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Collecting Data Sensibly

A primary goal of statistical studies is to collect data can then be used to make informed decisions. It sh come as no surprise that the ability to make good c sions depends on the quality of the information availa The data collection step is critical to obtaining reli information; both the type of analysis that is approp and the conclusions that can be drawn depend on the data are collected. In this chapter, we first cons two types of statistical studies and then focus on widely used methods of data collection: sampling experimentation.

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2.1 Statistical Studies: Observation and Experimentation

On September 25, 2009, results from a study of the relationship between spanking and IQ were reported by a number of different news media. Some of the headlines that appeared that day were:

"Spanking lowers a child's IQ" (*Los Angeles Times*)
"Do you spank? Studies indicate it could lower your kid's IQ" (*SciGuy, Houston Chronicle*)
"Spanking can lower IQ" (NBC4i, Columbus, Ohio)
"Smacking hits kids' IQ" (*newscientist.com*)

In the study that these headlines refer to, the investigators followed 806 kids age 2 to 4 and 704 kids age 5 to 9 for 4 years. IQ was measured at the beginning of the study and again 4 years later. The researchers found that at the end of the study, the average IQ of kids who were not spanked was 5 points higher than that of kids who were spanked among the kids who were 2 to 4 years old when the study began, and 2.8 points higher among the kids who were 5 to 9 years old when the study began.

These headlines all imply that spanking was the cause of the observed difference in IQ. Is this conclusion reasonable? The answer depends in a critical way on the study design. We'll return to these headlines and decide if they are on target after first considering some important aspects of study design.

Observation and Experimentation

Data collection is an important step in the data analysis process. When we set out to collect information, it is important to keep in mind the questions we hope to answer on the basis of the resulting data. Sometimes we are interested in answering questions about characteristics of a single existing population or in comparing two or more well-defined populations. To accomplish this, we select a sample from each population under consideration and use the sample information to gain insight into characteristics of those populations.

For example, an ecologist might be interested in estimating the average shell thickness of bald eagle eggs. A social scientist studying a rural community may want to determine whether gender and attitude toward abortion are related. These are examples of studies that are *observational* in nature. In these studies, we want to observe characteristics of members of an existing population or of several populations, and then use the resulting information to draw conclusions. In an observational study, it is important to obtain a sample that is representative of the corresponding population.

Sometimes the questions we are trying to answer deal with the effect of certain explanatory variables on some response and cannot be answered using data from an observational study. Such questions are often of the form, "What happens when ... ?" or, "What is the effect of ... ?" For example, an educator may wonder what would happen to test scores if the required lab time for a chemistry course were increased from 3 hours to 6 hours per week. To answer such questions, the researcher conducts an experiment to collect relevant data. The value of some response variable (test score in the chemistry example) is recorded under different experimental conditions (3-hour lab and 6-hour lab). In an experiment, the researcher manipulates one or more explanatory variables, also sometimes called **factors**, to create the experimental conditions.

AP* EXAM TIP

These definitions are important when deciding what conclusions can be drawn from a statistical study. If asked "What conclusions can be made from this study?", the very first consideration should be whether the study is observational or experimental.

DEFINITION

A study is an **observational study** if the investigator observes characteristic of a sample selected from one or more existing populations. The goal of a observational study is usually to draw conclusions about the correspondin population or about differences between two or more populations. In a well designed observational study, the sample is selected in a way that is designe to produce a sample that is respresentative of the population.

A study is an **experiment** if the investigator observes how a response variabl behaves when one or more explanatory variables, also called factors, are ma nipulated. The usual goal of an experiment is to determine the effect of th manipulated explanatory variables (factors) on the response variable. In a well designed experiment, the composition of the groups that will be exposed t different experimental conditions is determined by random assignment.

The type of conclusion that can be drawn from a statistical study dep on the study design. Both observational studies and experiments can be use compare groups, but in an experiment the researcher controls who is in w group, whereas this is not the case in an observational study. This seemingly s difference is critical when it comes to drawing conclusions based on data from study.

A well-designed experiment can result in data that provide evidence for a ca and-effect relationship. This is an important difference between an observati study and an experiment. In an observational study, it is impossible to draw cause-and-effect conclusions because we cannot rule out the possibility that the served effect is due to some variable other than the explanatory variable being stud Such variables are called confounding variables.

AP* EXAM TIP

Confounding is a very important concept. You should be able to recognize confounding variables given the description of a study. You should also be able to speculate intelligently about possible confounding variables when designing studies (especially experiments).

