CHAPTER 1

Research Principles

- Rationale for Statistics
- Research Questions
- Treatment and Control Groups
- Rationale for Random Assignment
- Hypothesis Formulation
- Reading Statistical Outcomes
- Accept/Reject Hypothesis
- Levels of Measure

The scientific mind does not so much provide the right answers as ask the right questions.

—Claude Lévi-Strauss

LEARNING OBJECTIVES

Upon completing this chapter, you will be able to:

- Discuss the rationale for using statistics
- Identify various forms of research questions
- Differentiate between *treatment* and *control* groups
- Comprehend the rationale for random assignment
- Understand the basis for hypothesis formulation
- Understand the fundamentals of reading statistical outcomes
- Appropriately accept or reject hypotheses based on statistical outcomes
- Understand the four levels of measure
- Determine the variable type: *categorical* or *continuous*

OVERVIEW—RESEARCH PRINCIPLES

This chapter introduces statistical concepts that will be used throughout this book. Applying statistics involves more than just processing tables of numbers; it involves being curious and assembling mindful questions in an attempt to better understand what is going on in a setting. As you will see, statistics extends far beyond simple averages and head counts. Just as a toolbox contains a variety of tools to accomplish a variety of diverse tasks (e.g., a screwdriver to place or remove screws, a saw to cut materials), there are a variety of statistical tests, each suited to address a different type of research question.

RATIONALE FOR STATISTICS

While statistics can be used to track the status of an *individual*, answering questions such as *What is my academic score over the course of the term?* or *What is my weight from week to week?*, this book focuses on using statistics to understand the characteristics of *groups* of people.

Descriptive statistics, described in Chapter 4, are used to comprehend one variable at a time, answering questions such as *What is the average age of people in this group?* or *How many females and males are there in this group?* Chapters 5 to 9 cover *inferential* statistics, which enable us to make determinations such as *Which patrolling method is best for reducing crime in this neighborhood? Which teaching method produces the highest test scores? Is Treatment A better than Treatment B for a particular disorder? Is there a relationship between salary and happiness?* and *Are female or male students more likely to graduate?*

Statistics enables professionals to implement evidence-based practice (EBP), meaning that instead of simply taking one's best guess at the optimal choice, one can use statistical results to help inform such decisions. Statistical analyses can aid in (more) objectively determining the most effective patrolling method, the best available teaching method, or the optimal treatment for a specific disease or disorder.

EBP involves researching the (published) statistical findings of others who have explored a field you are interested in pursuing; the statistical results in such reports provide evidence as to the effectiveness of such implementations. For example, suppose a researcher has studied 100 people in a sleep lab and now has statistical evidence showing that people who listened to soothing music at bedtime fell asleep faster than those who took a sleeping pill. Such evidence-based findings have the potential to inform professionals regarding best practices—in this case, how to best advise someone who is having problems falling asleep.

EBP, which is supported by statistical findings, helps reduce the guesswork and paves the way to more successful outcomes with respect to assembling more plausible requests for proposals (RFPs), independent proposals for new implementations, and plans for quality improvement, which could involve modifying or enhancing existing implementations (quality improvement), creating or amending policies, or assembling best-practices guidelines for a variety of professional domains.

Even with good intentions, without EBP, we risk adopting implementations that may have a neutral, suboptimal, or even negative impact, hence failing to serve or possibly harming the targeted population.

Additionally, statistics can be used to evaluate the performance of an existing program, which people may be simply assuming is effective, or statistics can be built in to a proposal for a new implementation as a way of monitoring the performance of the program on a progressive basis. For example, instead of simply launching a new program designed to provide academic assistance to students with learning disabilities, one could use EBP methods to design the program, such that the program that would be launched would be composed of elements that have demonstrated efficacy. Furthermore, instead of just launching the program and hoping for the best, the design could include periodic grade audits, wherein one would gather and statistically review the grades of the participants at the conclusion of each term to determine if the learning assistance program is having the intended impact. Such findings could suggest which part(s) of the program are working as expected, and which require further development.

