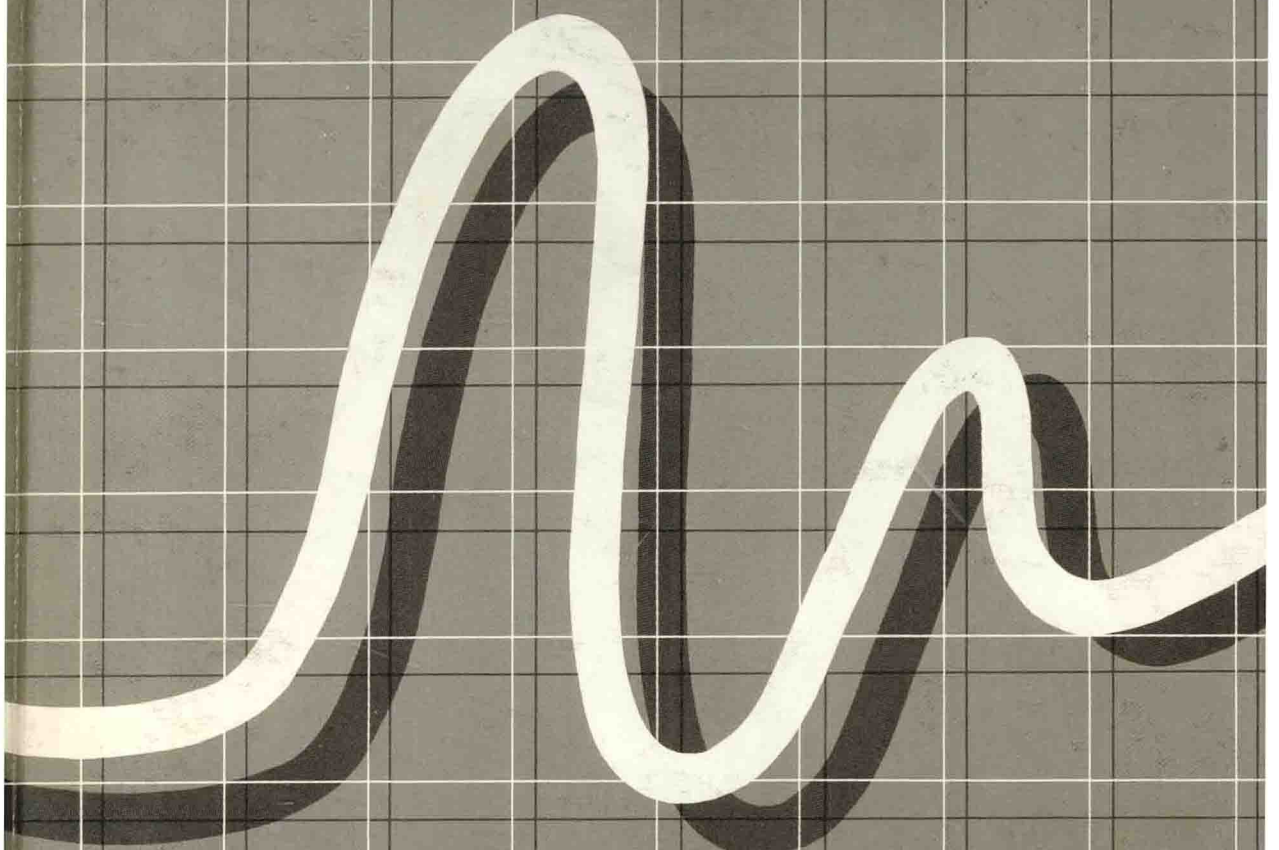
Statistics for the Behavioral Sciences



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Statistics for the Behavioral Sciences

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This book is dedicated to the city of Victor, Colorado.

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Preface

To the Instructor

While developing the outline for a new statistics text, I was haunted by my own reaction to new statistics books: "Oh no, not *another* introductory statistics text." There are hundreds of introductory statistics books available, many of which are excellent. Several have been on the market for a decade and have had the benefit of going through several editions. Basic introductory statistics, unlike content areas in the social sciences, does not become quickly dated. Many of the concepts taught ten years ago are still, for most purposes, taught today. So why one more text?

Despite the existence of some excellent texts, I have been unable to locate any that accomplish my own personal goals in teaching introductory statistics at the undergraduate level. What follows is, in part, an elaboration of some of these goals and of how the present text differs from those currently available.

