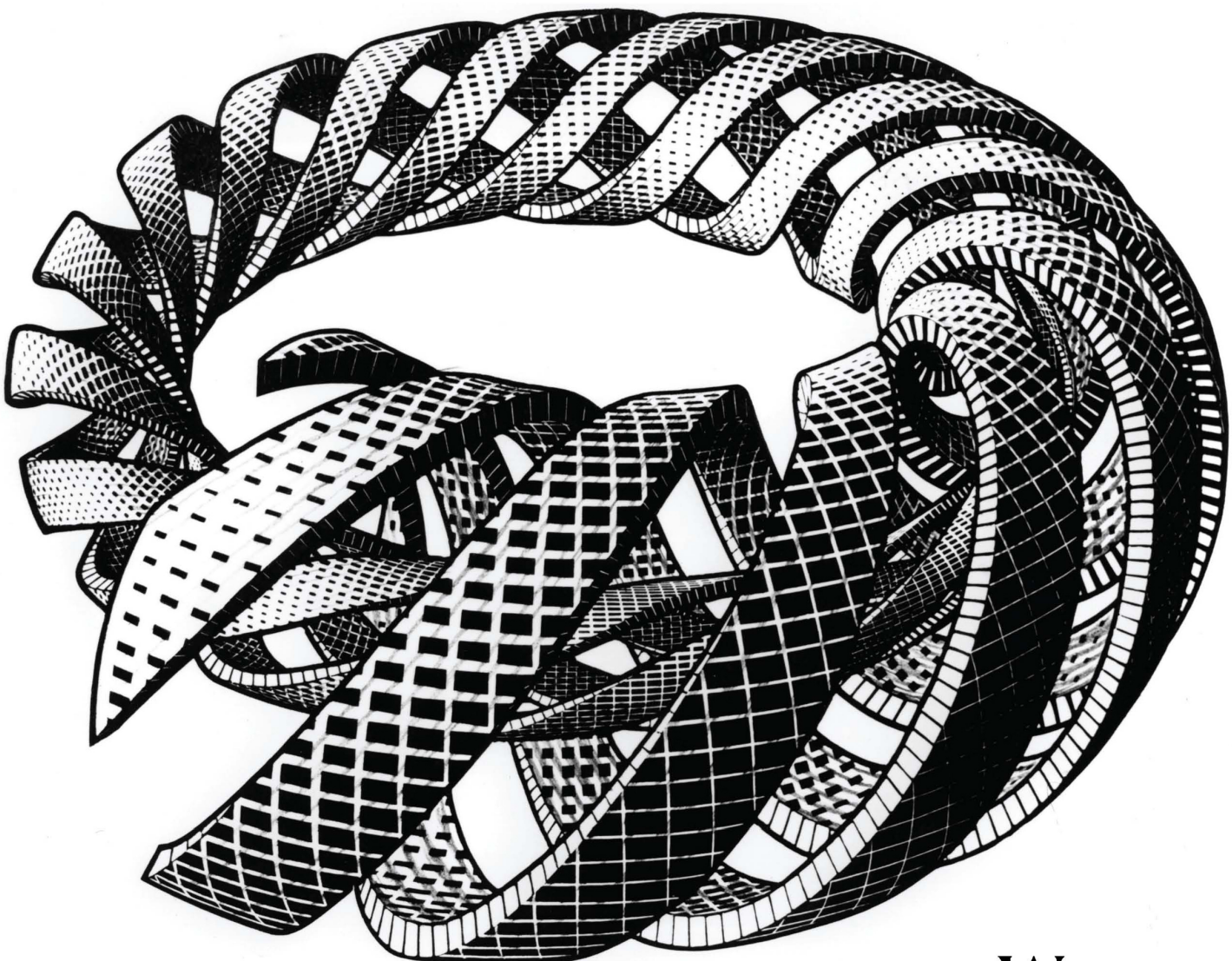
ELEVENTH EDITION

STATISTICS

ROBERT S. **WITTE**

JOHN S. **WITTE**



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STATISTICS

Eleventh Edition

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To Doris

Preface

TO THE READER

Students often approach statistics with great apprehension. For many, it is a required course to be taken only under the most favorable circumstances, such as during a quarter or semester when carrying a light course load; for others, it is as distasteful as a visit to a credit counselor—to be postponed as long as possible, with the vague hope that mounting debts might miraculously disappear. Much of this apprehension doubtless rests on the widespread fear of mathematics and mathematically related areas.

