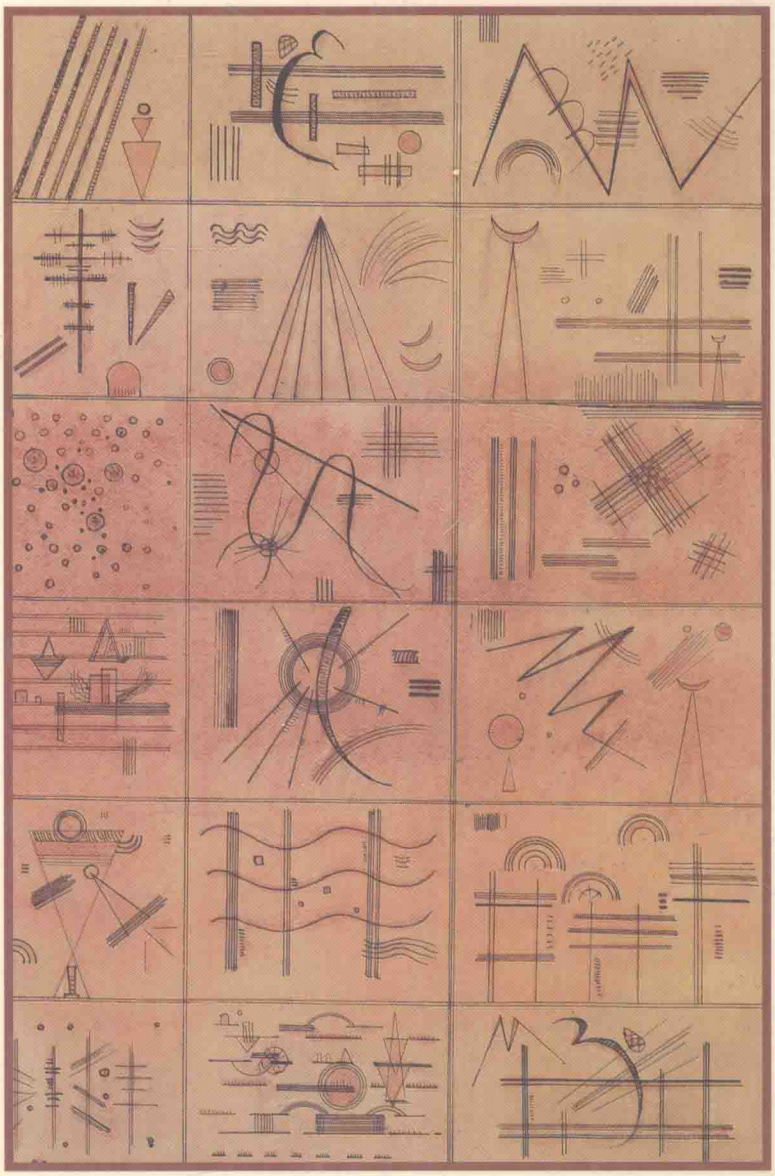
Statistics for the Behavioral Sciences

FOURTH EDITION



GRAVETTER & WALLNAU

STATISTICS for the BEHAVIORAL SCIENCES

A First Course for Students of Psychology and Education

FOURTH EDITION

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PREFACE

There are three kinds of lies: Lies, damned lies, and statistics.

This quote, attributed by Mark Twain to Benjamin Disraeli, reflects a commonly held belief that statistics (or perhaps even statisticians) should not be trusted. Unfortunately, this mistrust is sometimes justified. In this book, we shall see that statistical techniques are tools that are used to organize information and to make inferences from our data. Like any other tool, statistics can be misused, which may result in misleading, distorted, or incorrect conclusions. It is no small wonder that we are sometimes skeptical when a statistician presents findings. However, if we understand the correct uses of statistical techniques, then we will recognize those situations in which statistical procedures have been incorrectly applied. We can decide which statistics are more believable. Therefore, the goal of this book is to teach not only the methods of statistics, but also how to apply these methods appropriately. Finally, a certain amount of mistrust is healthy. That is, we should critically examine information and data before we accept their implications. As you will see, statistical techniques help us look at data with a critical eye.

For those of you who are familiar with previous editions of *Statistics for the Behavioral Sciences,* you will notice that some changes have been made. Our students are foremost in our minds when we revise the text. Over the years, they have provided honest and useful feedback. Their hard work and perseverance have made our writing and teaching most rewarding. We sincerely thank them.

Our friends at West Publishing once again have made an enormous contribution. We thank our editor Clark Baxter, developmental editor Patricia MacDonald, and production editor Emily Autumn. They are very capable people who possess many professional and technical skills. Just as important, they are very warm individuals who have worked with us in an atmosphere of friendship. We are most grateful to them for their contributions to this project and for their guidance and enthusiasm. We also give special thanks to Roxy Peck of California Polytechnic State University for carefully reviewing the manuscript in its final stages.

