

Understanding Statistics in the Behavioral Sciences

5TH EDITION

Robert R. Pagano

UNDERSTANDING STATISTICS IN THE BEHAVIORAL SCIENCES

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University of Pittsburgh



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Do you care about reality? Does truth matter to you? If so, then I dedicate this fifth edition to you.

PREFACE

I have been teaching a course in introductory statistics for over twenty-five years, first within the Department of Psychology at the University of Washington and subsequently within the Department of Neuroscience at the University of Pittsburgh. This textbook is the mainstay of the course. Most of my students have been psychology majors, but many have also come from biology, business, education, neuroscience, nursing, and other fields. Because these students generally do not have high aptitude for mathematics and are not well grounded in mathematical skills, I have used an informal rather than strictly mathematical approach. This approach assumes only high school algebra for background knowledge. It relies on clarity of presentation, a particularly effective sequencing of the inferential material, detailed verbal description, interesting illustrative examples, and many fully solved practice problems to help students understand the material.

My statistics course has been quite successful. Students are able to grasp the material, even the more complicated topics such as "power," and at the same time, many even enjoy learning it. Student ratings of this course have been quite high. Students rate the textbook even higher, saying among other things that it is very clear, they like the touches of humor, and that it helps them a lot to have the material presented in such great detail.

In preparing the fifth edition, I have again been guided by feedback from students and professors. Again, I am very pleased that this feedback has been quite positive, and that for most of the textbook the advice has been not to change anything because the text works very well. However, there were two recommended changes that had strong consensus: (1) remove the computer material from the textbook and put it in separate manuals, and (2) reverse the order of correlation and regression so that correlation precedes regression. Both changes have been made. In addition to moving the computer material to manuals, because SPSS now has a student edition running on the Windows platform, and because it is used so much in the behavioral sciences, I have included material on SPSS, rather than on MYSTAT, which was used in the fourth edition.

Following a theme that tries to simplify the fifth edition without compromising depth and quality, I have also eliminated the separate chapter on power and incorporated a discussion on power into Chapter 10, the introductory hypothesis testing chapter. I have done this somewhat reluctantly, because I believe having a separate chapter on power has real merit. However, because there are so many

important topics to cover in an introductory statistics course, there often is not enough time for such coverage. Moreover, discussing power in conjunction with the sign test allows briefer treatment of this complicated topic with understanding. Of course, I have kept the more extensive treatment of power that is given in Chapter 12 in conjunction with the z test. I have also made what I consider to be one other major change. I have changed the illustrative example that introduces hypothesis testing in Chapter 10. The example "Marijuana and Reaction Time" had been in the textbook since its inception in 1981, and had become dated. I have replaced it with a more current and I hope interesting example, "Marijuana and the Treatment of AIDS Patients."

The following additional changes have been made. A new section, Significance Versus Importance, has been added to Chapter 10. Proper names throughout the text have been changed to better reflect diversity and thereby enable all students to see themselves as statistical experts. Two new "What Is the Truth?" sections have been added: "What Is the Truth? Sperm Count Decline—Male or Research Inadequacy?" has been added at the end of Chapter 8; and "What Is the Truth? Statistics and Applied Social Research—Useful or 'Abuseful'?" has been added at the end of Chapter 18. Finally, in an effort to update and extend the end-of chapter Questions and Problems, there are over fifty new or revised questions and problems.

Textbook Rationale

This is an introductory textbook that covers both descriptive and inferential statistics. It is intended for students majoring in the behavioral sciences. For many behavioral sciences undergraduates, statistics is a subject that engenders considerable anxiety and that is avoided for as long as possible. Moreover, I think it is fair to say that when the usual undergraduate statistics course is completed, many students have not understood much of the inferential statistics material. This happens partly because the material is inherently difficult and the students themselves are not proficient in mathematics but also, in my opinion, partly because most textbooks do a poor job of explaining inferential statistics to this group of students. These texts usually err in one or more of the following ways: (1) They are not clearly written; (2) they are not sufficiently detailed, (3) they present the material too mathematically; (4) they present the material at too low a level; (5) they do not give a sufficient number of fully solved problems for the student to practice on; and (6) in inferential statistics, they use an inappropriate sequence of topics, beginning with the sampling distribution of the mean.

In this and the previous four editions, I have tried to correct such deficiencies through an informal writing style; a clearly written, detailed, and theoretically oriented presentation that requires only high school algebra for understanding; the inclusion of many interesting, fully solved practice problems that are located immediately following the relevant expository material; and a sequencing of the inferential material better suited to the students for whom this book is intended.