Applications and Integration. In my opinion, most introductory statistics texts fail to integrate sufficiently the subject matter of statistics with what students will experience in other social science courses and in social science journals. A statistics course should not only teach a student basic skills for analyzing data, but also help make him or her an intelligent consumer of scientific information. Students need to know how to make sense of research reports and journal articles, and a firm grasp of statistics is a major step in this direction.

In my view, there is a large gap between what a student learns in statistics classes and the way statistics are presented in research reports. Accordingly, one goal of the present book is to teach the reader how to present the results of statistical analyses when writing research reports. By definition, this also conveys to the reader the form in which he or she will encounter statistical information when *reading* research reports. Most statistics texts emphasize the importance of stating null and alternative hypotheses, critical values, and formal decision rules for drawing inferences with respect to the null and alternative hypotheses. Yet these are rarely explicitly stated in research reports and students often find this confusing. In fact, phrases like "the difference was statistically significant ($t = 2.89$, df $= 18$, $p < .05$)" have usually never been encountered by students who have had introductory statistics. The present book attempts to confront this discrepancy. A special section entitled Method of Presentation will be found in most chapters. This section discusses examples of how statistical analyses are typically presented in research reports and provides the rationale underlying the form of such presentation.

Learning When to Use a Statistical Test. Because of the way chapters and exercises are organized in most texts, students are essentially told which statistical procedure to use on a given set of data. This state of affairs is simply unrealistic. It is easy to teach a student *how to compute* a correlation coefficient, just as it is easy to teach a student *how to interpret* a correlation coefficient. It is much more difficult, but just as important, to teach the student *when* to use a correlation coefficient and *why* it should be used. Given a set of data, many students can't determine where to begin in answering their research questions. I have attempted to address this problem. To be sure, it is impossible to state any hard and fast rules for data analysis. It is always possible to find an exception or suggest a procedure that might give better insights into the data. But some rough guidelines can be given and the issues involved in selecting a form of data analysis can be explicated. In the present text, each statistical technique is introduced by stating instances where the test is most typically applied and an interesting research example is then given. Chapter 16 develops in detail issues to consider when selecting a statistical test to analyze one's data.

Relevance. A common complaint among students who take statistics courses is that statistics are irrelevant and boring. This view is fostered, in part, by our tendency to use examples and exercises that *are* irrelevant and boring. Sometimes it is necessary to use mundane examples to best illustrate concepts. I found many instances where this was necessary. But at the same time, it is possible to provide students with interesting applications of statistics. I have chosen two ways in which to accomplish this. First, in most chapters I have included boxed material that presents interesting research applications of the statistical method being developed. Second, in later chapters (9–17), I have presented example studies in the exercise section where students are to take representative data from research that has actually been conducted in the social science literature and analyze the data using what they have learned. Supplementing these are exercises that should help students to learn and understand the material covered in the chapter.

Unifying Themes. During the years I have taught statistics, I have found that students do not easily understand the common focus of the different statistical tests. Most students simply cannot appreciate the conceptual relationship between the *t* test, analysis of variance, correlation, and chi square tests. As a result, no unifying focal point is developed and the student loses sight of the purpose of the various tests. In the present book, a unifying structure is provided. Each of the major statistical techniques concerns the relationship between variables. The *t* test and analysis of variance are usually (but not always) applied when analyzing the relationship between a qualitative independent variable and a quantitative dependent variable, correlation is applied when analyzing the relationship between two quantitative variables, and the chi square test is applied when analyzing the relationship between two qualitative variables. Three questions serve as the organizing framework for each technique: (1) Given sample data, can we infer that a relationship exists between the variables?, (2) What is the strength of the relationship?, and (3) What is the nature of the relationship? As an example, in analysis of variance, the

first question is addressed by the test of the null hypothesis, the second by an index such as eta squared, and the third by Tukey's HSD test. By continually relating each technique to these three questions, a unified framework emerges.

