# BASIC STATISTICS for the BEHAVIORAL SCIENCES

2nd edition

Gary W. Heiman

# BASIC STATISTICS FOR THE BEHAVIORAL SCIENCES

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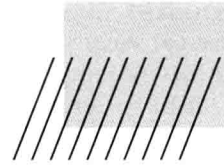

# Preface

Many of the undergraduates who enroll in my statistics course have a weak background in mathematics and some degree of "math phobia." By the end of the course, these same students must understand and perform the descriptive and inferential statistical procedures commonly used in behavioral research. The problem is that textbooks often dwell on the remarkable things statisticians can do with statistics and say too little about the things *researchers* commonly do. Such books present a catalog of procedures but do not explain the conceptual purposes of these procedures. Although students can then compute an answer on demand, they do not understand why they should perform the procedure nor what their answer reveals about the data. Therefore, I wanted my students to have a textbook that takes their needs more fully into account: a book that *explains*—clearly, patiently, and with an occasional touch of humor—the way a good teacher does.

## My Objectives

In writing this book, I pursued five objectives.

**1. Take a conceptual-intuitive approach** The text emphasizes the context in which statistics are used to make sense out of data. Each procedure is introduced in the context of a simple study with readily understandable goals. I focus on the purpose of research as examining the relationships between variables, then delineate the procedures for describing and inferring such relationships, and finally return to the conceptual purpose and interpretation of the study. Throughout, I provide students with simplified ways to think about statistical concepts and to see how these concepts translate into practical procedures for answering practical questions.

**2. Present statistics within an understandable research context** Many of the text's early examples involve simple variables and research questions taken from everyday life, so that students have an intuitive feel for the meaning of the scores and relationships discussed. In later chapters, along with students' developing statistical thinking, examples become more technical and "psychological." Virtually all examples and study questions involve specific variables and research questions, instead of generic data.

**3. Deal directly and positively with student weaknesses in mathematics** The text presents no formulas or statistical statements without explanation. Formulas are introduced in terms of what they accomplish, and an example of each is worked out completely, step by step. To further reduce the apparent complexity of statistics, I have stressed the similarities among different procedures, showing how, despite slight variations in computations, they have similar components and answer similar questions.

**4. Introduce new terms and concepts in an integrated way** I have strived to tie each new concept and procedure to previous material, briefly reviewing that material in every possible instance, including in the new chapter openings. Throughout, difficult concepts are presented in small chunks, which are then built into a foundation and later elaborated on.

**5. Create a text that students will enjoy as well as learn from** To make the text readable and engaging, I repeatedly point out the everyday usefulness of statistics. I have also tried to convey my own excitement about statistics and to dispel the notion that statistics (and statisticians) are boring. One can take a discipline seriously yet still recognize its quirks and foibles and have fun with it.

## Organization of the Text

In Part 1, *Getting Started*, Chapter 1 serves as a brief preface for the student and reviews basic math and graphing techniques. Chapter 2 then introduces the terminology, logic, and goals of statistics within the context of behavioral research.

Chapters 3 through 6 make up Part 2, *Descriptive Statistics* (along with a discussion of linear interpolation in Appendix A). I placed the chapter dealing with $z$-scores (Chapter 6) after the chapters on central tendency and variability (Chapters 4 and 5) so that these building blocks would be fresh in students' minds when discussing $z$-scores. I included sampling distributions and computing a $z$-score for a sample mean in this chapter so that students can later see how the logic of inferential statistics is essentially that of computing $z$-scores.

Part 3, *Describing Relationships*, consists of Chapters 7 and 8, in which correlation and regression are introduced as descriptive procedures, with emphasis on interpreting the correlation coefficient and the variance accounted for. (The point-biserial correlation is included to provide a bridge to measures of effect size in later chapters.) I placed the chapters dealing with correlation and linear regression before the inferential statistical procedures because otherwise it is confusing to introduce these procedures while discussing their inferential tests. Substantial cautions are given, however, about the need for performing inferential procedures on correlation coefficients, and when discussed later, they are presented as a logical variation of significance testing of means.