I believe a key to understanding inferential statistics is the material presented in the beginning inferential chapters and its sequencing. In my opinion, optimal learning of the material occurs when it is sequenced as follows: random sampling and probability, binomial distribution, introduction to hypothesis testing using the sign test, Mann-Whitney U test, sampling distributions (including their empirical generation), sampling distribution of the mean, z test for single samples, t test for single samples, confidence intervals, t test for correlated and independent

groups, introduction to analysis of variance, multiple comparisons, two-way ANOVA, nonparametric tests, and review of inferential statistics.

At the heart of statistical inference lies the concept of sampling distribution. The first sampling distribution discussed by most texts is the sampling distribution of the mean. The difficulty here is that the sampling distribution of the mean cannot be generated from simple probability considerations, which makes it hard to understand. This problem is compounded by the fact that most texts do not attempt to generate the sampling distribution of the mean in a concrete way. Rather, they define it theoretically, as a probability distribution that would result if an infinite number of random samples were taken of size N from the population and the mean of each sample were calculated. This definition is far too abstract for students, especially when this is their initial contact with the idea of sampling distributions. And when students fail to grasp the concept of sampling distributions, they fail to grasp the rest of inferential statistics. What appears to happen is that since students do not understand the material conceptually, they are forced to memorize the equations and to solve problems by rote. Thus, students are often able to solve the problems without genuinely understanding what they are doing—all because they fail to comprehend the essence of sampling distributions.

To impart a basic understanding, I believe it is much better to begin with the sign test (Chapter 10), a simple inference test for which the binomial distribution is the appropriate sampling distribution. The binomial distribution is easy to comprehend, and it can be derived from the basic probability rules developed in an earlier chapter (Chapter 8, Random Sampling and Probability). It depends entirely on logical considerations. Hence, its generation is easily followed. Moreover, it can also be generated by the same empirical process used later on for generating the sampling distribution of the mean. It therefore serves as an important bridge to understanding all the sampling distributions discussed later in the textbook. Introducing hypothesis testing along with the sign test has other advantages: All the important concepts involving hypothesis testing can be illustrated: e.g., null hypothesis, alternative hypothesis, alpha level, Type I and Type II errors, and power. The sign test also provides an illustration of the before-after (repeated measures) design, which is a superior way to begin, as most students are familiar with this type of experiment, and the logic of the design can be followed with ease.

Chapter 11 takes up the Mann-Whitney U test. This is a practical, powerful test that also has an easily understood sampling distribution. Both the sign test and Mann-Whitney U test have sampling distributions derived from basic probability considerations. The Mann-Whitney U test is additionally useful in that it illustrates the independent groups design. By the time students finish this chapter, they should have a sound knowledge of hypothesis testing as well as having experienced excellent exposure to the two basic experimental designs. Their confidence in "getting" the fundamentals of statistics should be greatly increased.

Chapter 12 initiates a formal discussion of sampling distributions and how they can be generated. After this, the sampling distribution of the mean is introduced, and discussion centers on how this sampling distribution can be generated empirically, which gives students a concrete understanding of the sampling distribution of the mean. With prior experience of the binomial distribution and the sampling distribution of U, and with knowledge of the empirical approach for the sampling distribution of the mean, most conscientious students will have

achieved a good grasp of why sampling distributions are essential for inferential statistics. Since the sampling distributions underlying Student's t test and the analysis of variance are also explained in terms of their empirical generation, students can conceptually comprehend the use of these tests rather than just solve problems by rote. This approach gives the insight that all the concepts of hypothesis testing are the same as we go from statistic to statistic—what varies from experiment to experiment is the statistic used and its accompanying sampling distribution. The stage is now set for covering the remaining inference tests.

Chapters 12, 13, 14, and 18 discuss, in a fairly conventional way, the z test and t test for single samples, the t test for correlated and independent groups, and nonparametric statistics. However, these chapters differ from those in other texts in their clarity of presentation, the quantity and interest value of the fully solved problems they contain, and the use of empirically derived sampling distributions. Then, too, there are differences specific to each test. For example: (1) the t test for correlated groups is developed as a special case of the t test for single samples, this time using difference scores rather than raw scores; (2) the sign test and the t test for correlated groups are compared to illustrate the difference in power that results from using one or the other; (3) the factors influencing the power of experiments using Student's t test are taken up; (4) the correlated and independent groups designs are contrasted with regard to utility.

Chapters 15 and 17 deal with analysis of variance. In these chapters single rather than double subscript notation is deliberately employed. The more complex double subscript notation serves to confuse students. In my view, the single subscript notation and resulting single summations work better for the undergraduate major in psychology and related fields because they are simpler and, for this audience, promote understanding of this reasonably complicated material. Here, I have followed in part the notation used by Edward Minium in *Statistical Reasoning in Psychology and Education*. I am indebted to Professor Minium for this contribution.