Consider another concise example, wherein a school has implemented an evidence-based strategy aimed at reducing absenteeism. Without a statistical evaluation, administrators would have no way of knowing if the approach worked or not. Alternatively, statistical analysis might reveal that the intervention has reduced absences except on Fridays—in which case, a supplemental attendance strategy could be considered, overall, or the strategy could be adapted to include some special Friday incentives.

RESEARCH QUESTIONS

A statistician colleague of mine once said, "I want the numbers to tell me a story." Those nine words elegantly describe the mission of statistics. Naturally, the story depends on the nature of the statistical question. Some statistical questions render descriptive (summary) statistics, such as: *How many people visit a public park on weekends? How many cars cross this bridge per day? What is the average age of students at a school? How many accidents have occurred at this intersection? What percentage of people in a geographical region have a particular disease? What is the average income per household in a community? What percentage of students graduate from high school?* Attempting to comprehend such figures simply by inspecting them visually may work for a few dozen numbers, but visual inspection of these figures would not be feasible if there were hundreds or even thousands of numbers to consider. To get a reasonable idea of the nature of these numbers, we can mathematically and graphically summarize them and thereby better understand any amount of figures using a concise set of **descriptive statistics**, as detailed in Chapter 4.

Another form of research question involves comparisons; often this takes the form of an experimental outcome. Some questions may involve comparisons of scores between two groups, such as: *In a fourth grade class, do girls or boys do better on math tests? Do smokers sleep more than nonsmokers? Do students whose parents are teachers have better test scores than students whose parents are not teachers? In a two-group clinical trial, one* *group was given a new drug to lower blood pressure, and the other group was given an existing drug; does the new drug outperform the old drug in lowering blood pressure?* These sorts of questions, involving the scores from two groups, are answered using the ***t* test** or the **Mann-Whitney *U* test**, which are covered in Chapter 5.

Research questions and their corresponding designs may involve several groups. For example, in a district with four elementary schools, each uses a different method for teaching spelling; is there a statistically significant difference in spelling scores from one school to another? Another example would be a clinical trial aimed at discovering the optimal dosage of a new sleeping pill. Group 1 gets a placebo, Group 2 gets the drug at a 10-mg dose, and Group 3 gets the drug at a 15-mg dose; is there a statistically significant difference among the groups in terms of number of hours of sleep per night? Questions involving analyzing the scores from more than two groups are processed using **ANOVA (analysis of variance)** or the **Kruskal-Wallis test**, which are covered in Chapter 6.

Some research questions involve assessing the effectiveness of a treatment by administering a pretest, then the treatment, then a posttest to determine if the group's scores improved after the treatment. For example, suppose it is expected that brighter lighting will enhance mood. To test for this, the researcher administers a mood survey under normal lighting to a group, which renders a score (e.g., 0 = *very depressed*, 10 = *very happy*). Next, the lighting is brightened, after which that group is asked to retake the mood test. The question is: *According to the pretest and posttest scores, did the group's mood (score) increase significantly after the lighting was changed?* Consider another example: Suppose it is expected that physical exercise enhances math scores. To test this, a fourth grade teacher administers a multiplication test to each student. Next, the students are taken out to the playground to run to the far fence and back three times, after which the students immediately return to the classroom to take another multiplication test. The question is: *Is there a statistically significant difference between the test scores before and after the physical activity?* Questions involving before-and-after scores within a group are processed with the **paired *t* test** or the **Wilcoxon test**, which are covered in Chapter 7.

Another kind of research question may seek to understand the (co)relation between two variables. For example: *What is the relationship between the number of homework hours per week and grade?* We might expect that as homework hours go up, grades would go up as well. Similarly, we might ask: *What is the relationship between exercise and weight (if exercise goes up, does weight go down)? What is the relationship between mood and hours of sleep per night (when mood is low, do people sleep less)?* Alternatively, we may want to assess how similarly (or dissimilarly) two lists are ordered. Questions involving the correlation between two scores are processed with **correlation** and **regression** using the **Spearman** or **Pearson** test, which are covered in Chapter 8.

Research questions may also involve comparisons between categories. For example: *Is there a difference in ice cream preference (chocolate, strawberry, vanilla) based on gender (male, female)—in other words, does gender have any bearing on ice cream flavor selection?* We could also investigate questions such as: *Does the marital status of parents (divorced, not divorced) have any bearing on their children's graduation from high school* *(graduated, not graduated)?* Questions involving comparisons among categories are processed using **chi-square** (*chi* is pronounced *k-eye*), which is covered in Chapter 9.