Part 4, *Inferential Statistics*, begins with Chapter 9, although extensive groundwork is laid in the previous chapters, with strong emphasis on understanding the proportion of the area under the normal curve. Chapter 9 introduces probability and previews hypothesis testing, focusing on using the normal curve to compute probability, with the goal of making decisions about the representativeness of

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sample means. In Chapter 10, hypothesis testing is formalized using the *z*-test. Chapter 11 presents the single-sample *t*-test, the confidence interval for a single mean, and significance testing of correlation coefficients. Chapter 12 covers two-sample *t*-tests and effect size. Chapter 13 introduces the one-way, between-subjects ANOVA, including *post hoc* tests for equal and unequal *n*'s, eta squared, and omega squared. (The one-way within-subjects ANOVA is described in Appendix C.) Chapter 14 deals with the two-way between-subjects ANOVA, *post hoc* tests for main effects and for unconfounded comparisons in an interaction, as well as graphing and interpreting interactions. Chapter 15 covers the one-way and two-way chi square, as well as the nonparametric versions of all previous parametric tests (with appropriate *post hoc* tests and measures of effect size).

The text is also designed to serve as a reference book for students. To that end, I've included such procedures as the formulas for transforming a raw score into a percentile and vice versa, for the semi-interquartile range, for T-scores, for the $F_{max}$ test, for several types of confidence intervals, and for a rather extensive collection of nonparametric procedures. The instructor can skip the more uncommon procedures, however, without disrupting the discussion of the major procedures.

The text strives to teach students how to interpret their data—not just to report that a result is significant. Thus, I have emphasized such topics as plotting and interpreting graphs and understanding the relationships demonstrated by research. I've also included practical discussions of power and measures of effect size. These discussions occur at the end of a section or chapter so that instructors wishing to skip these topics can easily do so.

## Pedagogical Format and Features

A number of features have been built into the book to enhance its usefulness as both a tool for study and a reference.

- New chapter-opening pedagogy encourages review of previous material and provides learning goals.
- "More Statistical Notation" sections introduce new statistical notations at the beginning of the chapter in which they are used, not before, and to reduce student confusion, they are introduced separately from the conceptual issues presented in the chapter.
- Each important procedural point is emphasized by a "STAT ALERT," a summary reminder set off from the text about the calculation or interpretation of a statistic.
- Computational formulas are highlighted throughout the text in color.
- Key terms are highlighted in bold, reviewed in the chapter summary, and listed in the end-of-text glossary. Many mnemonics and analogies are used to promote retention and understanding.
- Graphs and diagrams are thoroughly explained in captions and fully integrated into the discussion.
- "Finally" sections at the end of each chapter provide advice, cautions, and ways to integrate material from different chapters.

- Each "Chapter Summary" provides a substantive review of the material, not merely a list of the topics covered.
- Conceptual and procedural questions, as well as computational problems, are provided at the end of each chapter. Odd-numbered problems (with final and intermediate answers in Appendix E) provide students with a solid review of the material, and even-numbered problems (with answers in the Instructor's Resource Manual) can be used as assigned homework.
- A Summary of Formulas is provided at the end of each chapter, for quick reference. In addition, a list of formulas is shrinkwrapped with each student text for use in closed-book exams.
- A glossary of symbols appears on the inside back cover. New reference tables on the inside front cover provide guidelines for selecting the various descriptive and inferential procedures discussed in the text based on the type of data or research design employed.

