

Summary 291

Exercises 292

13 Analysis of Variance—Two-Way Classification 296

Factorial Design 296

Advantages of a Factorial Design 297

The Variables in Two-Wav ANOVA 299

Partitioning the Variation in a Two-Factor Design 300

Partitioning The Sum of Squares 302

Testing the Null Hypothesis 304

Computational Formulas for Sums of Squares 305

The Meaning of the Main Effects 310

The Meaning of Interaction 311

Reduction of Error Variance in Two-Way ANOVA 313

Assumptions of Two-Way ANOVA 315

The Linear Model **316**

Models for ANOVA, Two-Way Classification 317

Expected Mean Squares for the ANOVA Models 318

Multiple Comparison Procedures for Two-Way ANOVA **320** Two-Way ANOVA with Disproportionate Cell Frequencies **322** Summary **326** Exercises **328**

14 Selected Nonparametric Tests of Significance 332

The χ^2 -Distributions 333

The Critical Values of the χ^2 Distributions 337

Nominal Data: One-Sample Case **338** Nominal Data: Two-Sample Case **340**

Determination of the Expected Frequencies **341**Determination of the Degrees of Freedom **342**

The 2 \times 4 Contingency Table **343** The 2 \times 2 Contingency Table **344**

Nominal Data: k-Sample Case 346

Small Expected Frequencies in Contingency Tables 348

The Contingency Coefficient 349

Nominal Data: Two-Sample Case—Dependent Samples 350

Ordinal Data: Two-Sample Case 352

The Median Test 352

The Mann-Whitney U-Test **354**Ordinal Data: k-Sample Case **357**

Tied Ranks 359

Ordinal Data: Two-Sample Case—Dependent Samples 359

Summary **362** Exercises **364**

15 Linear Regression: Prediction and Estimation 368

Concepts of Prediction 368

The Predictive Relationship Between Two Variables 370

Determining the Regression Line 372

The Second Regression Line 375

Predicted Scores and Their Distributions 377

Errors in Prediction 379

The Estimated Standard Error of Prediction 379

Assumptions Underlying the Regression Line 380

The Relationships of Correlation and Prediction 382

Partitioning the Variance of the Predicted Variable (Y) 382

Correlation and the Regression Coefficients 384

Probability Associated with Regression and Prediction 386

Confidence Intervals in Prediction 388 Summary 389

Exercises 390

16 Multiple Correlation and Prediction 394

Concepts of Multiple Prediction 394

The Geometry of Multiple Prediction 395

Multiple Prediction in Standard Score Form 397

Characteristics of Multiple R 400

The Standard Error of Estimate 401

Selecting Predictor Variables 402

The Suppressor Variable 402

Number of Predictor Variables 403

Empirical Procedures for Selecting Predictor Variables 404

The Use of Multiple R in Inferential Statistics 406

Testing the Difference Between Two Multiple R's 407

Multiple Regression and ANOVA 408

Part and Partial Correlation 411

Summary 413

17 Introduction to Multivariate Statistics 414

Canonical Correlation 415
Conceptual Meaning of a Trait or Construct 416
Constructs and Canonical Correlation 416
Canonical Variates and Canonical Weights 417
Comments on the Computation of Canonical Correlation 418
Multivariate Analysis of Variance (MANOVA) 421
Underlying Concepts of MANOVA 421
Information Obtained from a MANOVA 424
Factor Analysis 431
Geometrical Concepts 433
The Concept of Communality 435
Types of Factors 436
Uses of Factor Analysis 436

Answers to Selected Exercises Appendix A Appendix B Bibliography

Index 485

Summary 440