Variance Extraction Approach. Although I have used traditional presentations of most statistical methods, I have employed a few nontraditional modes of presentation as well. This has involved the development of variance extraction techniques in selected chapters. The chapters where this is most conspicuous are those on the independent groups t test, the correlated groups t test, and repeated measures analysis of variance. In the chapter on the independent groups t test, variance extraction techniques are used to give an *intuitive* understanding of statistics such as eta squared. Such techniques are also used to make explicit the logic of the correlated groups t test. One particular advantage of this approach, as developed in the context of the correlated groups t test, is that generalizations to repeated measures analysis of variance are direct. Whereas most introductory courses do not even treat repeated measures analysis of variance, I have found that I can cover the basics of the topic in one lecture, given mastery of the variance extraction approach. Recognizing that not everyone will care to use this approach, I have included the more traditional presentations as well. Advanced students can benefit by comparing the two approaches. Beginning students need only consider one of the two methods of development, whichever the instructor cares to emphasize and directs them to read.

Conceptual versus Computational Emphasis. The emphasis of the present book is on a conceptual understanding of statistics. With rapid progress in the computer field and with the widespread use of hand calculators geared toward statistics, it seems unwise to spend considerable time on computational formulas and methods of calculation. Very few students who take introductory statistics ever end up calculating statistics. Rather, they read about them in a research report or learn to program a computer to do the calculations. Because of this, most of the computations and formulas used in this book are conceptually rather than computationally based. Although they are not computationally efficient, my teaching experience has demonstrated that they are well worth the extra effort in terms of fostering an understanding of statistics.

Although computational formulas are downplayed, they are not ignored. Chapters 1–7 provide the student with the relevant background for reading statistical notation they will encounter. Computational formulas are provided, largely in appendixes, and serve as a reference that can be used in case the student ever needs to compute a statistic as quickly and efficiently as possible. However, I personally encourage my students to avoid these procedures in favor of the conceptual formulas when trying to *learn about* statistics (as opposed to *computing* statistics).

Research Design. Another unique characteristic of the present text is a chapter on research methods. I have always believed that statistics and experimental design are highly intertwined and that statistics should be placed in the context of research design. For example, how can students really grasp the meaning of error variance without some elementary understanding of disturbance variables? Chapter 8 is

intended to provide an appropriate research context. In addition, each research example used to develop a statistical technique is discussed in the context of its methodological constraints. I hope this will encourage the student to consider the results of statistical analysis in a broader sense than most statistic books convey.

Advanced Students. I have included a special feature for advanced students who are especially interested and inquisitive with regard to statistics. This is the presence of appendixes to several chapters that explain in more detail certain advanced concepts. These appendixes are generally written at a higher level and should be skipped by introductory students.

Material Covered. At first glance, the table of contents suggests that this book is more advanced than the typical introductory statistics book. This is not the case. I recognize that different instructors like to emphasize different material. It is not expected that an introductory class could even begin to cover all seventeen chapters of the present book. Some instructors will wish to emphasize some topics at the expense of others. The chapters included are intended to provide the instructor with a useful set of topics from which to choose. The order of chapters is flexible, except for natural progressions (for example, no one would cover *t* tests before they covered means and standard deviations). The material not covered in class will be available as reference for students who pursue graduate work or advanced undergraduate research projects. Also, when students in my classes ask questions about topics not typically covered in an introductory text, I have found it useful to be able to give them appropriate reading material. The comprehensive coverage of the present text helps in this regard.

In talking with different statistics instructors, I have found one of the main differences in teaching statistics is how the topic of probability is treated. Some instructors prefer to cover it in some detail (as has been done in Chapter 5 of this book), while others prefer to give it less emphasis. *All* instructors recognize that probability is a key concept in most statistical procedures. However, some feel that topics such as conditional probabilities, joint probabilities, and sampling with and without replacement have little practical relevance in applied research settings (for example, for computing *t* tests, analysis of variance, and so on). Because of this, I have written Chapter 5 so that it can be omitted without disrupting succeeding chapters. The concept of probability is discussed in Chapters 1–4 in sufficient detail to give students the necessary appreciation for later statistical tests.

In my own one-semester courses (which are *very* introductory) I cover Chapters 1–16, omitting Chapters 5, 15, and 17. I try to give my students a brief, one to two lecture overview of what is in the remaining chapters and encourage them to read what I could not cover. Also, within certain chapters, I choose to skip selected sections (for example, percentiles) so I can emphasize later material that I think is more appropriate *for my particular students*. I have tried to structure sections within chapters so that instructors who want to skip a topic can easily do so.

I have also tried to focus discussion on those techniques that are most common in the social science literature. This is not to say that the omitted concepts are not

important. The decision to exclude these reflects space demands and a cost-benefit analysis of what the student needs from the course more than anything else.

