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Understanding Statistics in the Behavioral Sciences

行为科学中的统计学入门

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Understanding Statistics in the Behavioral Sciences,6e.

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出版说明

21世纪的竞争是人才的竞争，是全球性人才培养机制的较量。如何培养面向现代化、面向世界、面向未来的高素质的人才成为我国人才培养的当务之急。为此，教育部发出通知，倡导在全国普通高等学校中使用原版外国教材，进行双语教学，培养适应经济全球化的人才。

为了响应教育部的号召，促进统计教材的改革，培养既懂统计专业知识又具备较高英语语言能力的统计人才，全国统计教材编审委员会在国家统计局领导的大力支持下，组织引进了这套“外国优秀统计学教材”。

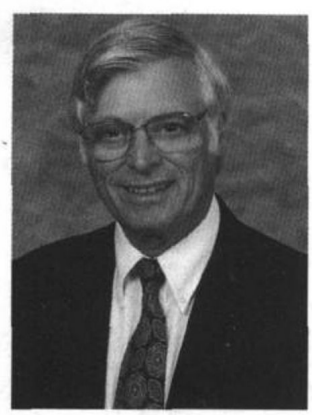
为了做好“外国优秀统计学教材”引进工作，全国统计教材编审委员会将其列入了“十五”规划，并成立了由海内外统计学家组成的专家委员会。在对国外统计学教材的使用情况进行了充分了解，对国内高等院校使用外国统计学教材的需求情况进行了仔细分析，并对从各种渠道推荐来的统计教材进行了认真审定的基础上，制定了引进教材书目。在确定引进教材书目的过程中，我们得到了国内外有关专家、有关院校和外国出版公司及其北京办事处的支持和帮助，在此致谢。中国人民大学统计学系的吴喜之教授不仅推荐了大量的优秀候选书目，而且校译了影印教材的翻译目录，为这套教材的及早出版作了大量的工作，我们表示衷心的谢意。

这套引进教材多数是国外再版多次、反响良好，又比较适合国内情况、易于教学的统计教材。我们希望这套引进教材的出版对促进我国统计教材的改革和高校统计学专业双语教学的发展能够起到重要的推动作用。

全国统计教材编审委员会

2002年8月28日

I dedicate this sixth edition to my wife, Carol Eikleberry, without whose love and support this edition could not have been written.



ABOUT THE AUTHOR

Robert R. Pagano received a Bachelor of Electrical Engineering degree from Rensselaer Polytechnic Institute in 1956 and a Ph.D. in Biological Psychology from Yale University in 1965. He was Assistant Professor and Associate Professor in the Department of Psychology at the University of Washington, Seattle, Washington, from 1965 to 1989. He was Associate Chairman of the Department of Neuroscience at the University of Pittsburgh, Pittsburgh, Pennsylvania, from 1990 to June 2000. While at the Department of Neuroscience, in addition to his other duties, he served as Director of Undergraduate Studies, was the departmental adviser for undergraduate majors, taught both undergraduate and graduate statistics courses, and served as a statistical consultant for departmental faculty. Bob was also Director of the Statistical Cores for two NIH center grants in schizophrenia and Parkinson's disease. He retired from the University of Pittsburgh in June 2000. Bob's research interests are in the psychobiology of learning and memory, and the physiology of consciousness. He has taught courses in introductory statistics at the University of Washington and at the University of Pittsburgh for over thirty years. He has been a finalist for the outstanding teaching award at the University of Washington for his teaching of introductory statistics.

Bob is married to Carol A. Eikleberry and they have a 10-year-old son, Robby. In addition, Bob has five grown daughters, Renee, Laura, Maria, Elizabeth, and Christina, and one granddaughter, Mikaela. Retirement presents new opportunities for him that complement his interests in teaching and writing. Bob loves tennis and is presently training for a shot at Wimbledon (although thus far he is having difficulty besting his son Robby). He also loves the outdoors, especially hiking, and his Starbucks coffee.

