CENGAGE

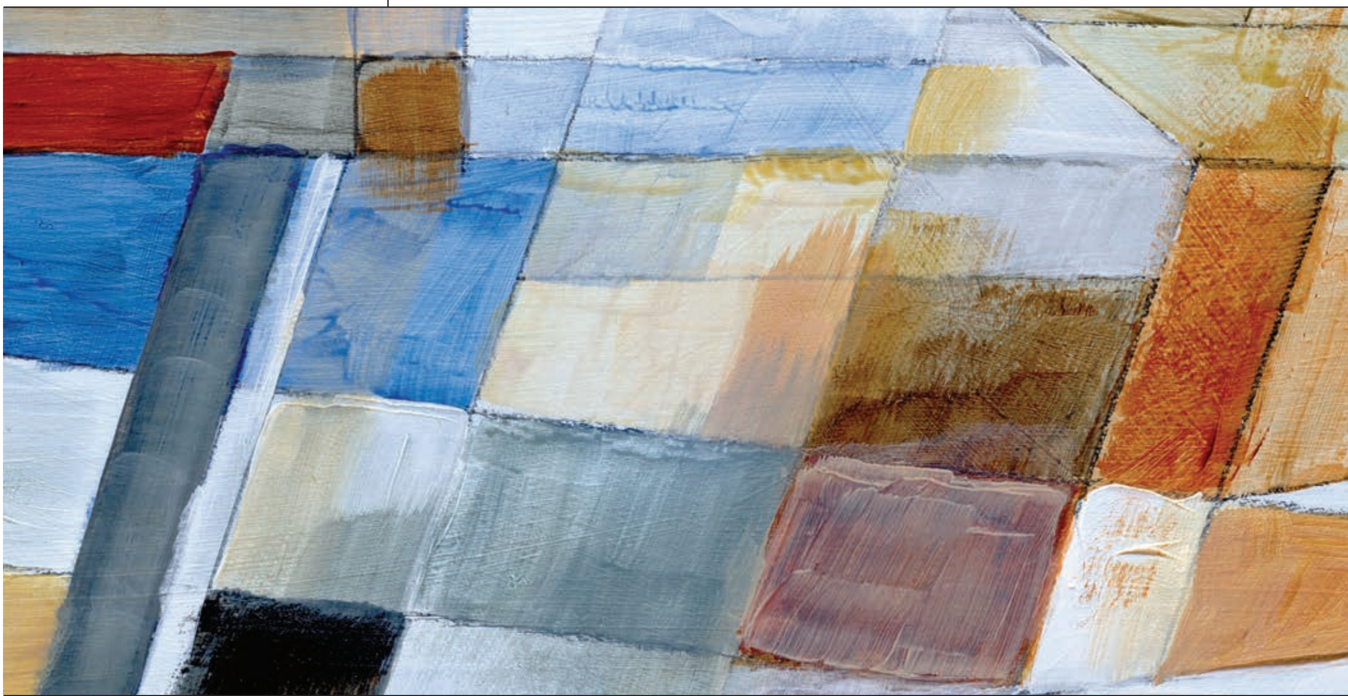
Tenth Edition

Essentials of Statistics for the Behavioral Sciences

Frederick J Gravetter | Larry B. Wallnau
Lori-Ann B. Forzano | James E. Witnauer

EDITION
10

Essentials of Statistics for the Behavioral Sciences



clivewa/Shutterstock.com

FREDERICK J GRAVETTER
Late of The College at Brockport, State University of New York

LARRY B. WALLNAU
The College at Brockport, State University of New York

LORI-ANN B. FORZANO
The College at Brockport, State University of New York

JAMES E. WITNAUER
The College at Brockport, State University of New York

CENGAGE
Australia • Brazil • Mexico • Singapore • United Kingdom • United States

Essentials of Statistics for the Behavioral Sciences, 10th Edition
Frederick J Gravetter, Larry B. Wallnau, Lori-Ann B. Forzano, James E. Witnauer

Senior Vice President, Higher Education & Skills Product: Erin Joyner

Product Director: Laura Ross

Product Manager: Josh Parrott

Content Manager: Tangelique Williams-Grayer, Brian Pierce

Product Assistant: Kat Wallace

Marketing Manager: Tricia Salata

Intellectual Property Analyst: Deanna Ettinger

Intellectual Property Project Manager: Nick Barrows

Production Service: Lori Hazzard, MPS Limited

Art Director: Bethany Bourgeois

Text Designer: Liz Harasymczuk

Cover Designer: Cheryl Carrington

Cover Image: clivewa/Shutterstock.com

Library of Congress Control Number: 2019911268

ISBN: 978-0-357-36529-8

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Cengage is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at **www.cengage.com.**

Cengage products are represented in Canada by Nelson Education, Ltd.

To learn more about Cengage platforms and services, register or access your online learning solution, or purchase materials for your course, visit **www.cengage.com.**

Printed in the United States of America
Print Number: 01 Print Year: 2019

BRIEF CONTENTS

CONTENTS

CHAPTER 1 Introduction to Statistics 1


clivewa/Shutterstock.com

CHAPTER 2 Frequency Distributions 43


clivewa/Shutterstock.com

CHAPTER 3 Central Tendency 73


clivewa/Shutterstock.com

CHAPTER 8 Introduction to Hypothesis Testing 243

clivewa/Shutterstock.com

CHAPTER 9 Introduction to the *t* Statistic 291

clivewa/Shutterstock.com

CHAPTER 10 The *t* Test for Two Independent Samples 323

clivewa/Shutterstock.com

CHAPTER 11 The *t* Test for Two Related Samples 359

clivewa/Shutterstock.com

CHAPTER 15 The Chi-Square Statistic: Tests for Goodness of Fit and Independence 533


clivewa/Shutterstock.com

APPENDIXES

PREFACE

Many students in the behavioral sciences view the required statistics course as an intimidating obstacle that has been placed in the middle of an otherwise interesting curriculum. They want to learn about psychology and human behavior—not about math and science. As a result, the statistics course is seen as irrelevant to their education and career goals. However, as long as psychology and the behavioral sciences in general are founded in science, knowledge of statistics will be necessary. Statistical procedures provide researchers with objective and systematic methods for describing and interpreting their research results. Scientific research is the system that we use to gather information, and statistics are the tools that we use to distill the information into sensible and justified conclusions. The goal of this book is not only to teach the methods of statistics, but also to convey the basic principles of objectivity and logic that are essential for the behavioral sciences and valuable for decision making in everyday life.