We were very fortunate to have many good people provide thoughtful reviews, helpful comments, and constructive criticism at various stages in the development of the manuscript. We thank the following colleagues for their earnest efforts:

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Finally, the authors thank their spouses, Debbie and JoAnn, for their assistance, encouragement, leeway, and, above all, patience.

TO THE INSTRUCTOR

We have made a number of revisions to *Statistics for the Behavioral Sciences,* while at the same time retaining the features that help students. You will recognize its organization, for example, We continue to use intuitive explanations of formulas, analogies, and many opportunities for review. We still try to anticipate the problems students have with statistics. Some of the noteworthy revisions are as follows.

Chapter 3 (Central Tendency) has a revised section on the weighted mean. We return to this topic in Chapter 10 to show how the formula for pooled variance is like a weighted mean (that is, a weighted mean-square). Also, there is discussion of the difficulties of identifying the "center" of the distribution.

Chapter 4 (Variability) includes more discussion of topics such as degrees of freedom and rough estimates of standard deviation.

Chapter 6 (Probability) has been a troublesome chapter. We have revised the sections concerning probability and the normal distribution. This change simplifies the use of the unit normal table, which has been reformatted.

Chapter 7 (Probability and Samples: The Distribution of Sample Means) provides a more thorough treatment of standard error. We also introduce an alternate formula for standard error based on variance. This formula carries over to standard error measures in Chapters 9, 10, and 11. Chapter 7 has a new section on standard error and statistical inference, which serves as a bridge to hypothesis testing (Chapter 8).

Chapter 11 (Hypothesis Tests with Related Samples) contains more coverage of the problems posed by repeated-measures studies. There is a detailed look at the role of individual differences by comparing the independent-measures and repeated-measures t statistics. There is also a new discussion of carry-over effects and progressive error.

A more conceptual approach has been added to the presentation of analysis of variance (Chapter 13) with the new section "A Conceptual View of ANOVA."

Chapter 15 (Two-Factor ANOVA) has revisions on the topic of interactions. We have added a section covering simple main effects for two-factor analysis of variance.

In Chapter 16, the section on hypothesis tests with the Pearson correlation has been revised in its form so that it is easier to follow. We have revised and expanded the discussion of r^2 for clarification.

The text now contains "In the Literature" sections in nearly every chapter. These sections demonstrate how statistical results are reported in APA style and the jargon we use.

A "Time Out" section appears after each series of related chapters. These sections summarize and integrate the concepts from the preceding set of chapters and prepare the students for the next series.

The math review appendix has been revised with new items for the self-tests and a new section on the order of operations.

Finally, we have revised or replaced many of the older end-of-chapter problems, and computer coverage now is contained in separate manuals (for SPSS, Minitab, and Mystat).

TO THE STUDENT

At the beginning of every semester, we watch our new students walking into the classroom as though they were about to have their teeth extracted. The expressions on their faces do not lie. They might look stone-cold (as if in shock), or extremely serious, or even distraught. Clearly, the tension of fear and dread fills the air. Despite the fears and anxieties you may have about this course (the majority of students do have some fear or dread), we think it is important to become literate in basic statistics. This is evident when one considers that our world has become information-laden and information-dependent. The media inform us of the latest findings on oat bran and your health, global warming, economic trends, aging and memory, the effects of educational programs, and so on. Information and data flow through the Internet in unfathomable volumes. Pollsters give us weekly findings. All these data-gathering efforts provide an enormous and unmanageable amount of information. Enter the statisticians, who use statistical procedures to analyze, organize, and interpret vast amounts of data. Having a basic understanding of a variety of statistical procedures will help you understand these findings and, perhaps more important, to examine them critically.

What about the fear of taking a course in statistics? One way to deal with the fear is to get plenty of practice. You will notice that this book provides you with a number of opportunities to repeat the techniques you will be learning in the form of Learning Checks, Examples, Demonstrations, and end-of-chapter Problems. We encourage you to take advantage of these opportunities. Also, we encourage you to read the text, rather than just memorizing the formulas. We have taken great pains to present each statistical procedure in a conceptual context that explains why the procedure was developed and when it should be used. If you read this material and gain an understanding of the basic concepts underlying each statistical formula, you will find that learning the formulas and how to use them will be much easier.