DEFINITION

A **confounding variable** is one that is related to both group membership an the response variable of interest in a research study.

Consider the role of confounding variables in the following three studies:

- The article "Panel Can't Determine the Value of Daily Vitamins" (*San Obispo Tribune,* July 1, 2003) summarized the conclusions of a governn advisory panel that investigated the benefits of vitamin use. The panel looke a large number of studies on vitamin use and concluded that the results "inadequate or conflicting." A major concern was that many of the studies observational in nature and the panel worried that people who take vitar might be healthier just because they tend to take better care of themselve general. This potential confounding variable prevented the panel from conc ing that taking vitamins is the cause of observed better health among those take vitamins.
- Studies have shown that people over age 65 who get a flu shot are less likely those who do not get a flu shot to die from a flu-related illness during the foll ing year. However, recent research has shown that people over age 65 who flu shot are also less likely than those who don't to die from *any* cause during following year (*International Journal of Epidemiology,* December 21, 20

This has lead to the speculation that those over age 65 who get flu shots are healthier as a group than those who do not get flu shots. If this is the case, observational studies that compare two groups—those who get flu shots and those who do not—may overestimate the effectiveness of the flu vaccine because general health differs in the two groups. General health is a possible confounding variable in such studies.

- The article "Heartfelt Thanks to Fido" (*San Luis Obispo Tribune*, July 5, 2003) summarized a study that appeared in the *American Journal of Cardiology* (March 15, 2003). In this study researchers measured heart rate variability (a measure of the heart's ability to handle stress) in patients who had recovered from a heart attack. They found that heart rate variability was higher (which is good and means the heart can handle stress better) for those who owned a dog than for those who did not. Should someone who suffers a heart attack immediately go out and get a dog? Well, maybe not yet. The American Heart Association recommends additional studies to determine if the improved heart rate variability is attributable to dog ownership or due to the fact that dog owners get more exercise. If in fact dog owners do tend to get more exercise than nonowners, level of exercise is a confounding variable that would prevent us from concluding that owning a dog is the cause of improved heart rate variability.

Each of the three studies described above illustrates why potential confounding variables make it unreasonable to draw a cause-and-effect conclusion from an observational study.

Let's return to the study on spanking and IQ described at the beginning of this section. Is this study an observational study or an experiment? Two groups were compared (children who were spanked and children who were not spanked), but the researchers did not randomly assign children to the spanking or no-spanking groups. The study is observational, and so cause-and-effect conclusions such as "spanking lowers IQ" are not justified based on the observed data. What we can say is that there is evidence that, as a group, children who are spanked tend to have a lower IQ than children who are not spanked. What we cannot say is that spanking is the cause of the lower IQ. It is possible that other variables—such as home or school environment, socio-economic status, or parents' education—are related to both IQ and whether or not a child was spanked. These are examples of possible confounding variables.

Fortunately, not everyone made the same mistake as the writers of the headlines given earlier in this section. Some examples of headlines that got it right are:

"Lower IQ's measured in spanked children" (*world-science.net*)
"Children who get spanked have lower IQs" (*livescience.com*)
"Research suggests an association between spanking and lower IQ in children" (*CBSnews.com*)

Drawing Conclusions from Statistical Studies

In this section, two different types of conclusions have been described. One type involves generalizing from what we have seen in a sample to some larger population, and the other involves reaching a cause-and-effect conclusion about the effect of an explanatory variable on a response. When is it reasonable to draw such conclusions? The answer depends on the way that the data were collected. Table 2.1 summarizes the types of conclusions that can be made with different study designs.

As you can see from Table 2.1, it is important to think carefully about the objectives of a statistical study before planning how the data will be collected. Both

TABLE 2.1 Drawing Conclusions from Statistical Studies

Study Description	Reasonable to Generalize Conclusions about Group Characteristics to the Population?	Reasonable t Draw Cause- and-Effect Conclusion?
Observational study with sample selected at random from population of interest	Yes	No
Observational study based on convenience or voluntary response sample (poorly designed sampling plan)	No	No
Experiment with groups formed by random assignment of individuals or objects to experimental conditions		
Individuals or objects used in study are volunteers or not randomly selected from some population of interest	No	Yes
Individuals or objects used in study are randomly selected from some population of interest	Yes	Yes
Experiment with groups not formed by random assignment to experimental conditions (poorly designed experiment)	No	No

observational studies and experiments must be carefully designed if the resul data are to be useful. The common sampling procedures used in observational s ies are considered in Section 2.2. In Sections 2.3 and 2.4, we consider experime tion and explore what constitutes good practice in the design of sir experiments.