Essentials of Statistics for the Behavioral Sciences, *Tenth Edition*, is intended for an undergraduate statistics course in psychology or any of the related behavioral sciences. The overall learning objectives of this book include the following, which correspond to some of the learning goals identified by the American Psychological Association (Noland and the Society for the Teaching of Psychology Statistical Literacy Taskforce, 2012).

1. Calculate and interpret the meaning of basic measures of central tendency and variability.
2. Distinguish between causal and correlational relationships.
3. Interpret data displayed as statistics, graphs, and tables.
4. Select and implement an appropriate statistical analysis for a given research design, problem, or hypothesis.
5. Identify the correct strategy for data analysis and interpretation when testing hypotheses.
6. Select, apply, and interpret appropriate descriptive and inferential statistics.
7. Produce and interpret reports of statistical analyses using APA style.
8. Distinguish between statistically significant and chance findings in data.
9. Calculate and interpret the meaning of basic tests of statistical significance.
10. Calculate and interpret the meaning of confidence intervals.
11. Calculate and interpret the meaning of basic measures of effect size statistics.
12. Recognize when a statistically significant result may also have practical significance.

The book chapters are organized in the sequence that we use for our own statistics courses. We begin with descriptive statistics (Chapters 1–4), then lay the foundation for inferential statistics (Chapters 5–8), and then we examine a variety of statistical procedures focused on sample means and variance (Chapters 9–13) before moving on to correlational methods and nonparametric statistics (Chapters 14 and 15). Information about modifying this sequence is presented in the "To the Instructor" section for individuals who prefer a different organization. Each chapter contains numerous examples (many based on actual research studies), learning objectives and learning checks for each section, a summary and list of key terms, instructions for using SPSS®, detailed problem-solving tips and demonstrations, and a set of end-of-chapter problems.

Those of you who are familiar with previous editions of *Statistics for the Behavioral Sciences* and *Essentials of Statistics for the Behavioral Sciences* will notice that some changes have been made. These changes are summarized in the "To the Instructor" section. Students who are using this edition should read the section of the preface entitled "To the Student." In revising this text, our students have been foremost in our minds. Over the years, they have provided honest and useful feedback, and their hard work and perseverance has made our writing and teaching most rewarding. We sincerely thank them.

To the Instructor

Previous users of any of the Gravetter-franchise textbooks should know that we have maintained all the hallmark features of our *Statistics* and *Essentials of Statistics* textbooks: the organization of chapters and content within chapters; the student-friendly, conversational tone; and the variety of pedagogical aids, including, Tools You Will Need, chapter outlines, and section-by-section Learning Objectives and Learning Checks, as well as end-of-chapter Summaries, Key Terms lists, Focus on Problem Solving tips, Demonstrations of problems solved, SPSS sections, and end-of-chapter Problems (with solutions to odd-numbered problems provided to students in Appendix C).

New to This Edition

Those of you familiar with the previous edition of *Statistics for the Behavioral Sciences* will be pleased to see that *Essentials of Statistics for the Behavioral Sciences* has the same "look and feel" and includes much of its content. For those of you familiar with *Essentials*, the following are highlights of the changes that have been made:

- Every chapter begins with a Preview, which highlights an example of a published study. These have been selected for level of interest so that they will draw the student in. The studies are used to illustrate the purpose and rationale of the statistical procedure presented in the chapter.
- There has been extensive revision of the end-of-chapter Problems. Many old problems have been replaced with new examples that cite research studies. As an enhanced instructional resource for students, the odd-numbered solutions in Appendix C now show the work for intermediate answers for problems that require more than one step. The even-numbered solutions are available online in the instructor's resources.
- The sections on research design and methods in Chapter 1 have been revised to be consistent with Gravetter and Forzano, *Research Methods for the Behavioral Sciences, Sixth Edition.* The interval and ratio scales discussion in Chapter 1 has been refined and includes a new table distinguishing scales of measurement.
- In Chapter 2, a new section on stem and leaf displays describes this exploratory data analysis as a simple alternative to a frequency distribution table or graph. A basic presentation of percentiles and percentile ranks has been added to the coverage of frequency distribution tables in Chapter 2. The topic is revisited in Chapter 6 (Section 6-4, Percentiles and Percentile Ranks), showing how percentiles and percentile ranks can be determined with normal distributions.