As you can see, even at this introductory level, a variety of statistical questions can be asked and answered. An important part of knowing which statistical test to reach for involves understanding the nature of the question and the type of data at hand.

TREATMENT AND CONTROL GROUPS

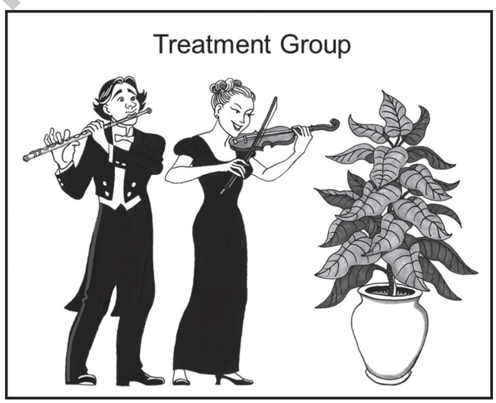
Even if you are new to statistics, you have probably heard of *treatment* and *control* groups. To understand the rationale for using this two-group design, we will explore the results of four examples aimed at answering the research question "Does classical music enhance plant growth?"

Example 1 (Figure 1.1) is a one-group design consisting of a treatment group only (no control group), wherein a good seed is planted in quality soil in an appropriate planter. The plant is given proper watering, sunlight, and 8 hours of classical music per day for 6 months.

At 6 months, the researcher will measure the plant's growth by counting the number of leaves. In this case, the plant produced 20 full-sized healthy leaves, leading the researchers to reason that *classical music facilitates quality plant growth*.

Anyone who is reasonably skeptical might ponder, "The plant had a lot of things going for it—a quality seed, rich soil, the right planter, regular watering and sunlight, and classical music. So, how do we really know that it was the *classical music* that made the plant grow successfully? Maybe it would have done fine without it." Example 2 (Figure 1.2) uses

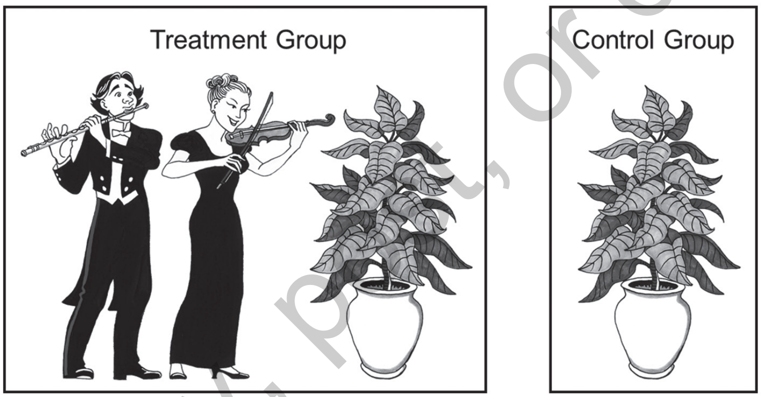
Figure 1.1 One group: treatment group only (positive treatment effect presumed).



a two-group design, consisting of a treatment group and a control group to address that reasonable question.

Notice that in Example 2, the treatment group is precisely the same as in Example 1, which involves a plant grown with a quality seed, rich soil, the right planter, regular watering and sunlight, and classical music. The exact same protocol is given to the other plant, which is placed in the control group, except for one thing: The control plant will receive *no music*. In other words, everything is the same in these two groups except that one plant gets the music and the other does not—this will help us isolate the effect of the music.

Figure 1.2 Two groups: treatment group performs the same as control group (neutral treatment effect).

