INTERMEDIATE STATISTICS
A MODERN APPROACH

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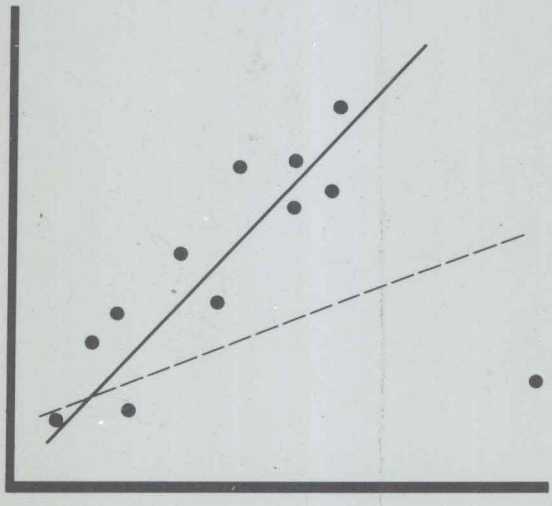

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JAMES STEVENS

INTERMEDIATE STATISTICS
A Modern Approach

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To my wife, Florence,
and my three sons—Mark, Jerry, and Jimmy

Preface

This book is written for applied social science researchers at the advanced undergraduate or beginning graduate level. The text emphasizes conceptual understanding of the statistical techniques (definitional formulas along with considerable narrative discussion are employed here), the effective use of statistical software to run the analyses, and the correct interpretation of the printout that results from such runs. Two of the major statistical packages, SPSSX and SAS, are an integral part of each chapter, as the cover design suggests.

The perennial question asked when a new book on statistical methods appears is, "What does this book have to offer that is new and/or different from all the others that have preceded it?" There are several ways in which this text is either entirely different or different in emphasis:

1. The assumptions underlying each analysis are given special attention, and the reader is shown how to test the critical assumption(s) using the statistical packages.
2. Power analysis is an integral part of the book. Jacob Cohen has graciously allowed me to use some selected tables from his classic book on power analysis. Also, this book shows how power estimates can be obtained for a wide range of designs with the SPSSX MANOVA program (starting with Release 2.2).
3. Complete, annotated control lines are provided for running each analysis on two of the major statistical packages (SAS and SPSSX). In my opinion any modern statistics book should feature at least one of the major packages. I have decided to include two to give the instructor some flexibility.

The reader will find the List of Tables in the front of the book very helpful in quickly locating the required SAS or SPSSX control lines for obtaining from simple descriptive statistics to a factorial ANOVA to fairly complex repeated measures analyses.

4. Selected, annotated printout is given from at least one of the packages for each analysis. The printout has been typeset for clarity of reading. It is important to have the explanation right on the printout, or on the same page. For students to have to flip back and forth from printout to explanation in the body of the text is awkward and reduces learning efficiency.
5. The importance of outliers is noted early and emphasized.
6. There are *no* computational formulas in this book. They are no longer needed, given the wide availability of high quality software (e.g., the major statistical packages).
7. Seven large real data sets are provided in the back of the text, and these data sets are used in some of the exercises. The data sets come from a variety of sources and represent several different populations: children involved in an assessment of the Sesame Street series, third to sixth graders in a midwestern public school, National Merit scholars, alcoholics, headache sufferers, and college students involved in a study on the behavior of people in a group situation.

These seven data sets, along with a data description file, are available on both 3.5 inch and 5.25 inch disks. Simply write to the publisher.

In line with the word "modern" in the subtitle of the book, over 70% of the references are from within the last 15 years. Also, numerous Monte Carlo studies and articles from various areas of social science research are used both in the body of the text and in the exercises.

The instructional mix of strategies that is employed to illustrate each statistical technique involves two parts: (a) First, I use definitional formulas on small data sets. These formulas are useful in conveying conceptual insight into what is being measured or quantified; (b) Then I proceed directly to the use of the packages to indicate how to efficiently process data.

I feel very strongly about using the above strategies for teaching statistics (as did three of the four reviewers of this text), and have employed this approach for the last 15 years.

Although familiarity with the packages is essential, because they are what is likely to be used in practice, merely presenting printout is not sufficient. Students need guidance as to what numbers to zero in on from the printout, and what those numbers mean. Also, the *order* of examining the printout becomes important, such as first looking at printout related to data screening (checking for outliers), then looking at printout related to a check of any crucial assumption(s), and finally, looking at printout pertaining to the main hypothesis or hypotheses being tested. Jumping right to the main hypothesis being tested can be very misleading

if an outlier is present, or if a certain critical assumption is violated, and this needs to be stressed.

The reader should have a background of a one quarter course in statistics that has covered at least the *t* tests for independent and dependent samples. The mathematics has been deliberately toned down, although there are a few proofs sprinkled throughout the text.