Chapter Structure. Chapters 9–17 develop the major statistical tests typically introduced in beginning statistics courses. I have imposed a common structure on each of these chapters to underscore the common focus of the tests.

Each chapter begins with a discussion of the conditions under which the test is typically applied. Attention then turns to inferring whether a relationship exists between the independent variable and the dependent variable, the strength of the relationship, and the nature of the relationship. These issues are developed in the context of a research example and critical computational stages are highlighted with study exercises that occur within the chapter. The statistics are then placed in context via a section on methodological considerations. This section underscores the importance of interpreting statistics relative to research design considerations. The Method of Presentation section discusses how the statistical technique will typically be reported in journal articles. This is followed by a numerical example that takes the student through an application of the statistical test from start to finish. Finally, a discussion of planning an investigation using the test is presented, with explicit consideration of power and sample size selection. The exercises for each chapter are of two types: (1) exercises designed to review and reinforce concepts the student has learned in the chapter, and (2) exercises designed so that the student can apply these concepts to a real research situation.

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Finally, I would like to acknowledge the contributions of Karyl Swartz throughout this project. Her patient ear and willingness to listen to statistic after statistic was but one source of support I valued so much during the writing of this text.

To the Student

This is an introductory statistics text designed for a first course in statistics. I have written the text assuming the student possesses a minimum of mathematical background (simple algebra). For most of you, much of the material in the book will be new. My experience in teaching statistics has led me to conclude that students generally find the logic of statistics easy to grasp. What is difficult is the amount of new material one must assimilate and use. Statistics courses are unique in several respects. Later material relies heavily on a clear understanding of previous material. There is a continual building process and you *must* keep up with the pace your instructor sets. Statistics is not the kind of material you can put off until the night before an exam and then "cram" for a test on the next day.

I have developed a number of features in the text that should help you in your study of statistics. First, I have included examples (called Study Exercises) that present a problem and then answer it, based upon the material previously covered. Working through these examples will help you to acquire many important statistical concepts. Second, key terms are **boldfaced**. These terms should be reviewed after reading each chapter. Make sure you understand and can define each one. Third, extensive exercises have been provided. It is strongly recommended that you work through *all* of the exercises as they will reinforce much of what you read. Fourth, I have included Boxes that present examples of interesting research that have used the concepts developed in a chapter. If you read the Boxes carefully, you will not only learn a good deal about social science research, but you will also be able to appreciate more fully the role of statistics in the social sciences. Fifth, I have included a glossary of symbols so you can have a ready reference to the many statistical symbols typically used in statistical texts. Finally, I have included a Method of Presentation section that describes how statistical tests are reported in professional journals and reports. This should help you to understand more fully not only the material presented in this book, but also the material you read in the course of your study of content areas in the social sciences.