This book is written to help you overcome any fear about statistics. Unnecessary quantitative considerations have been eliminated. When not obscured by mathematical treatments better reserved for more advanced books, some of the beauty of statistics, as well as its everyday usefulness, becomes more apparent.

You could go through life quite successfully without ever learning statistics. Having learned some statistics, however, you will be less likely to flinch and change the topic when numbers enter a discussion; you will be more skeptical of conclusions based on loose or erroneous interpretations of sets of numbers; you might even be more inclined to initiate a statistical analysis of some problem within your special area of interest.

TO THE INSTRUCTOR

Largely because they panic at the prospect of any math beyond long division, many students view the introductory statistics class as cruel and unjust punishment. A half-dozen years of experimentation, first with assorted handouts and then with an extensive set of lecture notes distributed as a second text, convinced us that a book could be written for these students. Representing the culmination of this effort, the present book provides a simple overview of descriptive and inferential statistics for mathematically unsophisticated students in the behavioral sciences, social sciences, health sciences, and education.

PEDAGOGICAL FEATURES

- Basic concepts and procedures are explained in plain English, and a special effort has been made to clarify such perennially mystifying topics as the standard deviation, normal curve applications, hypothesis tests, degrees of freedom, and analysis of variance. For example, the standard deviation is more than a formula; it roughly reflects the average amount by which individual observations deviate from their mean.
- Unnecessary math, computational busy work, and subtle technical distinctions are avoided without sacrificing either accuracy or realism. Small batches of data define most computational tasks. Single examples permeate entire chapters or even several related chapters, serving as handy frames of reference for new concepts and procedures.

- Each chapter begins with a preview and ends with a summary, lists of important terms and key equations, and review questions.
- Key statements appear in bold type, and step-by-step summaries of important procedures, such as solving normal curve problems, appear in boxes.
- Important definitions and reminders about key points appear in page margins.
- Scattered throughout the book are examples of computer outputs for three of the most prevalent programs: Minitab, SPSS, and SAS. These outputs can be either ignored or expanded without disrupting the continuity of the text.
- Questions are introduced within chapters, often section by section, as Progress Checks. They are designed to minimize the cumulative confusion reported by many students for some chapters and by some students for most chapters. Each chapter ends with Review Questions.
- Questions have been selected to appeal to student interests: for example, probability calculations, based on design flaws, that re-create the chillingly high likelihood of the *Challenger* shuttle catastrophe (8.18, page 165); a *t* test analysis of global temperatures to evaluate a possible greenhouse effect (13.7, page 244); and a chi-square test of the survival rates of cabin and steerage passengers aboard the *Titanic* (19.14, page 384).
- Appendix B supplies answers to questions marked with asterisks. Other appendices provide a practical math review complete with self-diagnostic tests, a glossary of important terms, and tables for important statistical distributions.

INSTRUCTIONAL AIDS

An electronic version of an instructor's manual accompanies the text. The instructor's manual supplies answers omitted in the text (for about one-third of all questions), as well as sets of multiple-choice test items for each chapter, and a chapter-by-chapter commentary that reflects the authors' teaching experiences with this material. Instructors can access this material in the Instructor Companion Site at http://www.wiley.com/college/witte.

An electronic version of a student workbook, prepared by Beverly Dretzke of the University of Minnesota, also accompanies the text. Self-paced and self-correcting, the workbook contains problems, discussions, exercises, and tests that supplement the text. Students can access this material in the Student Companion Site at http://www.wiley.com/college/witte.