- Chapter 3 (Central Tendency) has added coverage for the median when there are tied scores in the middle of the distribution. It includes a formula for determining the median with interpolation.
- The coverage of degrees of freedom in Chapter 4 (Variability) has been revised, including a new box feature (Degrees of Freedom, Cafeteria-Style) that provides an analogy for the student. Rounding and rounding rules are discussed in a new paragraph in Section 4-2, Defining Variance and Standard Deviation. It was presented in this section because Example 4.2 is the first instance where the answer is an irrational number. A section on quartiles and the interquartile range has been added.
- Coverage of the distribution of sample means (Chapter 7) has been revised to provide more clarification. The topic is revisited in Chapter 9, where the distribution of sample means is more concretely compared and contrasted with the distribution of *z*-scores, along with a comparison between the unit normal table and the *t* distribution table. Chapter 7 also includes a new box feature that depicts the law of large numbers using an illustration of online shopping (The Law of Large Numbers and Online Shopping).
- In Chapter 8 (Introduction to Hypothesis Testing), the section on statistical power has been completely rewritten. It is now organized and simplified into steps that the student can follow. The figures for this section have been improved as well.
- A new box feature has been added to Chapter 10 demonstrating how the *t* statistic for an independent-measures study can be calculated from sample means, standard deviations, and sample sizes in a published research paper. There is an added section describing the role of individual differences in the size of standard error.
- The comparison of independent- and repeated-measures designs has been expanded in Chapter 11, and includes the issue of power.
- In Chapter 12 the section describing the numerator and denominator in the *F*-ratio has been expanded to include a description of the sources of the random and unsystematic differences.
- Chapter 13 now covers only the two-factor, independent-measures ANOVA. The single-factor, repeated-measures ANOVA was dropped because repeated-measures designs are typically performed in a mixed design that also includes one (or more) between-subject factors. As a result, Chapter 13 now has expanded coverage of the two-factor, independent-measures ANOVA.
- For Chapter 14, three graphs have been redrawn to correct minor inaccuracies and improve clarity. As with other chapters, there is a new SPSS section with figures and end-of-chapter Problems have been updated with current research examples.
- Chapter 15 has minor revisions and an updated SPSS section with four figures. As with other chapters, the end-of-chapter Problems have been extensively revised and contain current research examples.
- Many research examples have been updated with an eye toward selecting examples that are of particular interest to college students and that cut across the domain of the behavioral sciences.
- Learning Checks have been revised.
- All SPSS sections have been revised using SPSS® 25 and new examples. New screenshots of analyses are presented. Appendix D, General Instructions for Using SPSS®, has been significantly expanded.
- A summary of statistics formulas has been added.

- This edition of *Essentials of Statistics for the Behavioral Sciences* has been edited to align with Gravetter and Forzano, *Research Methods*, providing a more seamless transition from statistics to research methods in its organization and terminology. Taken together, the two books provide a smooth transition for a two-semester sequence of Statistics and Methods, or, even an integrated Statistics/Methods course.

Matching the Text to Your Syllabus

The book chapters are organized in the sequence that we use for our own statistics courses. However, different instructors may prefer different organizations and probably will choose to omit or deemphasize specific topics. We have tried to make separate chapters, and even sections of chapters, completely self-contained, so that they can be deleted or reorganized to fit the syllabus for nearly any instructor. Instructors using MindTap® can easily control the inclusion and sequencing of chapters to match their syllabus exactly. Following are some common examples:

- It is common for instructors to choose between emphasizing analysis of variance (Chapters 12 and 13) or emphasizing correlation/regression (Chapter 14). It is rare for a one-semester course to complete coverage of both topics.
- Although we choose to complete all the hypothesis tests for means and mean differences before introducing correlation (Chapter 14), many instructors prefer to place correlation much earlier in the sequence of course topics. To accommodate this, Sections 14-1, 14-2, and 14-3 present the calculation and interpretation of the Pearson correlation and can be introduced immediately following Chapter 4 (Variability). Other sections of Chapter 14 refer to hypothesis testing and should be delayed until the process of hypothesis testing (Chapter 8) has been introduced.
- It is also possible for instructors to present the chi-square tests (Chapter 15) much earlier in the sequence of course topics. Chapter 15, which presents hypothesis tests for proportions, can be presented immediately after Chapter 8, which introduces the process of hypothesis testing. If this is done, we also recommend that the Pearson correlation (Sections 14-1, 14-2, and 14-3) be presented early to provide a foundation for the chi-square test for independence.

To the Student

A primary goal of this book is to make the task of learning statistics as easy and painless as possible. Among other things, you will notice that the book provides you with a number of opportunities to practice the techniques you will be learning in the form of Examples, Learning Checks, Demonstrations, and end-of-chapter Problems. We encourage you to take advantage of these opportunities. Read the text rather than just memorizing the formulas. We have taken care 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 a statistical formula, you will find that learning the formula and how to use it will be much easier. In the "Study Hints" that follow, we provide advice that we give our own students. Ask your instructor for advice as well; we are sure that other instructors will have ideas of their own.

Study Hints

You may find some of these tips helpful, as our own students have reported.

- The key to success in a statistics course is to keep up with the material. Each new topic builds on previous topics. If you have learned the previous material, then the new topic is just one small step forward. Without the proper background, however, the new topic can be a complete mystery. If you find that you are falling behind, get help immediately.

- You will learn (and remember) much more if you study for short periods several times a week rather than try to condense all of your studying into one long session. Distributed practice is best for learning. For example, it is far more effective to study and do problems for half an hour every night than to have a single three-and-a-half-hour study session once a week. We cannot even work on *writing* this book without frequent rest breaks.
- Do some work before class. Stay a little bit ahead of the instructor by reading the appropriate sections before they are presented in class. Although you may not fully understand what you read, you will have a general idea of the topic, which will make the lecture easier to follow. Also, you can identify material that is particularly confusing and then be sure the topic is clarified in class.
- Pay attention and think during class. Although this advice seems obvious, often it is not practiced. Many students spend so much time trying to write down every example presented or every word spoken by the instructor that they do not actually understand and process what is being said. Check with your instructor—there may not be a need to copy every example presented in class, especially if there are many examples like it in the text. Sometimes, we tell our students to put their pens and pencils down for a moment and just listen.
- Test yourself regularly. Do not wait until the end of the chapter or the end of the week to check your knowledge. As you are reading the textbook, stop and do the examples. Also, stop and do the Learning Checks at the end of each section. After each lecture, work on solving some of the end-of-chapter Problems and check your work for odd-numbered problems in Appendix C . Review the Demonstration problems, and be sure you can define the Key Terms. If you are having trouble, get your questions answered *immediately*—reread the section, go to your instructor, or ask questions in class. By doing so, you will be able to move ahead to new material.
- Do not kid yourself! Avoid denial. Many students observe their instructor solving problems in class and think to themselves, “This looks easy, I understand it.” Do you really understand it? Can you really do the problem on your own without having to read through the pages of a chapter? Although there is nothing wrong with using examples in the text as models for solving problems, you should try working a problem with your book closed to test your level of mastery.
- We realize that many students are embarrassed to ask for help. It is our biggest challenge as instructors. You must find a way to overcome this aversion. Perhaps contacting the instructor directly would be a good starting point, if asking questions in class is too anxiety-provoking. You could be pleasantly surprised to find that your instructor does not yell, scold, or bite! Also, your instructor might know of another student who can offer assistance. Peer tutoring can be very helpful.