## New Features in the Second Edition

The first edition was quite well received, and the various reviewers and users suggested little in the way of substantial change. Therefore, my focus was to tighten the conceptual presentations and to incorporate several new explanatory techniques that I developed since the first edition. Throughout, greater emphasis is placed on explaining how to use statistics to mentally "envision" a set of data and to "think" in statistical terms. Further, discussion of the mathematical steps in computing the various procedures has been streamlined, although I have kept the text very friendly to students with math phobia. In addition, I made the following specific changes:

- *New chapter-opening pedagogy* Each chapter now begins by identifying the previously discussed concepts that students should review before continuing, followed by learning goals for the chapter.
- *Expanded practice problems* The number of practice problems at the end of each chapter has increased by fifty percent, with an emphasis on both computational problems and challenging conceptual problems. In addition, practice problems are now provided in the appendices dealing with interpolation, probability, and the one-way within-subjects ANOVA.
- *New software appendix* Appendix F, "Introduction to Statistics Software Packages," provides the student with simple step-by-step instructions for performing all the major statistical procedures discussed in the text using one of three data-analysis software programs: HMSTAT (packaged free with each student text), MYSTAT, and SPSS/PC+ Studentware Plus™. Appendix F provides directions for installing the programs, entering data, running the various procedures, and interpreting the output.

Key changes also have been made to each chapter: Chapter 1 now provides instructions on how students should read a statistics text and study for exams. Chapter 2 has been revamped to emphasize that psychological research is based on the two goals of demonstrating a relationship in sample data and using samples

to draw inferences about the population. Chapter 3 includes an improved explanation of using the area under the normal curve to describe scores. Chapter 4 more clearly takes students through the important steps of using a mean score to describe obtained scores, to predict future scores, to convert raw scores to deviation scores, and to estimate the population mean. Chapter 5 now covers using inflection points on a normal distribution to identify the location of the scores that are one standard deviation above or below the mean. Chapter 6 features more discussion of how the normal curve, *z*-scores, and the central limit theorem allow us to envision the important characteristics of any set of data. Chapters 7 and 8 explain more fully the distinction between a correlational and experimental research design, as well as the similarities and differences in the statistical procedures used in each.

Chapters 9 and 10 clearly set the stage for inferential procedures, with an improved introduction to using a sampling distribution to describe the means we expect if we are representing a particular population and a description of how inferential procedures are ultimately designed to limit Type I and Type II errors. Chapter 11 contains expanded discussion of how researchers maximize statistical power in one-sample experiments and correlational studies. Chapter 12 presents a clearer description of using a squared correlation coefficient to describe effect size and mentions the latest American Psychological Association requirements for reporting effect size with all significant results. Chapter 13 includes an expanded discussion of how the between-groups mean square is an estimate of both error and treatment variance. Chapter 14 features improved graphics showing how the diagram of a two-way design is built from the diagrams of two one-way designs. Chapter 15 has been streamlined, especially in presenting the interpretation of a two-way chi square.

## Supplementary Materials

Supporting the text are several ancillaries for students and instructors:

- *Free Data-Analysis Software* A data-analysis program called HMSTAT, custom-tailored to the text by David Abbott of the University of Central Florida, is packaged free with each student text. This menu-driven program can accept and store data, perform all the procedures discussed in the text, and be operated by students with minimal computer background. Directions for using HMSTAT appear in the new Appendix F, prepared by Michael Gayle of the State University of New York at New Paltz, and the Instructor's Resource Manual offers suggestions for integrating computers into the course. The appendix also provides instructions for using MYSTAT and SPSS/PC+ Studentware Plus™ statistical programs.
- *Student Workbook and Study Guide* Additional practice problems are available in the Student Workbook and Study Guide, which I personally revised. Each chapter contains a review of objectives, terms, and formulas, a programmed review, conceptual and computational problems (with answers), and a set of multiple-choice questions similar to those in the Instructor's Resource Manual. A final chapter, called "Getting Ready for the Final

Exam," facilitates student integration of the entire course. Answers to all questions are now provided in each workbook chapter.

- *Instructor's Resource Manual with Test Questions* This supplement, revised by Kay Smith of Brigham Young University, contains approximately 750 test items and problems, as well as suggestions for classroom activities, discussion, and use of statistical software. It also includes answers to the even-numbered end-of-chapter problems from this book. The test items are also available on computer disk for IBM and Macintosh computers.

## Acknowledgments

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