CHANGES IN THIS EDITION

- Update discussion of polling and random digit dialing in Section 8.4
- A new Section 14.11 on the "file drawer effect," whereby nonsignificant statistical findings are never published and the importance of replication.
- Updated numerical examples.
- New examples and questions throughout the book.
- Computer outputs and website have been updated.

USING THE BOOK

The book contains more material than is covered in most one-quarter or one-semester courses. Various chapters can be omitted without interrupting the main development. Typically, during a one-semester course we cover the entire book except for analysis of variance (Chapters 16, 17, and 18) and tests of ranked data (Chapter 20). An instructor who wishes to emphasize inferential statistics could skim some of the earlier chapters, particularly *Normal Distributions and Standard Scores (z)* (Chapter 5), and *Regression* (Chapter 7), while an instructor who desires a more applied emphasis could omit *Populations, Samples, and Probability* (Chapter 8) and *More about Hypothesis Testing* (Chapter 11).

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STATISTICS

Eleventh Edition

CHAPTER 1 Introduction

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1.3 MORE ABOUT INFERENTIAL STATISTICS
1.4 THREE TYPES OF DATA
1.5 LEVELS OF MEASUREMENT
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1.7 HOW TO USE THIS BOOK

Summary / Important Terms / Review Questions

Preview

Statistics deals with variability. You're different from everybody else (and, we hope, proud of it). Today differs from both yesterday and tomorrow. In an experiment designed to detect whether psychotherapy improves self-esteem, self-esteem scores will differ among subjects in the experiment, whether or not psychotherapy improves self-esteem.

Beginning with Chapter 2, ***descriptive statistics*** *will provide tools, such as tables, graphs, and averages, that help you describe and organize the inevitable variability among observations. For example, self-esteem scores (on a scale of 0 to 50) for a group of college students might approximate a bell-shaped curve with an average score of 32 and a range of scores from 18 to 49.*

Beginning with Chapter 8, ***inferential statistics*** *will supply powerful concepts that, by adjusting for the pervasive effects of variability, permit you to generalize beyond limited sets of observations. For example, inferential statistics might help us decide whether—after an adjustment has been made for background variability (or chance)—an observed improvement in self-esteem scores can be attributed to psychotherapy rather than to chance.*

Chapter 1 provides an overview of both descriptive and inferential statistics, and it also introduces a number of terms—some from statistics and some from math and research methods—with which you already may have some familiarity. These terms will clarify a number of important distinctions that will aid your progress through the book.

1.1 WHY STUDY STATISTICS?

You're probably taking a statistics course because it's required, and your feelings about it may be more negative than positive. Let's explore some of the reasons why you should study statistics. For instance, recent issues of a daily newspaper carried these items:

- The annual earnings of college graduates exceed, *on average,* those of high school graduates by $20,000.
- On the basis of existing research, there is *no evidence of a relationship* between family size and the scores of adolescents on a test of psychological adjustment.
- Heavy users of tobacco suffer *significantly* more respiratory ailments than do nonusers.

Having learned some statistics, you'll not stumble over the italicized phrases. Nor, as you continue reading, will you hesitate to probe for clarification by asking, "Which *average* shows higher annual earnings?" or "What constitutes a *lack of evidence* about a relationship?" or "How many more is *significantly more* respiratory ailments?"

A statistical background is indispensable in understanding research reports within your special area of interest. Statistical references punctuate the results sections of most research reports. Often expressed with parenthetical brevity, these references provide statistical support for the researcher's conclusions:

- Subjects who engage in daily exercise score higher on tests of self-esteem than do subjects who do not exercise [$p < .05$].
- Highly anxious students are perceived by others as less attractive than nonanxious students [$t\ (48) = 3.21$, $p < .01$, $d = .42$].
- Attitudes toward extramarital sex depend on socioeconomic status [$x^2\ (4, n = 185) = 11.49$, $p < .05$, $\phi^2_c = .03$].

Having learned some statistics, you will be able to decipher the meaning of these symbols and consequently read these reports more intelligently.