Contact Us

Over the years, the students in our classes and other students using our book have given us valuable feedback. If you have any suggestions or comments about this book, you can write to Professor Emeritus Larry Wallnau, Professor Lori-Ann Forzano, or Associate Professor James Witnauer at the Department of Psychology, The College at Brockport, SUNY, 350 New Campus Drive, Brockport, New York 14420. You can also contact us directly at: lforzano@brockport.edu or jwitnaue@brockport.edu or lwallnau@brockport.edu.

Ancillaries

Ancillaries for this edition include the following.

- **MindTap® Psychology** *MindTap® Psychology for Gravetter/Wallnau/Forzano/Witnauer's Essentials of Statistics for the Behavioral Sciences, Tenth Edition,* is the digital learning solution that helps instructors engage and transform today's students into critical thinkers. Through paths of dynamic assignments and applications that you can personalize, real-time course analytics, and an accessible reader, MindTap helps you turn cookie cutter into cutting edge, apathy into engagement, and memorizers into higher-level thinkers. As an instructor using MindTap, you have at your fingertips the right content and unique set of tools curated specifically for your course, such as video tutorials that walk students through various concepts and interactive problem tutorials that provide students opportunities to practice what they have learned, all in an interface designed to improve workflow and save time when planning lessons and course structure. The control to build and personalize your course is all yours, focusing on the most relevant material while also lowering costs for your students. Stay connected and informed in your course through real-time student tracking that provides the opportunity to adjust the course as needed based on analytics of interactivity in the course.
- **Online Instructor's Manual** The manual includes learning objectives, key terms, a detailed chapter outline, a chapter summary, lesson plans, discussion topics, student activities, "What If" scenarios, media tools, a sample syllabus, and an expanded test bank. The learning objectives are correlated with the discussion topics, student activities, and media tools.
- **Online PowerPoints** Helping you make your lectures more engaging while effectively reaching your visually oriented students, these handy Microsoft PowerPoint® slides outline the chapters of the main text in a classroom-ready presentation. The PowerPoint slides are updated to reflect the content and organization of the new edition of the text.
- **Cengage Learning Testing, powered by Cognero®** Cengage Learning Testing, powered by Cognero®, is a flexible online system that allows you to author, edit, and manage test bank content. You can create multiple test versions in an instant and deliver tests from your LMS in your classroom.

Acknowledgments

It takes a lot of good, hard-working people to produce a book. Our friends at Cengage have made enormous contributions to this textbook. We thank: Laura Ross, Product Director; Josh Parrott, Product Manager; Kat Wallace, Product Assistant; and Bethany Bourgeois, Art Director. Special thanks go to Brian Pierce and Tangelique Williams-Grayer, our Content Managers, and to Lori Hazzard, who led us through production at MPS Limited.

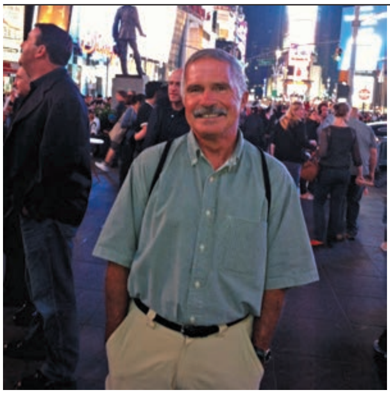
Reviewers play an important role in the development of a manuscript. Accordingly, we offer our appreciation to the following colleagues for their assistance: Kara Moore, Knox College; Tom Williams, Mississippi College; Stacey Todaro, Adrian College; Dave Matz, Augsburg University; Barbara Friesth, Indiana University-Purdue University Indianapolis; Bethany Jurs, Transylvania University; Ben Denkinger, Augsburg University; Sara Festini, University of Tampa; Lindsey Johnson, University of Southern Mississippi; Lawrence Preiser, York College CUNY; Stephen Blessing, University of Tampa; Pamela A MacLaughlin, Indiana University.

We must give our heartfelt thanks to our families: Naomi and Nico Wallnau; Charlie, Ryan, and Alex Forzano; and Beth, JJ, Nate, and Ben Witnauer. This book could not have been written without their patience and support.

Finally, it is with great sorrow that we acknowledge Fred Gravetter's passing. His expertise in statistics, teaching experience, and years of assisting students are woven into the fabric of every edition of this book. His students had the utmost praise for his courses and his teaching ability. Fred was appreciated as a mentor to students and faculty alike, including his fellow authors. Yet, he was modest despite his accomplishments, and he was approachable and engaging. We were reminded of his contributions as we worked on each chapter during the course of this revision and were guided by his vision during this process. He has, no doubt, left a lasting legacy for his students and colleagues. We were most fortunate to benefit from his friendship, and he is sorely missed.