PREFACE

I have been teaching a course in introductory statistics for over 30 years, first within the Department of Psychology at the University of Washington and most recently 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 most of these students 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. They rate the textbook even higher, saying among other things that it is very clear; they like the touches of humor; and that it helps to have the material presented in such great detail.

In preparing the sixth edition, I have been guided again by advice and feedback from students and professors. 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 are three recommended major changes that I have made in the sixth edition. First, the chapter on power that had been removed in the fifth edition has been put back into the sixth edition; it is Chapter 11. Second, I have eliminated the separate chapter on the Mann–Whitney *U* test. Instead, the material on the Mann–Whitney *U* test (Chapter 12 in the fifth edition) has been condensed and included with the other nonparametric tests in Chapter 18. Finally, due to the recent recognition of the importance of "size of effect," I have introduced this topic in Chapter 11 of the sixth edition with a general discussion of it in conjunction with power, and shown how to compute the size of effect in conjunction with the "*t* Test for In-

dependent Groups" in Chapter 14, and with "One-Way Analysis of Variance" in Chapter 15.

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 of these students, statistics is a subject that elicits considerable anxiety and which is avoided as long as possible. Moreover, I think it is fair to say that when the usual undergraduate course is completed, many students have not understood much of the inferential statistics material. This is partly because the material is inherently difficult and the students themselves are not proficient in mathematics. However, in my opinion, this situation also exists 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 five 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 better sequencing of the inferential material.

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 by using the sign test as the first inference test encountered by the student and by using the following sequences of topics: random sampling and probability, binomial distribution, introduction to hypothesis testing using the sign test, power, 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 finally, a review of all 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 problem with this approach is that the sampling distribution of the mean cannot be generated from simple probability considerations, which makes it hard for students 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 of size N were taken 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. *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 rotely. 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 of sampling distributions, I believe it is far 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 very easy to understand, and it can be derived from the basic probability rules developed in an earlier chapter (Chapter 8, "Random Sampling and Probability"). It is entirely dependent on simple, logical considerations. Hence, students can easily follow its generation. Moreover, it can also be generated by the same empirical process that is used later in the text 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 with the sign test has other advantages. All of 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 is quite easy to follow.

Chapter 11 discusses power. Many texts do not discuss power at all, or else leave it until near the end of the book. Power is a complicated topic. Using the sign test as the vehicle for a power analysis simplifies matters. Understanding power is necessary if one is to grasp the methodology of scientific investigation itself. When students gain insight into power, they can see why we bother discussing Type II errors. Further, they see for the first time why we conclude by "retaining H_0" as a reasonable explanation of the data rather than by "accepting H_0 as true" (a most important distinction). In this same vein, students also appreciate the error involved when one concludes that two conditions are equal from data that are not statistically significant. Thus, power is a topic that brings the whole hypothesis testing methodology into sharp focus.

At this state of the exposition, a diligent student can grasp the idea that data analysis basically involves two steps: (1) calculating the appropriate statistic and (2) evaluating the statistic based on its sampling distribution. The time is ripe for a formal discussion of sampling distributions and how they can be generated (Chapter 12). After this, the sampling distribution of the mean is introduced. Rather than depending on an abstract theoretical definition of the sampling distribution of the mean, the text discusses how this sampling distribution can be generated empirically. This gives a much more concrete understanding of the sampling distribution of the mean.

Due to previous experience with one easily understood sampling distribution, the binomial distribution, and using the empirical approach for the sampling distribution of the mean, most conscientious students have a good grasp of what sampling distributions are and why they 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 understand the use of these tests rather than just rotely solving problems. With this background, students can comprehend that all of 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 set for moving through 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 textbooks in the clarity of presentation, the number and interest value of fully solved problems, and the use of empirically derived sampling distributions. In addition, there are differences that are specific to each test. For example: (1) the *t* test for correlated groups is introduced directly following the *t* test for single samples and is developed as a special case of the *t* test for single samples, only 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) there is a discussion of the factors influencing the power of experiments using Student's *t* test; (4) the correlated and independent groups designs are compared with regard to utility; and (5) there is a discussion of "size of effect" in conjunction with the *t* test for independent groups.

