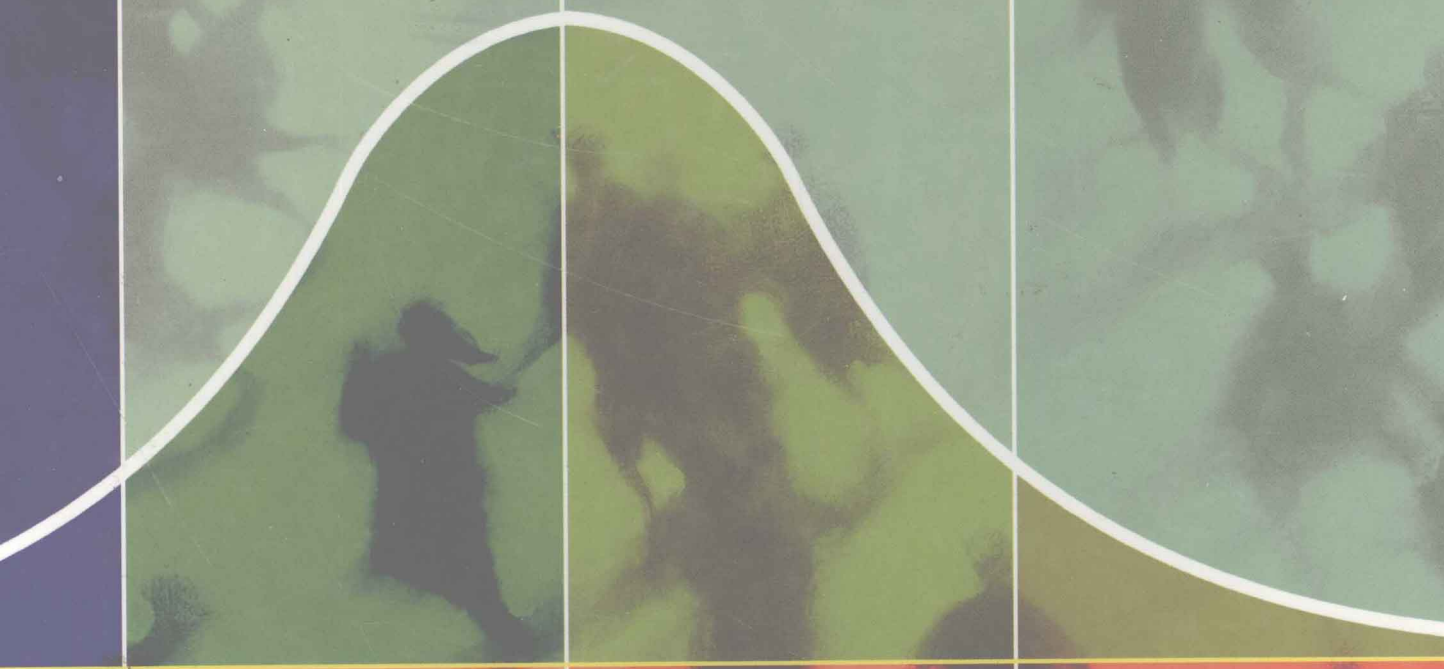
Gary W. Heiman

Basic Statistics FOR THE Behavioral Sciences



THIRD EDITION

Basic Statistics for the Behavioral Sciences

Third Edition

Gary W. Heiman
Buffalo State College

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Basic Statistics for the Behavioral Sciences

For my wife, Karen, the love of my life

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Preface

My reasons behind writing this book some ten years ago are the same as they are today. Many of the undergraduates entering my statistics course have a weak background in mathematics and some degree of "math phobia." Eventually, however, these same students must understand and perform the descriptive and inferential statistics 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. Although students can then compute an answer on demand, they do not understand why they should perform the procedure or what their answer reveals about the data. Therefore, I wanted to produce a textbook that takes students' needs 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 approach of the text is that statistics are used to make sense out of data. Each procedure is introduced using 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 "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 in a step by step manner. 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 tie each new concept and procedure to previous material, briefly reviewing that material in every possible instance. 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, *Introduction,* 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). The chapter dealing with z-scores (Chapter 6) is immediately after the chapters on central tendency and variability (Chapters 4 and 5) so that these building blocks are fresh in students' minds when discussing z-scores. I included sampling distributions and computing a z-score for a sample mean in Chapter 6 in order to later introduce inferential statistics as essentially 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 Chapter 6. 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 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 population 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 ns, eta squared, and briefly, omega squared. (The one-way within-subjects ANOVA is described in Appendix A.) 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. The two-way within-subjects ANOVA and the two-way mixed design ANOVA are also introduced, and computational formulas with examples are presented in Appendix A. Chapter 15 covers the one-way and two-way chi square, as well as the Mann-Whitney, rank sums, Wilcoxin, Kruskal-Wallis, and Friedman nonparametric tests (with appropriate post hoc tests and measures of effect size.)