Larry B. Wallnau
Lori-Ann B. Forzano
James E. Witnauer

ABOUT THE AUTHORS



FREDERICK J GRAVETTER was Professor Emeritus of Psychology at The College at Brockport, State University of New York. While teaching at Brockport, Dr. Gravetter specialized in statistics, experimental design, and cognitive psychology. He received his bachelor's degree in mathematics from M.I.T. and his Ph.D. in psychology from Duke University. In addition to publishing this textbook and several research articles, Dr. Gravetter coauthored all editions of the best-selling *Statistics for the Behavioral Sciences, Essentials of Statistics for the Behavioral Sciences,* and *Research Methods for the Behavioral Sciences*. Dr. Gravetter passed away in November 2017.

LARRY B. WALLNAU is Professor Emeritus of Psychology at The College at Brockport, State University of New York. While teaching at Brockport, his research has been published in journals such as *Pharmacology Biochemistry and Behavior, Physiology and Behavior, Journal of Human Evolution, Folia Primatologica,* and *Behavior Research Methods and Instrumentation*. He also has provided editorial consultation. His courses have included statistics, biopsychology, animal behavior, psychopharmacology, and introductory psychology. With Dr. Gravetter, he coauthored all previous editions of *Statistics for the Behavioral Sciences* and *Essentials of Statistics for the Behavioral Sciences*. Dr. Wallnau received his bachelor's degree from the University of New Haven and his Ph.D. in psychology from the State University of New York at Albany. In his leisure time, he is an avid runner with his canine companion, Gracie.

LORI-ANN B. FORZANO is Professor of Psychology at The College at Brockport, State University of New York, where she regularly teaches undergraduate and graduate courses in research methods, statistics, learning, animal behavior, and the psychology of eating. She earned a Ph.D. in experimental psychology from the State University of New York at Stony Brook, where she also received her B.S. in psychology. Dr. Forzano's research examines impulsivity and self-control in adults and children. Her research has been published in the *Journal of the Experimental Analysis of Behavior, Learning and Motivation,* and *The Psychological Record.*

Dr. Forzano has also coauthored *Essentials of Statistics for the Behavioral Sciences, Ninth Edition,* and all previous editions of *Research Methods for the Behavioral Sciences,* now in its sixth edition.

JAMES E. WITNAUER is Associate Professor of Psychology at The College at Brockport, State University of New York, where he teaches undergraduate courses in experimental psychology and graduate courses in statistics and biopsychology. He earned a Ph.D. in cognitive psychology from State University of New York, Binghamton, and a B.A. in psychology from State University of New York, Buffalo State College. Dr. Witnauer's research aims to test mathematical models of learning and behavior and has been published in *Behavioural Processes*, *Journal of Experimental Psychology: Animal Behavior Processes*, and *Neurobiology of Learning and Memory.*

CHAPTER

1

Introduction to Statistics

clivewa/Shutterstock.com

PREVIEW

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 classic 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, the paragraph describes the everyday task of doing laundry. Now that you know the topic (or context) 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 (1972) 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 laundry. When you are given the appropriate background, it is much easier to fit new material into your memory and recall it later. In this book each chapter begins with a preview that provides the background context for the new material in the chapter. As you read each preview section, you should gain a general overview of the chapter content. Similarly, we begin each section within each chapter with clearly stated learning objectives that prepare you for the material in that section. Finally, we introduce each new statistical procedure by explaining its purpose. Note that 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 and remember 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 in 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, even if those early chapters seem basic. The content of the first seven chapters provides an essential background and context for the statistical methods presented in Chapter 8. If you turn directly to Chapter 8 without reading the first seven chapters, you will find the material incomprehensible. However, if you learn the background material and practice the statistics procedures and methods described in early chapters, you will have a good frame of reference for understanding and incorporating new concepts as they are presented in each new chapter.

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.

1-1 Statistics and Behavioral Sciences

LEARNING OBJECTIVES

1. Define the terms population, sample, parameter, and statistic, and describe the relationships between them; identify examples of each.
2. Define the two general categories of statistics, descriptive and inferential statistics, and describe how they are used to summarize and make decisions about data.
3. Describe the concept of sampling error and explain how sampling error creates the fundamental problem that inferential statistics must address.

Definitions of Statistics

By one definition, *statistics* consist of facts and figures such as the average annual snowfall in Buffalo or the average yearly income of recent college graduates. These statistics are usually informative and time-saving because they condense large quantities of information into a few simple figures. Later in this chapter we return to the notion of calculating statistics (facts and figures) but, for now, we concentrate on a much broader definition of statistics. Specifically, we use the term statistics to refer to a general field of mathematics. In this case, we are using the term *statistics* as a shortened version of *statistical methods* or *statistical procedures*. For example, you are probably using this book for a statistics course in which you will learn about the statistical procedures that are used to summarize and evaluate research results in the behavioral sciences.

Research in the behavioral sciences (and other fields) involves gathering information. To determine, for example, whether college students learn better by reading material on printed pages or on a computer screen, you would need to gather information about students' study habits and their academic performance. When researchers finish the task of gathering information, they typically find themselves with pages and pages of measurements such as preferences, personality scores, opinions, and so on. In this book, we present the statistics that researchers use to analyze and interpret the information that they gather. Specifically, statistics serve two general purposes:

1. Statistics are used to organize and summarize the information so that the researcher can see what happened in the study and can communicate the results to others.
2. Statistics help the researcher to answer the questions that initiated the research by determining exactly what general conclusions are justified based on the specific results that were obtained.

The term **statistics** refers to a set of mathematical procedures 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 analysis with a full understanding of how it was done and what the results signify.