Chapters 15 and 17 deal with the 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, they promote understanding of this reasonably complicated material. In using single subscript notation, I have followed in part the notation used by E. Minium, *Statistical Reasoning in Psychology and Education,* 2nd edition, John Wiley & Sons, New York, 1978. 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 of the inference tests contained in this textbook can be built by the use of basic probability definitions, in conjunction with the addition and multiplication rules, as has been done in Chapter 8. Chapter 15 differs from most textbooks in that it includes a discussion of "size of effect" in conjunction with one-way ANOVA. 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 two-way 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 concepts 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 in this chapter 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.

Some comments about the descriptive statistics part of this book are in order. The descriptive material is written at a level that (1) serves as a foundation for the inference chapters and (2) enables students to adequately describe the data for the data's 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 scientific method, which is somewhat unusual for a statistics textbook.

Sixth Edition Changes

New Material As mentioned earlier, because of positive feedback from users of the fifth edition, sixth edition changes are not extensive. However, there are

several major changes as well as many additional minor ones. These changes include:

- *Reintroducing into the Textbook Chapter 11, "Power."* In the fifth edition, I removed the chapter discussing power in conjunction with the sign test that was contained in the first four editions. I did so because I believed that most instructors skipped this chapter, due to time constraints. However, many instructors have informed me that contrary to my belief, they did use this material in their courses and asked that it be put back. Since I basically believe that power is a very important topic, and since many of the instructors that use my text apparently agree, I have gladly reintroduced this power chapter in the sixth edition.
- *Elimination of a Separate Chapter on the Mann–Whitney U Test.* The first five editions of the textbook contained a separate chapter on the Mann–Whitney *U* test, which was Chapter 11 in the fifth edition. Sequentially, this chapter came after the students had experienced one sampling distribution, the binomial distribution, and before they were introduced to the sampling distribution of the mean. I believe that covering the Mann–Whitney *U* test in this order facilitates understanding of sampling distributions. It also serves as a vehicle for introducing the independent groups design to students. However, due to feedback from users of the fifth edition, I have eliminated this chapter, condensed the material it contained, and placed this abbreviated treatment of the Mann–Whitney *U* test in Chapter 18, "Chi-Square and Other Nonparametric Tests." Thus, treatment of the Mann–Whitney *U* test in the sixth edition follows the manner in which this test is covered in most textbooks. Professors wanting this change stated that they didn't have time to cover this chapter, and didn't think the Mann–Whitney *U* test deserved such special treatment, given the more important topics they needed to cover. I do see both sides of the argument. I, myself, have skipped this chapter on many occasions, due to time constraints. However, when time allowed, it was an excellent chapter that helped students understand the remaining chapters and gain confidence in their ability to understand inferential statistics. Professors that prefer the separate chapter treatment of the Mann–Whitney *U* test (0-534-58621-X) for their students can obtain the chapter, shrink-wrapped with their textbook orders, by contacting their local Wadsworth representative or Wadsworth Publishing at *http://psychology.wadsworth.com.*.
- *Including the Topic "Size of Effect."* Most introductory statistics textbooks do not include this topic. Instead, the material concentrates on how, using sample data, one can infer whether the independent variable had a real effect. However, assuming there is a real effect, it is also important to know the size of the effect. Failure to include this topic in introductory statistics textbooks can give students the false impression that finding a significant effect is all that matters. Too often, after finding or reading about a significant effect, students and—if the truth be known—scientists, too, fail to ask the question, "How large is the effect?"

  I think it is obvious that, in general, large effects are more important than small ones. Certainly, from a practical standpoint, there is great interest in knowing the size of an effect. For example, assume a study has shown that a costly new teaching method is significantly better than the old one. Before spending millions of dollars on implementing the new teaching method, we would want to know how much better the new teaching method is, that is, how large is the effect. Most probably, we would be very

hesitant to make the investment if the size of the effect was quite small, say, only a few percentage points, in end-of-course performance. On the other hand, if the effect were a large one, assuming other factors were favorable, it could make sense to bite the bullet and incorporate the new teaching method into the curriculum.