Sometime in the future—possibly sooner than you think—you might want to plan a statistical analysis for a research project of your own. Having learned some statistics, you'll be able to plan the statistical analysis for modest projects involving straightforward research questions. If your project requires more advanced statistical analysis, you'll know enough to consult someone with more training in statistics. Once you begin to understand basic statistical concepts, you will discover that, with some guidance, your own efforts often will enable you to use and interpret more advanced statistical analysis required by your research.

1.2 WHAT IS STATISTICS?

It is difficult to imagine, even as a fantasy exercise, a world where there is no variability—where, for example, everyone has the same physical characteristics, intelligence, attitudes, etc. Knowing that one person is 70 inches tall, and has an intelligence quotient (IQ) of 125 and a favorable attitude toward capital punishment, we could immediately conclude that everyone else also has these characteristics. This mind-numbing world would have little to recommend it, other than that there would be no need for the field of statistics (and a few of us probably would be looking for work).

Descriptive Statistics

Statistics exists because of the prevalence of variability in the real world. In its simplest form, known as **descriptive statistics,** *statistics provides us with tools—tables, graphs, averages, ranges, correlations—for organizing and summarizing the inevitable variability in collections of actual observations or scores.* Examples are:

1. A tabular listing, ranked from most to least, of the total number of romantic affairs during college reported anonymously by each member of your stat class
2. A graph showing the annual change in global temperature during the last 30 years
3. A report that describes the average difference in grade point average (GPA) between college students who regularly drink alcoholic beverages and those who don't

Inferential Statistics

Statistics also provides tools—a variety of tests and estimates—for generalizing beyond collections of actual observations. This more advanced area is known as **inferential statistics.** Tools from inferential statistics permit us to use a relatively small collection of actual observations to evaluate, for example:

1. A pollster's claim that a majority of all U.S. voters favor stronger gun control laws
2. A researcher's hypothesis that, on average, meditators report fewer headaches than do nonmeditators
3. An assertion about the relationship between job satisfaction and overall happiness

In this book, you will encounter the most essential tools of descriptive statistics (Part 1), beginning with Chapter 2, and those of inferential statistics (Part 2), beginning with Chapter 8.

Progress Check *1.1 Indicate whether each of the following statements typifies descriptive statistics (because it describes sets of actual observations) or inferential statistics (because it generalizes beyond sets of actual observations).

(a) Students in my statistics class are, on average, 23 years old.

(b) The population of the world exceeds 7 billion (that is, 7,000,000,000 or 1 million multiplied by 7000).

(c) Either four or eight years have been the most frequent terms of office actually served by U.S. presidents.

(d) Sixty-four percent of all college students favor right-to-abortion laws.

Answers on page 420.

1.3 MORE ABOUT INFERENTIAL STATISTICS

Population

Any complete collection of observations or potential observations.

Populations and Samples

Inferential statistics is concerned with generalizing beyond sets of actual observations, that is, with generalizing from a sample to a population. In statistics, a **population**

Sample
Any smaller collection of actual observations from a population.

refers to *any complete collection of observations or potential observations,* whereas a **sample** refers to *any smaller collection of actual observations drawn from a population.* In everyday life, populations often are viewed as collections of real objects (e.g., people, whales, automobiles), whereas in statistics, populations may be viewed more abstractly as collections of properties or measurements (e.g., the ethnic backgrounds of people, life spans of whales, gas mileage of automobiles).

Depending on your perspective, a given set of observations can be either a population or a sample. For instance, the weights reported by 53 male statistics students in **Table 1.1** can be viewed either as a population, because you are concerned about exceeding the load-bearing capacity of an excursion boat (chartered by the 53 students to celebrate successfully completing their stat class!), or as a sample from a population because you wish to generalize to the weights of *all* male statistics students or *all* male college students.