Over the years, the students in our classes have given us many helpful suggestions. We learn from them. If you have any suggestions or comments about this book, you can send a note to us at the Department of Psychology, 350 New Campus Drive, SUNY College at Brockport, Brockport, NY 14420. We may not be able to answer every letter, but we always appreciate the feedback. (LBW also receives e-mail at the following Internet address: lwallnau@acspr1.acs.brockport.edu)

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SUPPLEMENTS *Instructor's Manual* with Problem Solutions and Test Bank to Accompany *Statistics for the Behavioral Sciences,* 4/e, offers

- Approximately 35 test questions per chapter consisting of true/false, multiple choice, and computational problems
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Study Guide to Accompany *Statistics for the Behavioral Sciences,* 4/e, includes:

- Learning Objectives
- Chapter Summaries
- List of New Terms and Concepts
- List of New Formulas
- Hints and Cautions
- Self Test
- Reviews consisting of 10 to 15 questions and their answers.

MYSTAT Software:

- *MYSTAT™ Software* by SYSTAT™ Inc. is available for IBM® PCs and Macintosh® computers. This software provides a full screen data editor, algebraic variable transformations, sorting, ranking and weighting, descriptive statistics, multi-way tabulations, chi-square, correlation, regression, ANOVA, ANOCOVA, nonparametric tests, scatterplots, box plots, histograms, stem-and-leaf diagrams and time series plots. Available to adoptors upon their request.

New . . . MYSTAT and *Minitab Manuals:*

- Contains information in how the programs are used in behavioral statistics. The Minitab Manual contains examples from the text.

New . . . SPSS Manual by Zandra Gratz and Gloria Volpe of Kean College of New Jersey:

- Introduces students to the Statistics Package for Social Sciences followed by analyzed examples from the text.

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- Over 100 figures and tables from the book.

CONTENTS

CHAPTER 1 INTRODUCTION TO STATISTICS

CONTENTS

PREVIEW

Before we begin our discussion of statistics, we ask you to take a few moments to read the following paragraph, which has been adapted from a psychology experiment reported by Bransford and Johnson (1972).

> The procedure is actually quite simple. First you arrange things into different groups depending on their makeup. Of course, one pile may be sufficient, depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step; otherwise you are pretty well set. It is important not to overdo any particular endeavor. That is, it is better to do too few things at once than too many. In the short run this may not seem important, but complications from doing too many can easily arise. A mistake can be expensive as well. The manipulation of the appropriate mechanisms should be self-explanatory, and we need not dwell on it here. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one never can tell.*

You probably find the paragraph a little confusing, and most of you probably think it is describing some obscure statistical procedure. Actually, this paragraph describes the everyday task of doing laundry. Now that you know the topic of the paragraph, try reading it again—it should make sense now.

Why did we begin a statistics textbook with a paragraph about washing clothes? Our goal is to demonstrate the importance of context—when not in the proper context, even the simplest material can appear difficult and confusing. In the Bransford and Johnson experiment, people who knew the topic before reading the paragraph were able to recall 73% more than people who did not know that it was about doing laundry. When you have the appropriate background, it is much easier to fit new material into your memory and to recall it later. In this book, we begin each chapter with a preview. The purpose of the preview is to provide the background or context for the new material in the chapter. As you read each preview section, you should gain a general overview of the chapter content. Remember, all statistical methods were developed to serve a purpose. If you understand why a new procedure is needed, you will find it much easier to learn the procedure.

The objectives for this first chapter are to provide an introduction to the topic of statistics and to give you some background for the rest of the book. We will discuss the role of statistics within the general field of scientific inquiry, and we will introduce some of the vocabulary and notation that are necessary for the statistical methods that follow. In some respects, this chapter serves as a preview section for the rest of the book.

As you read through the following chapters, keep in mind that the general topic of statistics follows a well-organized, logically developed progression that leads from basic concepts and definitions to increasingly sophisticated techniques. Thus, the material presented in the early chapters of this book will serve as a foundation for the material that follows. The content of the first nine chapters, for example, provides an essential background and context for the statistical methods presented in Chapter 10. If you turn directly to the Chapter 10 without reading the first nine chapters, you will find the material confusing and incomprehensible. However, if you learn and use the background material, you will have a good frame of reference for understanding and incorporating new concepts as they are presented. To help you take advantage of the logical, step-by-step development of statistics, we have included two specific elements in this book. First, the opening page of each chapter includes a section titled "Tools You Will Need." This section lists topics from earlier parts of the book that we have identified as essential background for the new material that will be introduced in the chapter. Second, we have included special "Time Out" sections that appear after a series of related chapters. The "Time Out" sections summarize and integrate concepts from the series of preceding chapters in order to help prepare you for the next series of chapters.

Finally, we cannot promise that learning statistics will be as easy as washing clothes. But if you begin each new topic with the proper context, you should eliminate some unnecessary confusion.

*Bransford, J. D., and Johnson, M. K. (1972), Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11,* 717–726. Copyright by Academic Press. Reprinted by permission of the publisher and M. K. Johnson.