The text is also designed as a reference book for students, so I've included the formulas for transforming a raw score into a percentile and vice versa, for the semi-interquartile range, for the F_{max} test, for several types of confidence intervals, and for an extensive collection of nonparametric procedures. An 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 may easily skip these topics.

Pedagogical Format and Features

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

- Each chapter begins with a "Getting Started" section, which lists previously discussed concepts that students should review, followed by the learning goals for the chapter.
- "More Statistical Notation" sections introduce new statistical notations at the beginning of the chapter in which they are needed and to reduce student confusion, they are introduced separately from the conceptual issues presented in the chapter.
- A new opening section in each chapter titled "WHY IS IT IMPORTANT TO KNOW ABOUT . . . ?" introduces the major topic of the chapter, immediately placing it in a research context.
- Each important procedural point is emphasized by a "REMEMBER" 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 a new "Key Terms" section at the end of the chapter. There is also an end-of-text glossary. Many mnemonics and analogies are used throughout the text to promote retention and understanding.
- Graphs and diagrams are thoroughly explained in captions and fully integrated into the discussion.
- "Putting It All Together" 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.
- A minimum of 25 conceptual and procedural review questions, as well as computational problems, are provided at the end of each chapter. Odd-numbered problems (with final and intermediate answers in Appendix C) 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.
- A glossary of symbols appears on the inside back cover. Tables on the inside front cover provide guidelines for selecting from the descriptive and inferential procedures discussed in the text based on the type of data or research design employed.

New Features in the Third Edition

The first two editions have been quite well received, and the various reviewers and users suggested little in the way of substantial change. The major change is that the entire text has been extensively revised and edited to streamline the narrative, without removing content or losing understandability. I also tightened the conceptual presentations and incorporated a number of new explanatory techniques. Throughout, greater emphasis was placed on explaining how to use statistics and how to "think" in statistical terms. At the same time, every discussion reinforces that the final step in an analysis is to interpret the results in psychological terms. In addition, I made the following changes:

General Changes

- Headings were revised, including changing STAT ALERT to REMEMBER, and FINALLY to PUTTING IT ALL TOGETHER.
- Existing end-of-chapter questions were revised and new types of questions were added, including more graphing questions, questions in which students interpret statements similar to those encountered in published research, and questions requiring students to organize a chapter by identifying the major procedures learned.
- The introduction of statistical notation now emphasizes the importance of upper- or lower-case in the symbols.
- Each chapter now begins with a new section titled "WHY IS IT IMPORTANT TO KNOW ABOUT . . . ?" which introduces and orients students to the major topic of the chapter.
- A list of KEY TERMS was added to the end of each chapter.
- A number of new summary tables were added to help students organize different procedures.

Specific Chapter Changes

- The discussion of grouped distributions and calculating percentiles (Chapter 3) was moved to Appendix A.
- Additional coverage of using the means and standard deviation to interpret experiments was added to Chapters 4, 5, and 12.
- Chapter 5 has an expanded discussion of how variability relates to the normal curve.
- The presentation of sampling distributions in Chapter 6 was reorganized, and T-scores were deleted.
- The discussion of prediction error and variance accounted for in Chapter 8 was extensively revised and shortened.
- In Chapter 10, the discussion of power was revised. The review of power in Chapter 12 was shortened, and the particulars now occur within a section for each *t*-test.
- The discussion of one-tailed inferential tests in Chapters 11 and 12 was shortened and more end-of-chapter review questions now involve two-tailed tests.

- A new intuitive explanation for variability between and within groups is now in Chapter 13 and the computation of omega squared was deleted.
- The labels in the *z*-score tables and correlation tables were improved.
- In Chapter 14, the introduction to a two-way interaction was expanded, and is no longer presented as similar to a one-way ANOVA.
- In addition to the one-way within-subjects ANOVA, computational formulas for the two-way within-subjects ANOVA and two-way mixed-design ANOVA (with examples and practice problems) are now provided in the appendix.
- One practice problem for the two-way within-subjects ANOVA uses the same data as a problem for the mixed-design ANOVA, so that instructors may compare a between-subjects versus a within-subjects factor.
- The appendix describing computer applications was deleted now that more user-friendly software has become readily available.

Supplementary Materials

Supporting the text are several ancillaries for students and instructors:

- *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 Beverly Roskos-Ewoldsen from the University of Alabama, 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.
- *Using SPSS for Windows* A brief, compatible guide to the latest version of SPSS for Windows (with data sets) is available separately or shrinkwrapped with this text. Contact a Houghton Mifflin sales representative.
- *Psychology Web Site* Some useful and innovative teaching resources can be found at Houghton Mifflin's Web site. Go to http://www.hmco.com and then click on the College Division's Psychology Page.

Acknowledgments

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