Table 1.1
QUANTITATIVE DATA: WEIGHTS (IN POUNDS) OF MALE STATISTICS STUDENTS

160	168	133	170	150	165	158	165
193	169	245	160	152	190	179	157
226	160	170	180	150	156	190	156
157	163	152	158	225	135	165	135
180	172	160	170	145	185	152	
205	151	220	166	152	159	156	
165	157	190	206	172	175	154	

Ordinarily, populations are quite large and exist only as potential observations (e.g., the *potential* scores of all U.S. college students on a test that measures anxiety). On the other hand, samples are relatively small and exist as actual observations (the *actual* scores of 100 college students on the test for anxiety). When using a sample (100 actual scores) to generalize to a population (millions of potential scores), it is important that the sample represent the population; otherwise, any generalization might be erroneous. Although conveniently accessible, the anxiety test scores for the 100 students in stat classes at your college probably would not be representative of the scores for all students. If you think about it, these 100 stat students might tend to have either higher or lower anxiety scores than those in the target population for numerous reasons including, for instance, the fact that the 100 students are mostly psychology majors enrolled in a required stat class at your particular college.

Random Sampling (Surveys)

Random Sampling
A procedure designed to ensure that each potential observation in the population has an equal chance of being selected in a survey.

Whenever possible, a sample should be randomly selected from a population in order to increase the likelihood that the sample accurately represents the population. **Random sampling** *is a procedure designed to ensure that each potential observation in the population has an equal chance of being selected in a survey.* Classic examples of random samples are a state lottery where each number from 1 to 99 in the population has an equal chance of being selected as one of the five winning numbers or a nationwide opinion survey in which each telephone number has an equal chance of being selected as a result of a series of random selections, beginning with a three-digit area code and ending with a specific seven-digit telephone number.

Random sampling can be very difficult when a population lacks structure (e.g., all persons currently in psychotherapy) or specific boundaries (e.g., all volunteers who could conceivably participate in an experiment). In this case, a random sample

becomes an ideal that can only be approximated—always with an effort to remove obvious biases that might cause the sample to misrepresent the population. For example, lacking the resources to sample randomly the target population of all U.S. college students, you might obtain scores by randomly selecting the 100 students, not just from stat classes at your college but also from one or more college directories, possibly using some of the more elaborate techniques described in Chapter 8. Insofar as your sample only approximates a true random sample, any resulting generalizations should be qualified. For example, if the 100 students were randomly selected only from several public colleges in northern California, this fact should be noted, and any generalizations to all college students in the United States would be both provisional and open to criticism.

Random Assignment (Experiments)

Estimating the average anxiety score for all college students probably would not generate much interest. Instead, we might be interested in determining whether relaxation training causes, on average, a reduction in anxiety scores between two groups of otherwise similar college students. Even if relaxation training has no effect on anxiety scores, we would expect average scores for the two groups to differ because of the inevitable variability between groups. The question becomes: How should we interpret the apparent difference between the treatment group and the control group? Once variability has been taken into account, should the difference be viewed as real (and attributable to relaxation training) or as transitory (and merely attributable to variability or chance)?

College students in the relaxation experiment probably are not a random sample from any intact population of interest, but rather a *convenience sample* consisting of volunteers from a limited pool of students fulfilling a course requirement. Accordingly, our focus shifts from random sampling to the random assignment of volunteers to the two groups. **Random assignment** *signifies that each person has an equal chance of being assigned to any group in an experiment.* Using procedures described in Chapter 8, random assignment should be employed whenever possible. Because chance dictates the membership of both groups, not only does random assignment minimize any biases that might favor one group or another, it also serves as a basis for estimating the role of variability in any observed result. Random assignment allows us to evaluate any finding, such as the actual average difference between two groups, to determine whether this difference is larger than expected just by chance, once variability is taken into account. In other words, it permits us to generalize beyond mere appearances and determine whether the average difference merits further attention because it *probably is real* or whether it should be ignored because it *can be attributed to variability or chance.*

Random Assignment
A procedure designed to ensure that each person has an equal chance of being assigned to any group in an experiment.

Overview: Surveys and Experiments

Figure 1.1 compares surveys and experiments. Based on random samples from populations, surveys permit generalizations from samples back to populations. Based on the random assignment of volunteers to groups, experiments permit decisions about whether differences between groups are real or merely transitory.