Populations and Samples

Research in the behavioral sciences typically begins with a general question about a specific group (or groups) of individuals. For example, a researcher may want to know what factors are associated with academic dishonesty among college students. Or a researcher may want to determine the effect of lead exposure on the development of emotional problems in school-age children. In the first example, the researcher is interested in the group of college students. In the second example the researcher is studying school-age children. In statistical terminology, a *population* consists of all possible members of the group a researcher wishes to study.

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

As you can well imagine, a population can be quite large—for example, the entire set of all registered voters in the United States. A researcher might be more specific, limiting the study's population to people in their twenties who are registered voters in the United States. A smaller population would be first-time voter registrants in Burlington, Vermont. Populations can be extremely small too, such as those for people with a rare disease or members of an endangered species. The Siberian tiger, for example, has a population of roughly only 500 animals.

Thus, populations can obviously vary in size from extremely large to very small, depending on how the investigator identifies the population to be studied. The researcher should always specify the population being studied. In addition, the population need not consist of people—it could be a population of laboratory rats, North American corporations, engine parts produced in an automobile factory, or anything else an investigator wants to study. In practice, however, populations are typically very large, such as the population of college sophomores in the United States or the population of coffee drinkers that patronize a major national chain of cafés.

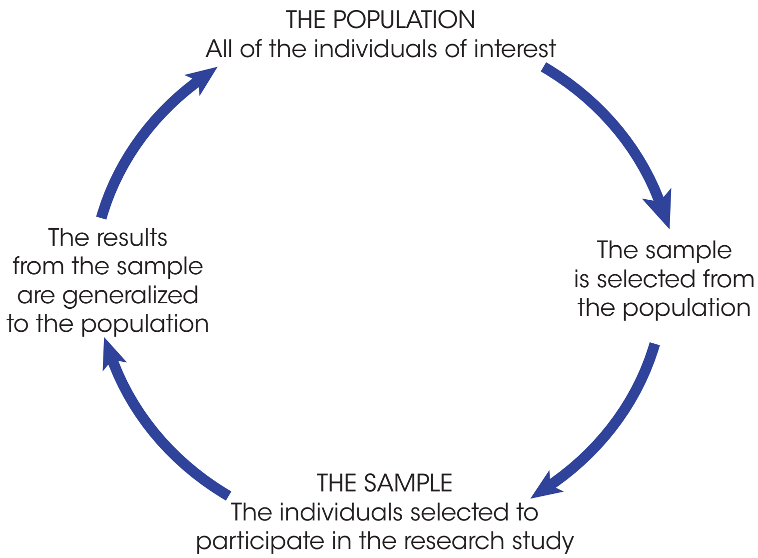
Because populations tend to be very large, it usually is impossible for a researcher to examine every individual in the population of interest. Therefore, researchers typically select a smaller, more manageable group from the population and limit their studies to the individuals in the selected group. In statistical terms, a set of individuals selected from a population is called a *sample*. A sample is intended to be representative of its population, and a sample should always be identified in terms of the population from which it was selected. We shall see later that one way to ensure that a sample is representative of a population is to select a *random sample*. In random sampling every individual has the same chance of being selected from the population.

A **sample** is a set of individuals selected from a population, usually intended to represent the population in a research study. In a **random sample** everyone in the population has an equal chance of being selected.

Just as we saw with populations, samples can vary in size. For example, one study might examine a sample of only 20 middle-school students in an experimental reading program, and another study might use a sample of more than 2,000 people who take a new cholesterol medication.

So far, we have talked about a sample being selected from a population. However, this is actually only half of the full relationship between a sample and its population. Specifically, when a researcher finishes examining the sample, the goal is to generalize the results

FIGURE 1.1
The relationship between a population and a sample.



back to the entire population. Remember that the researcher started with a general question about the population. To answer the question, a researcher studies a sample and then generalizes the results from the sample to the population. The full relationship between a sample and a population is shown in Figure 1.1.

■ Variables and Data

Typically, researchers are interested in specific characteristics of the individuals in the population (or in the sample), or they are interested in outside factors that may influence behavior of the individuals. For example, Bakhshi, Kanuparthy, and Gilbert (2014) wanted to determine if the weather is related to online ratings of restaurants. As the weather changes, do people's reviews of restaurants change too? Something that can change or have different values is called a *variable.*

A **variable** is a characteristic or condition that changes or has different values for different individuals.

In the case of the previous example, both weather and people's reviews of restaurants are variables. By the way, in case you are wondering, the authors did find a relationship between weather and online reviews of restaurants. Reviews were worse during bad weather (for example, during extremely hot or cold days).

Once again, variables can be characteristics that differ from one individual to another, such as weight, gender identity, personality, or motivation and behavior. Also, variables can be environmental conditions that change, such as temperature, time of day, or the size of the room in which the research is being conducted.

To demonstrate changes in variables, it is necessary to make measurements of the variables being examined. The measurement obtained for each individual is called a *datum*, or more commonly, a *score* or *raw score.* The complete set of scores is called the *data set* or simply the *data.*

Data (plural) are measurements or observations. A **data set** is a collection of measurements or observations. A **datum** (singular) is a single measurement or observation and is commonly called a **score** or **raw score**.

Before we move on, we should make one more point about samples, populations, and data. Earlier, we defined populations and samples in terms of *individuals*. For example, we previously discussed a population of registered voters and a sample of middle-school children. Be forewarned, however, that we will also refer to populations or samples of *scores*. Research typically involves measuring each individual to obtain a score, therefore every sample (or population) of individuals produces a corresponding sample (or population) of scores.

Parameters and Statistics

When describing data it is necessary to distinguish whether the data come from a population or a sample. A characteristic that describes a population—for example, the average score for the population—is called a *parameter*. A characteristic that describes a sample is called a *statistic*. Thus, the average score for a sample is an example of a statistic. Typically, the research process begins with a question about a population parameter. However, the actual data come from a sample and are used to compute sample statistics.