Other features of this textbook are worth noting. Chapter 8, on probability, does not delve deeply into probability theory. This is not necessary since the proper mathematical foundation for all the inference tests contained in this textbook can be built as is done in Chapter 8 by the use of basic probability definitions, the addition rule and the multiplication rule. Chapter 16, covering both planned and post hoc comparisons, contains two post hoc tests: the Tukey HSD test and the Newman-Keuls test. Chapter 17 is a separate chapter on twoway ANOVA for instructors wishing to cover this topic in depth. For instructors with insufficient time for in-depth handling of two-way ANOVA, at the end of Chapter 15 on one-way ANOVA, I have qualitatively described the two-way ANOVA technique, emphasizing the concept of main effects and interactions. Chapter 19 is a review chapter that brings together all of the inference tests and provides practice in determining which test to use when analyzing data from different experimental designs and data of different levels of scaling. Students especially like the tree diagram on page 473 for helping them determine the appropriate test. Finally, at various places throughout the text, there are sections titled "What Is the Truth?" These sections show students practical applications of statistics.

The inferential material in this textbook is intended to be used in the sequence presented. However, if time constrains, Chapter 11 (the Mann-Whitney U test) may be omitted without injuring the rest of the material.

Some comments about the descriptive statistics part of this book: The material

is presented at a level that (1) serves as a foundation for the inference chapters and (2) enables students to adequately describe the data for its own sake. For the most part, material on descriptive statistics follows a traditional format because this works well. Chapter 1 is an exception. It discusses approaches for determining truth and establishes statistics as part of the scientific method, which is somewhat unusual for a statistics text.

Finally, I should say something about how I have handled the use of computers. I have written the textbook so that it can be used with or without computers. In the fifth edition, I have removed all computer material from the textbook and placed it in two manuals. This was done in response to suggestions from the reviewers. It was felt that incorporating the computer material into the textbook itself, as was done in the previous editions, had the potential to detract from the text material, particularly for students in classes that do not use computers, or that do so minimally. There are two computer manuals, one covering MINITAB and the other SPSS; both use the Windows platform. These manuals have been written in sufficient detail for student use with minimal recourse to additional manuals. Both manuals contain fully solved computer problems and computer end-of-chapter problems tailored for specific textbook chapters. It is important to note the following:

The computer material can be totally ignored or used at different levels, varying from just having students read selected, fully solved computer problems, to having students use MINITAB or SPSS software to illustrate concepts and solve computer exercises covering material throughout the textbook.

Fifth Edition Changes

New Material As mentioned earlier, because of positive feedback from users of the fourth edition, fifth edition changes are not extensive. However, there are several major changes as well as many additional less basic ones. These changes include:

 Reversing the presentation order of correlation and regression. In the previous editions, Linear Regression (Chapter 6) was presented first, followed by Correlation (Chapter 7). This was done because (1) I believed that the concept of correlation is better understood after first having treated regression, and (2) linear regression was rather straightforward and easily understood. This order was resisted from the beginning in the reviews for the first edition and has continued through the fourth edition. Most professors teaching statistics are used to seeing correlation presented before regression. They probably learned it in that order themselves. Moreover, it does make logical sense to present correlation first. After all, one first needs to know that a correlation exists between two variables, before attempting to do any prediction. Because the support for this ordering seems to have grown over the years, and was particularly strong amongst the reviewers for the fifth edition, I have decided to accept their wisdom and reverse the ordering, presenting Correlation first in Chapter 6 followed by Linear Regression in Chapter 7. Chapter 6 begins with background material on relationships, and then presents the material on correlation itself. Discussion of Pearson r as the slope of the least squares regression line using z scores has been moved to the chapter on linear regression.