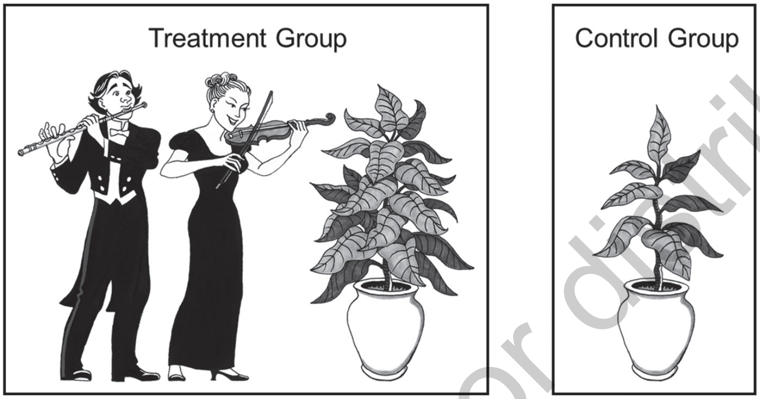


At 6 months, the researcher would then assess the plant growth for each group: In this case, the treatment plant produced 20 leaves, and the control plant also produced 20 leaves. Now we are better positioned to answer the question "How do we really know that it was the *classical music* that made the plant grow successfully?" The control group is the key to answering that question. Both groups were handled identically except for one thing: The treatment group got classical music and the control group did not. Since the control plant received no music but did just as well as the plant that did get the music, we can reasonably conclude that the classical music had a *neutral* effect on the plant growth. Without the control group, we may have mistakenly concluded that classical music had a *positive* effect on plant growth, since the (single) plant did so well in producing 20 leaves.

Next, consider Example 3, which is set up the same as Example 2: a treatment group, in which the plant gets music, and a control group, in which the plant gets no music (Figure 1.3).

In Example 3, we see that the plant in the treatment group produced 20 leaves, whereas the plant in the control group produced only 8 leaves. Since the only difference

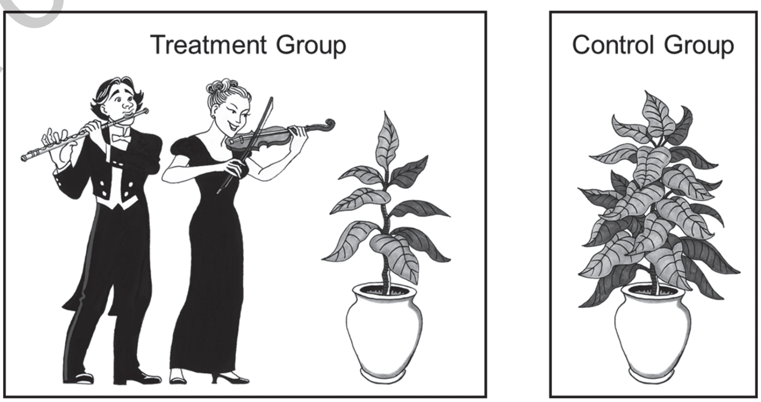
Figure 1.3 Two groups: treatment group outperforms control group (positive treatment effect).



between these two groups is that the treatment group got the music and the control group did not, the results of this experiment suggest that the music had a *positive* effect on plant growth.

Finally, Example 4 (Figure 1.4) shows that the plant in the treatment group produced only 8 leaves, whereas the control plant produced 20 healthy leaves; these results suggest that the classical music had a *negative* effect on plant growth.

Figure 1.4 Two groups: control group outperforms treatment group (negative treatment effect).



Clearly, having the control group provides a comparative basis for more realistically evaluating the outcome of the treatment group. As in this set of examples, in the best circumstances, the treatment group and the control group should begin as identically as possible in every respect, except that the treatment group will get the specified treatment, and the control group proceeds without the treatment. Intuitively, to determine the effectiveness of an intervention, we are looking for substantial differences in the performance between the two groups—is there a significant difference between the results of those in the treatment group compared with the control group?

The statistical tests covered in this text focus on different types of procedures for evaluating the difference(s) between groups (treatment : control) to help determine the effectiveness of the intervention—whether the treatment group significantly outperformed the control group.

To simplify the foregoing examples, the illustrations were drawn with a single plant in each group. If this had been an actual experiment, the design would have been more robust if each group contained multiple plants (e.g., about 30 plants per group); instead of counting the leaves on a single plant, we would compute an average (mean) number of leaves in each group. This would help protect against possible anomalies; for example, the results of a design involving only one plant per group could be compromised if, unknowingly, a good seed were used in one group and a bad seed were used in the other group. Such adverse effects such as this would be minimized if more plants were involved in each group. The rationale and methods for having larger sample sizes (greater than one member per group) are covered in Chapter 2 ("Sampling").