1.1 STATISTICS, SCIENCE, AND OBSERVATIONS

DEFINITIONS OF STATISTICS

Why study statistics? is a question countless students ask. One simple answer is that statistics have become a common part of everyday life and, therefore, deserve some attention. A quick glance at the newspaper yields statistics that deal with crime rates, birth rates, average income, average snowfall, and so on. By a common definition, therefore, statistics consist of facts and figures.

These statistics generally are informative and time saving because they condense large quantities of information into a few simple figures or statements. For example, the average snowfall in Chicago during the month of January is based on many observations made over many years. Few people would be interested in seeing a complete list of day-by-day snowfall amounts for the past 50 years. Even fewer people would be able to make much sense of all those numbers at a quick glance. But nearly everyone can understand and appreciate the meaning of an average.

In this book, however, we will use another definition of the term *statistics*. When researchers use the word *statistics,* they are referring to a set of mathematical procedures that are used to organize, summarize, and interpret information.

DEFINITION

The term *statistics* refers to a set of methods and rules for organizing, summarizing, and interpreting information.

Statistical procedures help ensure that the information or observations are presented and interpreted in an accurate and informative way. In somewhat grandiose terms, statistics help researchers bring order out of chaos. In addition, statistics provide researchers with a set of standardized techniques that are recognized and understood throughout the scientific community. Thus, the statistical methods used by one researcher will be familiar to other researchers, who can accurately interpret the statistical analyses with a full understanding of how the analysis was done and what the results signify. Although facts and figures can be important, this book will focus on the methods and procedures of statistics (see Box 1.1).

STATISTICS AND SCIENCE

It is frequently said that science is *empirical*. That is, scientific investigation is based on making observations. Statistical methods enable researchers to describe and analyze the observations they have made. Thus, statistical methods are tools for science. We might think of science as consisting of methods for making observations and of statistics as consisting of methods for analyzing them.

These observations should be public, in the sense that others are able to repeat the observations using the same methods to see if the same findings will be obtained.

On one mission of the space shuttle Columbia, so much scientific data were relayed to computers on earth that scientists were hard pressed to convey, in terms the public could grasp, how much information had been gathered. One individual made a few quick computations on a pocket calculator and determined that if all the data from the mission were printed on pages, they would pile up as high as the Washington Monument. Such an enormous amount of information is unmanageable in this crude form. To interpret the data, many months of work have to be done by many people to statistically analyze them. Statistical methods serve scientific investigation by organizing and interpreting data.

1.1 STATISTICS IN EVERYDAY LIFE

THE FOLLOWING article appeared in the *New York Times* January, 4, 1991, and provides a good example of why a basic understanding of statistics is important for everyday tasks such as reading (and understanding) a newspaper article. This article presents a variety of statistics, using both definitions of the term. First, the report includes numerous facts and figures. In addition, the article reports the results of statistical methods that were used to help organize and interpret the figures.

Although you probably can make some sense of this report, there are a few statistical terms, such as median income, that you may not understand. After you finish Chapter 3, come back and read this newspaper article again. It should be perfectly clear by then.

Purchase index up for homes:

WASHINGTON, Jan. 3 (AP)—Falling home prices and rising incomes combined to raise the typical American family's ability to buy a home to its highest level in 13 years, a real estate trade group said today.

The National Association of Realtors said its Housing Affordability Index reached 115.6 in November, up from 113.3 in October. This was the highest level since the index hit 116 in December 1977.

The 115.6 reading means a family earning the national median income of $35,467 had 115.6 percent of the income needed to qualify for conventional financing covering 80 percent of a median-priced home costing $91,300.

The median price of an existing home dropped $1,600, from $92,900 in October, while median income rose $114, from $32,353.

Improvement in housing affordability conditions were posted in all of the regions between October and November. But the typical family still fell short of having the funds to buy a median-priced home in the Northeast and the West, areas with the highest median prices.

In the northeast, a family earning the median income of $41,565 had 91.9 percent of the income needed to buy a median-priced home costing $133,600. A western family with the median income of $37,825 had 82.2 percent of the income needed to buy a $138,700 home.

1.2 POPULATIONS AND SAMPLES

WHAT ARE THEY?

Scientific research typically begins with a general question about a specific group (or groups) of individuals. For example, a researcher may be interested in the effect of divorce on the self-esteem of preteen children. Or a researcher may want to examine the attitudes toward abortion for men versus women. In the first example, the researcher is interested in the group of *preteen children*. In the second example, the researcher wants to compare the group of *men* with the group of *women*. In statistical terminology, the entire group that a researcher wishes to study is called a *population*. By entire group, we literally mean every single individual.

DEFINITION

A *population* is the set of all individuals of interest in a particular study.

As you can well imagine, a population can be quite large—for example, the entire set of women on the planet earth. A researcher might be more specific, limiting the population for study to women who are registered voters in the United States. Perhaps the investigator would like to study the population consisting of