- Removing all the computer material from the textbook, except an introductory section in Chapter 1, and placing the computer material in two new computer manuals. This was done because reviewers were almost unanimous in preferring this arrangement, regardless of whether they used computers in their courses or not. Most said that they felt inclusion in the textbook of the computer material detracted from the text material itself, and added so many pages to the textbook that it was becoming too big.
- Two new computer manuals, one for MINITAB for Windows and one for SPSS for Windows. The MINITAB manual illustrates the use of Release 11 and the SPSS manual SPSS 7.5. I have replaced MYSTAT with SPSS because SPSS is so widely used in the behavioral sciences, and because SPSS now has a student version running on the Windows platform. I have opted for the Windows platform because PCs running this operating system have become so widespread and inexpensive. Both manuals are similar, differing only in the software discussed. It is beyond the scope of these manuals to cover all of MINITAB or SPSS. However, these manuals do describe the software in sufficient detail for student use with the textbook material. Each manual contains fully solved and end-of-chapter computer problems for appropriate textbook chapters. Answers to the end-of-chapter problems are also provided.
- Abbreviated treatment of power. In the fifth edition, instead of presenting a separate chapter on power as was done in the fourth edition (Chapter 11, Power), this chapter has been eliminated, and an abbreviated discussion of power has been presented at the end of Chapter 10, Introduction to Hypothesis Testing Using the Sign Test. This has been done somewhat reluctantly because there are many advantages to having a separate chapter on power. This change has been made to streamline the textbook, and because feedback from instructors indicates that many do not use this chapter or use it only in an attenuated manner. Fortunately, discussing power in conjunction with the sign test, as is done in Chapter 10, allows briefer treatment of power with understanding. The extensive treatment of power in conjunction with the z test in Chapter 12 has been kept.
- Change in illustrative example that introduces hypothesis testing in Chapter 10. For the first four editions, hypothesis testing was introduced through the example, "Marijuana and Reaction Time." This example has become dated and has been replaced with a more current and hopefully interesting example, "Marijuana and the Treatment of AIDS Patients."
- New section in Chapter 10, Significance Versus Importance. In the past editions, this important topic was covered in the "What Is the Truth?" section at the end of Chapter 16. It was decided that it properly belongs in Chapter 10, and deserves more prominent exposure.
- Proper names changed. At various places throughout the textbook, proper names have been changed to better reflect diversity and thereby enable all students to see themselves as potential statistical experts.
- Two new "What Is the Truth?" sections. "What Is the Truth? Sperm Count Decline—Male or Research Inadequacy?" has been added at the end of Chapter 8, Random Sampling and Probability. This section is an applied illustration of the importance of random sampling to the inference process. "What Is the Truth? Statistics and Applied Social Research—Useful or 'Abuseful'?" has been added at the end of Chapter 18, Chi-Square and Other

Nonparametric Tests. This section discusses how applied social research can become biased due to the personal interests of the researchers or funding group, and raises the question of its utility and ethics. It has been placed in this chapter because chi-square is one of the main inference tests used in applied social research.

- New or revised end-of-chapter questions and problems. Over fifty new or revised end-of-chapter questions and problems have been added to update and extend this material.
- Appendices changed. Appendices B and C of the fourth edition that dealt with computers have been removed. In addition, Appendix D, Symbols, has been moved to the inside covers of the textbook. Finally, a Glossary has been added.

Ancillary Package The supplements consist of:

- A student's study guide, intended for review and consolidation of the material contained in each chapter of the textbook. Each chapter of the study guide has a chapter outline, a programmed learning concept review, exercises and answers to exercises, true—false questions and answers, and an end-of-chapter self-quiz with answers. Many students have commented on the helpfulness of this study guide.
- An **instructor's manual** contains short answer, multiple-choice, and true-false questions for each chapter. The answers to the multiple-choice and true-false questions are given in bold type to the left of the questions. This manual also contains answers to selected end-of-chapter problems contained in the textbook. Because of requests from instructors, I have not included answers to *all* the computational end-of-chapter problems found in the text; rather, I have omitted answers from at least one problem in each chapter. The omitted answers are found near the end of the instructor's manual.
- Software: A MINITAB manual and an SPSS manual illustrate use of these statistical software packages in conjunction with the material covered in the textbook. The MINITAB manual covers MINITAB release 11 for Windows, and the SPSS manual SPSS 7.5 for Windows. Each manual discusses its respective software, and contains fully solved and end-of-chapter computer problems for appropriate textbook chapters. Each also contains answers to these problems.
- Transparency masters feature a selection of key figures and tables from the text.
- WESTEST 3.2, a computerized testing package for Windows or Macintosh computers that allows instructors to create, edit, store, and print exams.

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Over the past four editions, many people have contributed to this textbook. Foremost is Clyde Perlee, who was editor-in-chief of the College Division of West Publishing Company. It is with distinct sadness and much gratitude that I bid farewell to Clyde. He has been a real driving force and inspiration for over 15 years. Thank you, Clyde.

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The material covered in this textbook, study guide, instructor's manual, and MINITAB and SPSS manuals is appropriate for undergraduate students with a major in psychology or related behavioral science discipline. I believe the approach I have followed helps considerably to impart this subject matter with understanding. I am grateful to receive any comments that will improve the quality of these materials.

Robert R. Pagano

Sources

Many of the examples and problems used in this textbook are adapted from actual research. The citations for this research are given below.

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