RATIONALE FOR RANDOM ASSIGNMENT

Understanding the utility of randomly assigning participants to treatment or control groups is best explained by example: Dr. Zinn and Dr. Zorders have come up with Q-Math, a revolutionary system for teaching multiplication. The Q-Math package is shipped out to schools in a local district to determine if it is more effective than the current teaching method. The instructions specify that each fourth grade class should be divided in half and routed to separate rooms, with students in one room receiving the Q-Math teaching and students in the other room getting their regular math lesson. At the end, both groups are administered a multiplication test, and the results of both groups are compared. The question is: *How should the class be divided into two groups?* This is not such a simple question. If the classroom is divided into boys and girls, this may influence the outcome, because gender may be a relevant factor in math skills—if by chance we send the gender with stronger math skills to receive the Q-Math intervention, this may serve to inflate those scores. Alternatively, suppose we decided to slice the class in half by seating. This introduces a different potential confound—what if the half who sit near the front of the classroom are naturally more attentive than those who sit in the back half of the classroom? Again, this grouping method may confound the findings of the study. Finally, suppose the teacher splits the class by age. This presents yet another potential confound—maybe older students are able to perform math better than younger students. In addition, it is unwise to allow participants to self-select which group they want to be in; it may be that more proficient math students, or students who take their studies more seriously, may systemically opt for the Q-Math group, thereby potentially influencing the outcome.

Through this simple example, it should be clear that the act of selectively assigning individuals to (treatment or control) groups can unintentionally affect the outcome of a study; it is for this reason that we often opt for random assignment to assemble more balanced groups. In this example, the Q-Math instructions may specify that a coin flip be used to assign students to each of the two groups: Heads assigns a student to Q-Math, and tails assigns a student to the usual math teaching method. This random assignment method ultimately means that regardless of factors such as gender, seating position, age, math proficiency, and academic motivation, each student will have an equal (50/50) chance of being assigned to either group. The process of random assignment will generally result in roughly the same proportion of girls and boys, the same propotion of math-smart students, the same proportion of front- and back-of-the-room students, and the same proportion of older and younger students being assigned to each group. If done properly, random assignment helps cancel out factors inherent to participants that may have otherwise biased the findings one way or another.

HYPOTHESIS FORMULATION

Everyone has heard of the word *hypothesis*; hypotheses simply spell out each of the anticipated possible outcomes of an experiment. In simplest terms, before we embark on the experiment, we need one hypothesis that states that nothing notable happened, because sometimes experiments fail. This would be the *null hypothesis* (H_0), basically meaning that the treatment had a null effect—nothing notable happened.

Another possibility is that something notable did happen (the experiment worked), so we would need an *alternative hypothesis* (H_1) that accounts for this.

Continuing with the above example involving Q-Math, we first construct the null hypothesis (H_0); as expected, the null hypothesis states that the experiment produced null results—basically, the experimental group (the group that got Q-Math) and the control group (the group that got regular math) performed about the same; essentially, that would mean that Q-Math was no more effective than the traditional math lesson. The alternative hypothesis (H_1) is phrased indicating that the treatment (Q-Math) group outperformed the control (regular math lesson) group. Hypotheses are typically written in this fashion:

H_0: Q-Math and regular math teaching methods produce equivalent test results.

H_1: Q-Math produces higher test results compared with regular teaching methods.

When the results are in, we would then know which hypothesis to reject and which to accept; from there, we can document and discuss our findings.

Remember: In simplest terms, the statistics we will be processing are designed to answer the question: *Do the members of the treatment group (who get the innovative* *treatment) significantly outperform the members of the control group (who get no treatment, a placebo, or treatment as usual)?* As such, the hypotheses need to reflect each possible outcome. In this simple example, we can anticipate two possible outcomes: H_0 states that there is *no* significant difference between the treatment group and the control group, suggesting that *the treatment was ineffective*. On the other hand, we need another hypothesis that anticipates that the treatment will significantly outperform the control condition; as such, H_1 states that there *is* a significant difference in the outcomes between the treatment and control conditions, suggesting that *the treatment was effective*. The outcome of the statistical test will point us to which hypothesis to accept and which to reject.