PROGRESS CHECK *1.2 Indicate whether each of the following terms is associated primarily with a survey (S) or an experiment (E).

(a) random assignment

(b) representative

(c) generalization to the population

(d) control group

Answers on page 420.

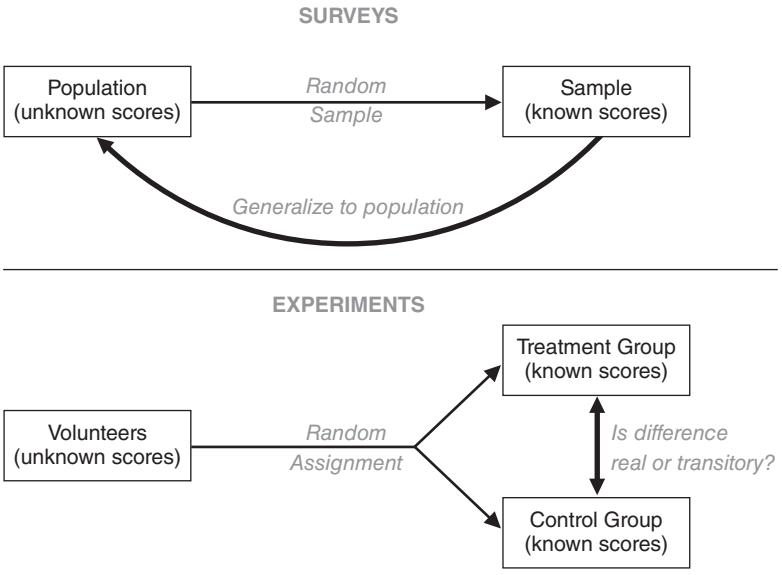

FIGURE 1.1
Overview: surveys and experiments.

(e) real difference

(f) random selection

(g) convenience sample

(h) volunteers

Answers on page 420.

Data
A collection of actual observations or scores in a survey or an experiment

1.4 THREE TYPES OF DATA

Any statistical analysis is performed on **data,** a *collection of actual observations or scores in a survey or an experiment.*

The precise form of a statistical analysis often depends on whether data are qualitative, ranked, or quantitative.

Qualitative Data
A set of observations where any single observation is a word, letter, or numerical code that represents a class or category.

Ranked Data
A set of observations where any single observation is a number that indicates relative standing.

Quantitative Data
A set of observations where any single observation is a number that represents an amount or a count.

Generally, **qualitative data** consist of words (Yes or No), letters (Y or N), or numerical codes (0 or 1) that represent a class or category. **Ranked data** consist of numbers (1st, 2nd, . . . 40th place) that represent relative standing within a group. **Quantitative data** consist of numbers (weights of 238, 170, . . . 185 lbs) that represent an amount or a count. To determine the type of data, focus on a single observation in any collection of observations. For example, the weights reported by 53 male students in Table 1.1 are quantitative data, since any single observation, such as 160 lbs, represents an amount of weight. If the weights in Table 1.1 had been replaced with ranks, beginning with a rank of 1 for the lightest weight of 133 lbs and ending with a rank of 53 for the heaviest weight of 245 lbs, these numbers would have been ranked data, since any single observation represents not an amount, but only relative standing within the group of 53 students. Finally, the Y and N replies of students in **Table 1.2** are qualitative data, since any single observation is a letter that represents a class of replies.

Table 1.2
QUALITATIVE DATA: "DO YOU HAVE A FACEBOOK PROFILE?" YES (Y) OR NO (N) REPLIES OF STATISTICS STUDENTS

Y	Y	Y	N	N	Y	Y	Y
Y	Y	Y	N	N	Y	Y	Y
N	Y	N	Y	Y	Y	Y	Y
Y	Y	N	Y	N	Y	N	Y
Y	N	Y	N	N	Y	Y	Y
Y	Y	N	Y	Y	Y	Y	Y
N	N	N	N	Y	N	N	Y
Y	Y	Y	Y	Y	N	Y	N
Y	Y	Y	Y	N	N	Y	Y
N	Y	N	N	Y	Y	Y	Y
	Y	Y	N				

Progress Check *1.3 Indicate whether each of the following terms is *qualitative* (because it's a word, letter, or numerical code representing a class or category); *ranked* (because it's a number representing relative standing); or *quantitative* (because it's a number representing an amount or a count).