Because of the importance of this topic, we have decided to include it in the sixth edition. "Size of effect" is discussed generally in conjunction with power in Chapter 11 and specifically in conjunction with the *t* test for independent groups in Chapter 14 and the analysis of variance in Chapter 15.

- *Including the Topic, "Effect of Extreme Score" in Chapter 6, "Correlation."* This section alerts the student to the rather large effect that an extreme score can have on the value of the correlation coefficient, particularly when N is small. Accordingly, the student is cautioned to check the scatter plot for extreme scores when computing correlation coefficients.
- *Two new "What Is the Truth?" Sections.* A new "What Is the Truth?" section has been added at the end of Chapter 8, titled "A Sample of a Sample." This section discusses how representative samples for polls are formed, using the New York Times/CBS News Poll as an example. Another new "What Is the Truth?" section has been added at the end of Chapter 10, titled "Anecdotal Reports Versus Systematic Research." This section queries the students about an article that appeared in a recent issue of the *New York Times on the Web*. The article presents an important and fairly common occurrence in real life, namely, a situation where testimony from individuals about the effectiveness of a product is in conflict with systematic research concerning the product.
- *New or Revised End-of-Chapter Questions and Problems.* More than 30 new or revised end-of chapter questions and problems have been added to update and extend this material.
- *New Web-Based End-of-Chapter Section, "Web Connection."* In the sixth edition, there is a new section at the end of each chapter that alerts students that the following new Web-based material for that chapter is available for their use:
  1. An on-line quiz to test their knowledge before moving on. These quizzes exist for each chapter and are located at *http://psychology.wadsworth.com/courses/statistics.*
  2. Additional on-line, fully solved practice problems for the chapter. If they desire, students can get more practice in solving problems appropriate for the chapter material by doing these practice problems. There are additional, fully solved practice problems for each chapter; they are located at *http://psychology.wadsworth.com/courses/statistics.*
- *Adding Chapter Outlines.* Chapter outlines have been added at the beginning of each chapter to help students preview the forthcoming material.
- *Wording and Formatting Changes.* Minor wording and formatting changes have been made throughout the textbook to improve clarity and interest.

Ancillary Package

The supplements consist of:

- A **student's study guide** that is 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 re-

view, 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. (0-534-57772-5)

- An **instructor's manual** that 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 question. 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; instead, I have omitted answers from at least one problem in each chapter. These answers are found at the end of the instructor's manual. The instructor's manual also contains end-of-chapter problems suitable for computer use (see below). (0-534-57773-3)
- **Software:** The **MINITAB Manual** that accompanied the fifth edition has been discontinued because of low demand. The end-of-chapter computer problems contained in the MINITAB manual have been placed in the instructor's manual for instructors to use as desired. For instructors who desire to use SPSS in conjunction with their statistics course, I recommend L. A. Kirkpatrick and B. C. Feeney's, *A Simple Guide to SPSS for Windows for Versions 8.0, 9.0, and 10.0 Revised Edition,* Wadsworth/Thomson Learning, Belmont CA 94002. (0-534-58086-6)
- **ExamView,** a computerized testing package for Windows or Macintosh computers that allows instructors to create, edit, store, and print exams. (0-534-57774-1)

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The material covered in this textbook, study guide, and instructor's manual 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 feedback that will improve the quality of these materials. Please send your comments to the Web master at *http://www.psychology.wadsworth.com/courses/statistics.*

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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Material for the "What Is the Truth?" sections has been adapted from the following sources:

What Is the Truth? (p. 12): Advertisement in *Psychology Today,* 1984, June, p. 13. Reprinted with permission.

What Is the Truth? (p. 13): Advertisement in *Cosmopolitan,* 1983, October, p. 154.

What Is the Truth? (p. 57): Puget Power awaits rate decision (1984, September 25), *Journal American,* Section D, p. 1. Graph reprinted with permission.

What Is the Truth? (p. 123): Equation for success: Good principal = good elementary school (1985, August 23), *Seattle Post-Intelligencer,* Section A, pp. 1, 11.

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