The topics included in the text are the traditional ones for an intermediate statistics course: one way analysis of variance (both approaches, overall test and post hoc analysis versus use of planned comparisons), factorial ANOVA, analysis of covariance, and repeated measures analysis.

The exercises involve a mixture of numerical, conceptual, and computer related problems. I have de-emphasized purely numerical exercises, for I agree entirely with Cobb (1987, p. 323) that "computing rules are just the skin of our subject; it is focus that reveals the skeleton of fundamental concepts and connections that hold the body of knowledge together." Answers are provided to about half of the exercises.

On the quarter system at the University of Cincinnati I have been able to cover all chapters except the one on repeated measures (although parts of the covariance chapter also needed to be omitted). It therefore seems plausible that the entire book could be covered in a one semester course.

There are many people to thank in a major effort such as this. I have been fortunate to have had four reviewers who provided me with many pages of very helpful, constructive criticism. Listed alphabetically, they are Corenna Cummings (Northern Iowa University), Lynn Edwards (University of Minnesota), Stephen Raudenbush (Michigan State University) and Jeffrey Smith (Rutgers University). I am deeply indebted to them for their detailed comments and thoughtful insights. Also, several colleagues at the University of Cincinnati have read one or more chapters of the book and have helped me to clarify or better express some ideas. They are: Daniel Wheeler, Ellen Cook, Roger Stuebing.

Three people at Erlbaum have been most helpful, not only with this book, but with my earlier book on multivariate statistics. Larry Erlbaum has been consistently very supportive and helpful. Joe Petrowski has in good humor tolerated my repeated phone calls, and Art Lizza has been diligent in producing two very handsome looking books.

James P. Stevens

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1 Introduction

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1.1 FOCUS AND OVERVIEW OF TOPICS

This book has been written for applied social science researchers at the advanced undergraduate or beginning graduate level. It is assumed that you have had a one quarter course in beginning statistics that covered measures of central tendency, measures of variability, standard scores (z, T, stanines, etc.), correlation, and inferential statistics, including at least the t tests for independent and dependent samples. In the next four sections of this chapter, we review briefly some descriptive statistics, summation notation, and testing for a "significant" difference. These sections are not intended to thoroughly teach this material again, but to refresh your memory.

The emphasis in the book is on conceptual understanding of the statistical techniques, learning how to effectively use statistical software to run the analy-

ses, and learning how to interpret the computer printout that results from such runs. Two of the three major statistical packages, SAS (Statistical Analysis System) and SPSSX (Statistical Package for the Social Sciences), are an integral part of this book. The third major package, BMDP (biomedical programs), is also used for certain analyses. Details on SAS and SPSSX are given in Section 1.7. I have attempted to make the text as practical as possible. To accent the practical emphasis, seven large real data sets have been provided in Appendix A in the back of the book. Some of the exercises in the chapters involve running these data sets. Singer and Willett (1988) have provided an excellent annotated bibliography, indicating where numerous other real data sets may be found.

The instructional mix of strategies adopted to illustrate each statistical technique involves two parts:

1. First, we illustrate each technique using *definitional* formulas on small data sets. These formulas are useful in yielding conceptual insight into what is being measured or quantified. As a simple example, the definitional formula for sample variance is

$$s^2 = [(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots + (x_n - \bar{x})^2]/(n - 1)$$

This formula shows very clearly that variance is measuring how much the scores for the subjects scatter or disperse about the mean.

2. Then we move directly to the computer, that is, to the statistical packages, to show how to efficiently process data. And more importantly, how to interpret the printout from the packages. In practice, analyses will very likely be run on one or more of these packages, and thus it is important to become familiar with them.

Now we give an overview of the topics in the book. The reader may recall that the t test for independent samples is appropriate for comparing two groups to determine whether they differ on the average on a dependent variable. But what if we wish to compare more than two groups *simultaneously* on a dependent variable? For example, we wish to compare the effect of four counseling methods on attitude toward education. Then a statistical procedure called analysis of variance is needed. This technique is covered in Chapter 2. Suppose that for this example there was reason to believe that the sex of the subjects might moderate the effect of the counseling methods, and we wanted to check this possibility. This would lead us to a more complicated analysis of variance design, since we are examining the effect of two independent variables (sex and counseling method) on attitude toward education. It is an example of a factorial design. These designs are covered in Chapter 4.

Chapter 3 deals with power analysis. The power of a statistical test is the probability of rejecting the null hypothesis when it is false. Although it may seem obvious that we would want to achieve this, many researchers in the literature have failed to do so, as Cohen (1969) and others have pointed out. The reason is that power is generally inadequate with small group sizes (especially with 20 or less subjects per group), and in some areas of research such sample sizes are