(a) ethnic group

(b) age

(c) family size

(d) academic major

(e) sexual preference

(f) IQ score

(g) net worth (dollars)

(h) third-place finish

(i) gender

(j) temperature

Answers on page 420.

Level of Measurement

Specifies the extent to which a number (or word or letter) actually represents some attribute and, therefore, has implications for the appropriateness of various arithmetic operations and statistical procedures.

1.5 LEVELS OF MEASUREMENT

Learned years ago in grade school, the abstract statement that $2 + 2 = 4$ qualifies as one of life's everyday certainties, along with taxes and death. However, not all numbers have the same interpretation. For instance, it wouldn't make sense to find the sum of two Social Security numbers or to claim that, when viewed as indicators of academic achievement, two GPAs of 2.0 equal a GPA of 4.0. To clarify further the differences among the three types of data, let's introduce the notion of level of measurement. Looming behind any data, the **level of measurement** *specifies the extent to which a number (or word or letter) actually represents some attribute and, therefore, has implications for the appropriateness of various arithmetic operations and statistical procedures.*

For our purposes, there are three levels of measurement—nominal, ordinal, and interval/ratio—and these levels are paired with qualitative, ranked, and quantitative data, respectively. The properties of these levels—and the usefulness of their associated numbers—vary from nominal, the simplest level with only one property, to interval/ratio, the most complex level with four properties. Progressively more complex levels contain all properties of simpler levels, plus one or two new properties.

More complex levels of measurement are associated with numbers that, because they better represent attributes, permit a wider variety of arithmetic operations and statistical procedures.

Qualitative Data and Nominal Measurement

Nominal Measurement
Words, letters, or numerical codes of qualitative data that reflect differences in kind based on classification.

If people are classified as either male or female (or coded as 1 or 2), the data are qualitative and measurement is nominal. *The single property of* **nominal measurement** *is classification*—that is, sorting observations into different classes or categories. Words, letters, or numerical codes reflect only differences in kind, not differences in amount. Examples of nominal measurement include classifying mood disorders as manic, bipolar, or depressive; sexual preferences as heterosexual, homosexual, bisexual, or nonsexual; and attitudes toward stricter pollution controls as favor, oppose, or undecided.

A distinctive feature of nominal measurement is its bare-bones representation of any attribute. For instance, a student is either male or female. Even with the introduction of arbitrary numerical codes, such as 1 for male and 2 for female, it would never be appropriate to claim that, because female is 2 and male is 1, females have twice as much gender as males. Similarly, calculating an average with these numbers would be meaningless. Because of these limitations, only a few sections of this book and Chapter 19 are dedicated exclusively to an analysis of qualitative data with nominal measurement.

Ranked Data and Ordinal Measurement

Ordinal Measurement
Relative standing of ranked data that reflects differences in degree based on order.

When any single number indicates only *relative standing,* such as first, second, or tenth place in a horse race or in a class of graduating seniors, the data are *ranked* and the level of measurement is ordinal. *The distinctive property of* **ordinal measurement** *is order*. Comparatively speaking, a first-place finish reflects the fastest finish in a horse race or the highest GPA among graduating seniors. Although first place in a horse race indicates a *faster* finish than second place, we don't know *how much* faster.

Since ordinal measurement fails to reflect the actual distance between adjacent ranks, simple arithmetic operations with ranks are inappropriate. For example, it's inappropriate to conclude that the arithmetic mean of ranks 1 and 3 equals rank 2, since this assumes that the actual distance between ranks 1 and 2 equals the distance between ranks 2 and 3. Instead, these distances might be very different. For example, rank 2 might be virtually tied with either rank 1 or rank 3. Only a few sections of this book and Chapter 20 are dedicated exclusively to an analysis of ranked data with ordinal measurement.*

*Strictly speaking, ordinal measurement also can be associated with qualitative data whose classes are ordered. Examples of *ordered* qualitative data include the classification of skilled workers as master craftsman, journeyman, or apprentice; socioeconomic status as low, middle, or high; and academic grades as A, B, C, D, or F. It's worth distinguishing between qualitative data with nominal and ordinal measurement because, as described in Chapters 3 and 4, a few extra statistical procedures are available for ordered qualitative data.