A **parameter** is a value, usually a numerical value, that describes a population. A parameter is usually derived from measurements of the individuals in the population.

A **statistic** is a value, usually a numerical value, that describes a sample. A statistic is usually derived from measurements of the individuals in the sample.

Every population parameter has a corresponding sample statistic, and most research studies involve using statistics from samples as the basis for answering questions about population parameters. As a result, much of this book is concerned with the relationship between sample statistics and the corresponding population parameters. In Chapter 7, for example, we examine the relationship between the mean obtained for a sample and the mean for the population from which the sample was obtained.

Descriptive and Inferential Statistical Methods

Although researchers have developed a variety of different statistical procedures to organize and interpret data, these different procedures can be classified into two general categories. The first category, *descriptive statistics*, consists of statistical procedures that are used to simplify and summarize data.

Descriptive statistics are statistical procedures used to summarize, organize, and simplify data.

Descriptive statistics are techniques that take raw scores and organize or summarize them in a form that is more manageable. Often the scores are organized in a table or graph so that it is possible to see the entire set of scores. Another common technique is to summarize a set of scores by computing an average. Note that even if the data set has hundreds of scores, the average provides a single descriptive value for the entire set.

The second general category of statistical techniques is called *inferential statistics*. Inferential statistics are methods that use sample data to make general statements about a population.

Inferential statistics consist of techniques that allow us to study samples and then make generalizations about the populations from which they were selected.

Because populations are typically very large, it usually is not possible to measure everyone in the population. Therefore, researchers select a sample that represents the population. By analyzing the data from the sample, we hope to make general statements about the population. Typically, researchers use sample statistics as the basis for drawing conclusions about population parameters or relationships between variables that might exist in the population. One problem with using samples, however, is that a sample provides only limited information about the population. Although samples are generally *representative* of their populations, a sample is not expected to give a perfectly accurate picture of the whole population. There usually is some discrepancy between a sample statistic and the corresponding population parameter. This discrepancy is called *sampling error*, and it creates the fundamental problem inferential statistics must always address.

Sampling error is the naturally occurring discrepancy, or error, that exists between a sample statistic and the corresponding population parameter.

The concept of sampling error is illustrated in Figure 1.2. The figure shows a population of 1,000 college students and two samples, each with five students who were selected from the population. Notice that each sample contains different individuals who have different characteristics. Because the characteristics of each sample depend on the specific people in the sample, statistics will vary from one sample to another. For example, the five students in sample 1 have an average age of 19.8 years and the students in sample 2 have an average age of 20.4 years. It is unlikely that the statistics for a sample will be identical to the parameter for the entire population. Both of the statistics in the example vary slightly from the population parameter (21.3 years) from which the samples were drawn. The difference between these sample statistics and the population parameter illustrate sampling error.

You should also realize that Figure 1.2 shows only two of the hundreds of possible samples. Each sample would contain different individuals and would produce different statistics. This is the basic concept of sampling error: sample statistics vary from one sample to another and typically are different from the corresponding population parameters.

One common example of sampling error is the error associated with a sample proportion (or percentage). For instance, in newspaper articles reporting results from political polls, you frequently find statements such as this:

> Candidate Brown leads the poll with 51% of the vote. Candidate Jones has 42% approval, and the remaining 7% are undecided. This poll was taken from a sample of registered voters and has a margin of error of plus or minus 4 percentage points.

The "margin of error" is the sampling error. In this case, the reported percentages were obtained from a sample and are being generalized to the whole population of potential voters.

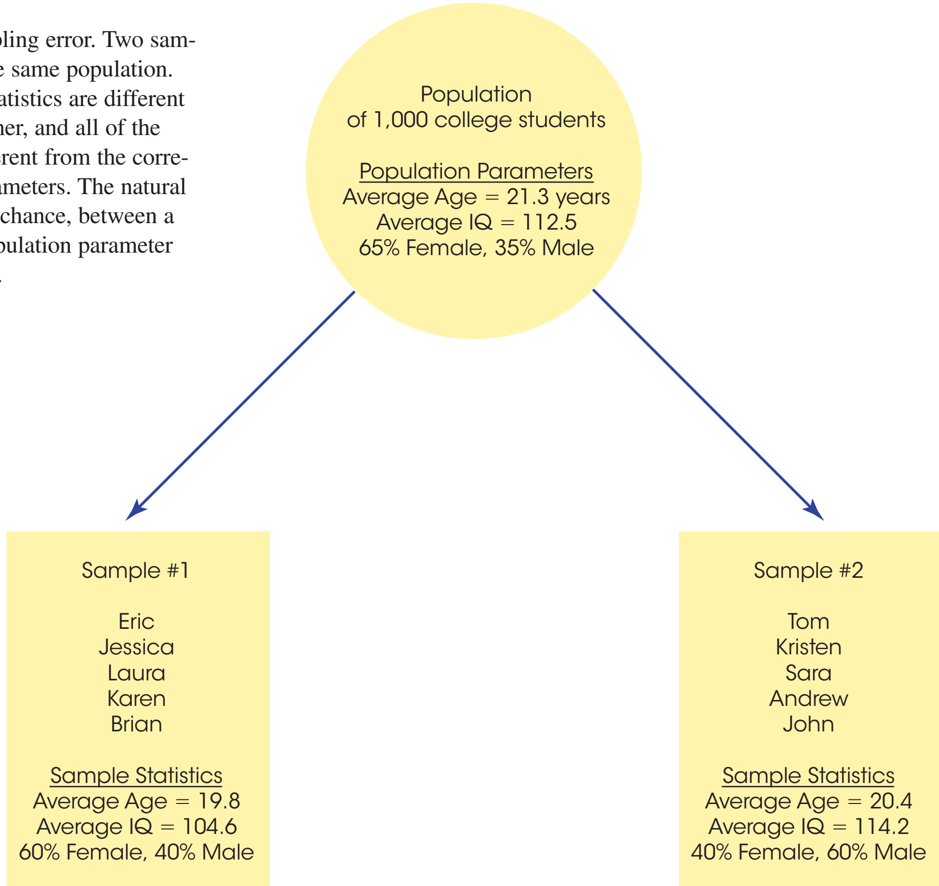


FIGURE 1.2
A demonstration of sampling error. Two samples are selected from the same population. Notice that the sample statistics are different from one sample to another, and all of the sample statistics are different from the corresponding population parameters. The natural differences that exist, by chance, between a sample statistic and a population parameter are called sampling error.