READING STATISTICAL OUTCOMES

Statistical tests vary substantially in terms of the types of research questions each is designed to address, the format of the source data, their respective equations, and the content of their results, which can include figures, tables, and graphs. Although there are some similarities in reading statistical outcomes (e.g., means, alpha [α] levels, *p* values), these concepts are best explained in the context of working examples; as such, how to read statistical outcomes will be thoroughly explained as each emerges in Chapters 4 through 9.

ACCEPT OR REJECT HYPOTHESES

As is the case with reading statistical outcomes, the decision to accept or reject a hypothesis depends on the nature of the test and, of course, the results: the alpha (α) level, *p* value, and, in some cases, the means. Just as with reading statistical outcomes, instructions for accepting or rejecting hypotheses for each test are best discussed in the context of actual working examples; these concepts will be covered in Chapters 5 through 9.

VARIABLE TYPES AND LEVELS OF MEASURE

Comprehending the types of variables involved in a data set or research design is essential when it comes to properly selecting, running, and documenting the results of statistical tests. There are two types of variables: *continuous* and *categorical*. Each has two levels of measure; continuous variables may be either *interval* or *ratio*, and categorical variables may be either *nominal* or *ordinal*.

Basically, you will need to be able to identify the types of variables you will be processing (*continuous* or *categorical*), which will help guide you in selecting and running the proper statistical analyses.

Continuous

Continuous variables contain the kinds of numbers we are accustomed to dealing with in counting and mathematics. A continuous variable may be either *interval* or *ratio*.

Interval

Interval variables range from $-\infty$ to $+\infty$, like numbers on a number line. These numbers have equal spacing between them; the distance between 1 and 2 is the same as the distance between 2 and 3, which is the same as the distance between 3 and 4, and so on. Such variables include bank account balance (which could be negative) and temperature (e.g., –40° to 85°), as measured on either the Fahrenheit or Celsius scale. Interval variables are considered continuous variables.

Ratio

Ratio variables are similar to interval variables, except that interval variables can have negative values, whereas ratio variables cannot be less than zero. The zero value in a ratio variable indicates that there is none of that variable; temperature measured in degrees Celsius or Fahrenheit is not a ratio variable, because zero degrees Celsius does not mean there is no temperature. Finally, by definition, when comparing two ratio variables, you can look at the *ratio* of two measurements; an adult who weighs 160 pounds weighs twice as much as a child who weighs 80 pounds. Examples of ratio variables include weight, distance, income, calories, academic grade (0% to 100%), number of pets, number of pencils in a pencil cup, number of siblings, or number of members in a group. Ratio variables are considered continuous variables.

Learning tip: Notice that the word *ratio* ends in *o*, which looks like a *zero*.

Categorical

Categorical variables (also known as discrete variables) involve assigning a number to an item in a category. A categorical variable may be either *nominal* or *ordinal*.

Nominal

Nominal variables are used to represent categories that defy ordering. For example, suppose you wish to code eye color, and there are six choices: amber, blue, brown, gray, green, and hazel. There is really no way to put these in any order; for coding and computing purposes, we could assign 1 = amber, 2 = blue, 3 = brown, 4 = gray, 5 = green, and 6 = hazel. Since order does not matter among nominal variables, these eye colors could have just as well been numbered differently: 1 = blue, 2 = green, 3 = hazel, 4 = gray, 5 = amber, and 6 = brown. Nominal variables may be used to represent categorical variables such as gender (1 = female, 2 = male), agreement (1 = yes, 2 = no), religion (1 = atheist, 2 = Buddhist, 3 = Catholic, 4 = Hindu, 5 = Jewish, 6 = Taoist, etc.), or marital status (1 = single, 2 = married, 3 = separated, 4 = divorced, 5 = widow or widower).

Since the numbers are arbitrarily assigned to labels within a category, it would be inappropriate to perform traditional arithmetic calculations on such numbers. For example, it would be foolish to compute the average marital status (e.g., would 1.5 indicate a *single married* person?). The same principle applies to other nominal variables, such as gender or religion. There are, however, appropriate statistical operations for processing nominal variables that will be discussed in Chapter 4 ("Descriptive Statistics"). In terms of statistical tests, nominal variables are considered categorical variables.