Quantitative Data and Interval/Ratio Measurement

Interval/Ratio Measurement
Amounts or counts of quantitative data reflect differences in degree based on equal intervals and a true zero.

Often the products of familiar measuring devices, such as rulers, clocks, or meters, *the distinctive properties of* **interval/ratio measurement** *are equal intervals and a true zero.* Weighing yourself on a bathroom scale qualifies as interval/ratio measurement. *Equal intervals* imply that hefting a 10-lb weight while on the bathroom scale always registers your actual weight plus 10 lbs. Equal intervals imply that the difference between 120 and 130 lbs represents an *amount* of weight equal to the difference between 130 and 140 lbs, and it's appropriate to describe one person's weight as a certain amount greater than another's.

A *true zero* signifies that the bathroom scale registers 0 when not in use—that is, when weight is completely absent. Since the bathroom scale possesses a true zero, numerical readings reflect the *total amount* of a person's weight, and it's appropriate to describe one person's weight as a certain ratio of another's. It can be said that the weight of a 140-lb person is twice that of a 70-lb person.

In the absence of a true zero, numbers—much like the exposed tips of icebergs—fail to reflect the total amount being measured. For example, a reading of 0 on the Fahrenheit temperature scale does not reflect the complete absence of heat—that is, the absence of any molecular motion. In fact, true zero equals –459.4°F on this scale. It would be inappropriate, therefore, to claim that 80°F is twice as hot as 40°F. An appropriate claim could be salvaged by adding 459.4°F to each of these numbers: 80° becomes 539.4° and 40° becomes 499.4°. Clearly, 539.4°F is not twice as hot as 499.4°F.

Interval/ratio measurement appears in the behavioral and social sciences as, for example, bar-press rates of rats in Skinner boxes; the minutes of dream-friendly rapid eye movement (REM) sleep among participants in a sleep-deprivation experiment; and the total number of eye contacts during verbal disputes between romantically involved couples. Thanks to the considerable amount of information conveyed by each observation, interval/ratio measurement permits meaningful arithmetic operations, such as calculating arithmetic means, as well as the many statistical procedures for quantitative data described in this book.

Measurement of Nonphysical Characteristics

When numbers represent nonphysical characteristics, such as intellectual aptitude, psychopathic tendency, or emotional maturity, the attainment of interval/ratio measurement often is questionable. For example, there is no external standard (such as the 10-lb weight) to demonstrate that the addition of a fixed amount of intellectual aptitude always produces an equal increase in IQ scores (equal intervals). There also is no instrument (such as the unoccupied bathroom scale) that registers an IQ score of 0 when intellectual aptitude is completely absent (true zero).

In the absence of equal intervals, it would be inappropriate to claim that the difference between IQ scores of 120 and 130 represents the same amount of intellectual aptitude as the difference between IQ scores of 130 and 140. Likewise, in the absence of a true zero, it would be inappropriate to claim that an IQ score of 140 represents twice as much intellectual aptitude as an IQ score of 70.

Other interpretations are possible. One possibility is to treat IQ scores as attaining only ordinal measurement—that is, for example, a score of 140 represents more intellectual aptitude than a score of 130—without specifying the actual size of this difference. This strict interpretation would greatly restrict the number of statistical procedures for use with behavioral and social data. A looser (and much more common) interpretation, adopted in this book, assumes that, although lacking a true zero, IQ scores provide a crude measure of corresponding differences in intellectual aptitude (equal intervals). Thus, the difference between IQ scores of 120 and 130 represents a *roughly similar* amount of intellectual aptitude as the difference between scores of 130 and 140.