As always, you do not expect the statistics from a sample to be a perfect reflection of the population. There always will be some "margin of error" when sample statistics are used to represent population parameters.

As a further demonstration of sampling error, imagine that your statistics class is separated into two groups by drawing a line from front to back through the middle of the room. Now imagine that you compute the average age (or height, or GPA) for each group. Will the two groups have exactly the same average? Almost certainly they will not. No matter what you choose to measure, you will probably find some difference between the two groups. However, the difference you obtain does not necessarily mean that there is a systematic difference between the two groups. For example, if the average age for students on the right-hand side of the room is higher than the average for students on the left, it is unlikely that some mysterious force has caused the older people to gravitate to the right side of the room. Instead, the difference is probably the result of random factors such as chance. The unpredictable, unsystematic differences that exist from one sample to another are an example of sampling error. Inferential statistics tell us whether the differences between samples (e.g., a difference in age, height, or GPA) are the result of random factors (sampling error) or the result of some meaningful relationship in the population.

Statistics in the Context of Research

The following example shows the general stages of a research study and demonstrates how descriptive statistics and inferential statistics are used to organize and interpret the data. At the end of the example, note how sampling error can affect the interpretation of experimental results, and consider why inferential statistical methods are needed to deal with this problem.

EXAMPLE 1.1

Figure 1.3 shows an overview of a general research situation and demonstrates the roles that descriptive and inferential statistics play. The purpose of the research study is to address a question that we posed earlier: do college students learn better by studying text on printed pages or on a computer screen? Two samples of six students each are selected from the population of college students. The students in sample A read text on a computer

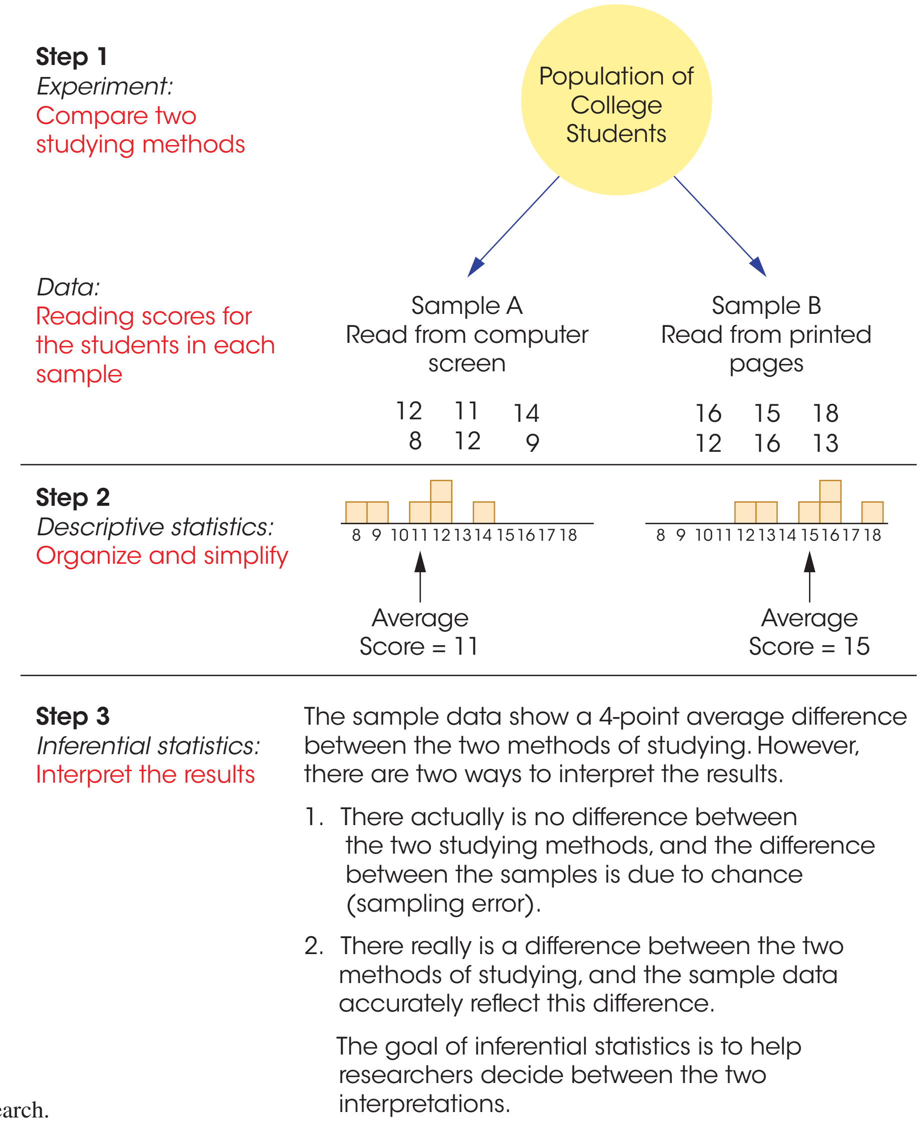


FIGURE 1.3
The role of statistics in research.