> **Learning tip:** There is no order among the categories in a nominal variable; notice that the word *nominal* starts with *no*, as in *no order*.

Ordinal

Ordinal variables are similar to nominal variables in that numbers are assigned to represent items within a category. Whereas nominal variables have no real rank order to them (e.g., amber, blue, brown, gray, green, hazel), the values in an ordinal variable can be placed in a ranked order. For example, there is an order to educational degrees (1 = high school diploma, 2 = associate's degree, 3 = bachelor's degree, 4 = master's degree, 5 = doctoral degree). Other examples of ordinal variables include military rank (1 = private, 2 = corporal, 3 = sergeant, etc.) and meals (1 = breakfast, 2 = brunch, 3 = lunch, 4 = dinner, 5 = late-night snack). In terms of statistical tests, ordinal variables are considered categorical variables.

> **Learning tip:** Notice that the root of the word *ordinal* is *order*, suggesting that the categories have a meaningful *order* to them.

Summary of Variable Types

Continuous	Interval	(…−3, −2, −1, 0, 1, 2, 3…)
	Ratio	(0, 1, 2, 3…)
Categorical	Nominal	(Red, Blue, Green)
	Ordinal	(Breakfast, Lunch, Dinner)

GOOD COMMON SENSE

As we explore the results of multiple statistics throughout this text, keep in mind that no matter how precisely we proceed, the process of statistics is not perfect. Our findings do not *prove* or *disprove* anything; rather, statistics helps us reduce uncertainty—to help us better comprehend the nature of those we study.

Additionally, what we learn from statistical findings speaks to the *group* we studied on an *overall basis*, not any one *individual*. For instance, suppose we find that the average age within a group is 25; this does not mean that we can just point to any one person in that group and confidently proclaim "You are 25 years old."

Key Concepts

- Rationale for statistics
- Research question
- Treatment group
- Control group
- Random assignment
- Hypotheses (null, alternative)
- Statistical outcomes
- Accepting or rejecting hypotheses
- Types of data (continuous, categorical)
- Level of data (continuous: interval, ratio; categorical: nominal, ordinal)

Practice Exercises

Each of the following exercises describes the basis for an experiment that would render data that could be processed statistically.

Exercise 1.1

It is expected that aerobic square dancing during the 30-minute recess at an elementary school will help fight childhood obesity.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.2

Recent findings suggest that nursing home residents may experience fewer depressive symptoms when they participate in pet therapy with certified dogs for 30 minutes per day.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.3

A chain of retail stores has been experiencing substantial cash shortages in cashier balances across 10 of its stores. The company is considering installing cashier security cameras.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.4

Anytown Community wants to determine if implementing a neighborhood watch program will reduce vandalism incidents.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.5

Employees at Acme Industries, consisting of four separate buildings, are chronically late. An executive is considering implementing a "get out of Friday free" lottery; each day an employee is on time, he or she gets one token entered into the weekly lottery.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.6

The Acme Herbal Tea Company advertises that its product is "the tea that relaxes."

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.7

Professor Madrigal has a theory that singing improves memory.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.8

Mr. Reed believes that providing assorted colored pens will prompt his students to write longer essays.

a. State the research question.

b. Identify the control and experimental group(s).

c. Explain how you would randomly assign participants to groups.

d. State the hypotheses (H_0 and H_1).

e. Discuss the criteria for accepting or rejecting the hypotheses.

Exercise 1.9

Ms. Fractal wants to determine if working with flash cards helps students learn the multiplication table.

a. State the research question.
b. Identify the control and experimental group(s).
c. Explain how you would randomly assign participants to groups.
d. State the hypotheses (H_0 and H_1).
e. Discuss the criteria for accepting or rejecting the hypotheses

Exercise 1.10

A manager at the Acme Company Call Center wants to see if running a classic movie on a big screen (with the sound off) will increase the number of calls processed per hour.

a. State the research question.
b. Identify the control and experimental group(s).
c. Explain how you would randomly assign participants to groups.
d. State the hypotheses (H_0 and H_1).
e. Discuss the criteria for accepting or rejecting the hypotheses.