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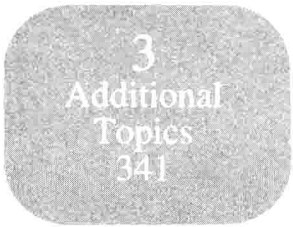
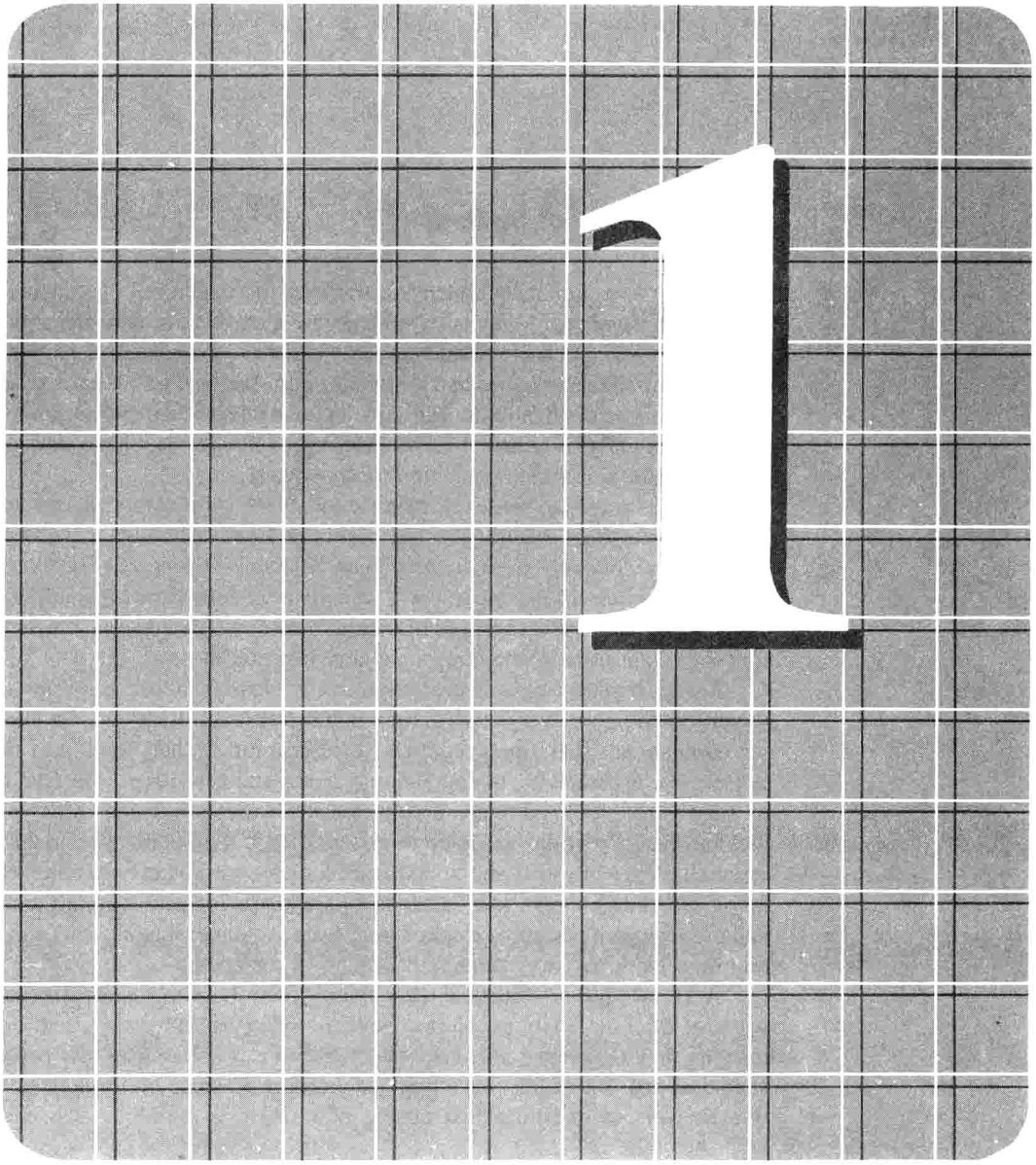
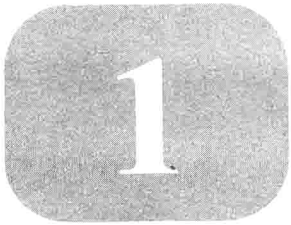


Statistical Preliminaries





Introduction and Mathematical Preliminaries

1.1 / The Study of Statistics

It has become common for courses in statistics to be required of students majoring in the social sciences. Many such students are unclear as to why statistical training is necessary. There are several reasons. Statistics is an integral part of research activity. Important questions and issues are addressed in social science research, and statistics can be a valuable tool in developing answers to these questions. For the student who makes a career of conducting research, statistical analysis should prove to be a useful aid in the acquisition of knowledge.

But the fact of the matter is, many students who take statistical courses will not develop careers that require an active part in research. Although these students may not actually conduct research, they may be required to read, interpret, and use research reports. These reports will usually rely on statistical analyses to draw conclusions and suggest courses of action to take. Knowledge of statistics is therefore important to help one understand and interpret these reports.

Research that uses statistical analysis is clearly having a greater impact on society, both in our everyday lives and in more abstract situations. On television we see commercials that report research "demonstrating" that Brand A is three times as effective as Brand X. In national magazines and newspapers we read the results of surveys of public opinion and attitudes toward politicians. Many magazines include special sections designed to disseminate to the public at large the results of research in the physical and social sciences. As our society becomes more technologically complex, greater demands will be placed on professionals to understand and use results of research designed to answer applied problems. This will generally require a working understanding of statistical methods.

A knowledge of statistical analysis may also help to foster new and creative ways of thinking about problems. Several colleagues have remarked on the new insights they developed when they approached a problem from the perspective of statistical analysis. Statistical "thinking" can be a useful aid in suggesting alternative answers to questions and posing new ones. In addition, statistics helps to