EXERCISES 2.1 - 2.12

2.1 ✦ The article "Television's Value to Kids: It's All in How They Use It" (*Seattle Times,* July 6, 2005) described a study in which researchers analyzed standardized test results and television viewing habits of 1700 children. They found that children who averaged more than 2 hours of television viewing per day when they were younger than 3 tended to score lower on measures of reading ability and short-term memory.

a. Is the study described an observational study or an experiment?

b. Is it reasonable to conclude that watching two or more hours of television is the cause of lower reading scores? Explain.

2.2 The article "Acupuncture for Bad Backs: E Sham Therapy Works" (*Time,* May 12, 2009) sum rized a study conducted by researchers at the Gı Health Center for Health Studies in Seattle. In this st 638 adults with back pain were randomly assigned to of four groups. People in group 1 received the usual for back pain. People in group 2 received acupunctu a set of points tailored specifically for each indivic People in group 3 received acupuncture at a standar of points typically used in the treatment of back p Those in group 4 received fake acupuncture—they poked with a toothpick at the same set of points usec the people in group 3! Two notable conclusions from study were: (1) patients receiving real or fake acupunc

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experienced a greater reduction in pain than those receiving usual care; and (2) there was no significant difference in pain reduction for those who received acupuncture (at individualized or the standard set of points) and those who received fake acupuncture toothpick pokes.

a. Is this study an observational study or an experiment? Explain.
b. Is it reasonable to conclude that receiving either real or fake acupuncture was the cause of the observed reduction in pain in those groups compared to the usual care group? What aspect of this study supports your answer?

2.3 The article "Display of Health Risk Behaviors on MySpace by Adolescents" (*Archives of Pediatrics and Adolescent Medicine* [2009]:27–34) described a study in which researchers looked at a random sample of 500 publicly accessible MySpace web profiles posted by 18-year-olds. The content of each profile was analyzed. One of the conclusions reported was that displaying sport or hobby involvement was associated with decreased references to risky behavior (sexual references or references to substance abuse or violence).

a. Is the study described an observational study or an experiment?
b. Is it reasonable to generalize the stated conclusion to all 18-year-olds with a publicly accessible MySpace web profile? What aspect of the study supports your answer?
c. Not all MySpace users have a publicly accessible profile. Is it reasonable to generalize the stated conclusion to all 18-year-old MySpace users? Explain.
d. Is it reasonable to generalize the stated conclusion to all MySpace users with a publicly accessible profile? Explain.

2.4 Can choosing the right music make wine taste better? This question was investigated by a researcher at a university in Edinburgh (*www.decanter.com/news*). Each of 250 volunteers was assigned at random to one of five rooms where they were asked to taste and rate a glass of wine. In one of the rooms, no music was playing and a different style of music was playing in each of the other four rooms. The researchers concluded that cabernet sauvignon is perceived as being richer and more robust when bold music is played than when no music is heard.

a. Is the study described an observational study or an experiment?
b. Can a case be made for the researcher's conclusion that the music played was the cause for the higher rating? Explain.

2.5 Consider the following graphical display that appeared in the *New York Times:*

Image not available due to copyright restrictions

Based on the data summarized in the graph, we can see that students who have a high school GPA or 3.5 or higher and a combined SAT score of over 1200 have an 89% graduation rate when they attend a "most selective" college, but only a 59% graduation rate when they attend a "least selective" college. Give an example of a potential confounding variable that might explain why the following statement is not reasonable: If all the students that have a GPA of 3.5 or higher and a combined SAT score of 1200 or higher and that were admitted to a "least selective" college were moved to a "most selective" college, the graduation rate for these students would be approximately 89%.

2.6 "Fruit Juice May Be Fueling Pudgy Preschoolers, Study Says" is the title of an article that appeared in the *San Luis Obispo Tribune* (February 27, 2005). This article describes a study that found that for 3- and 4-year-olds, drinking something sweet once or twice a day doubled the risk of being seriously overweight one year later. The authors of the study state

> Total energy may be a confounder if consumption of sweet drinks is a marker for other dietary factors associated with overweight (*Pediatrics*, November 2005).

Give an example of a dietary factor that might be one of the potentially confounding variables the study authors are worried about.

2.7 The article "Americans are 'Getting the Wrong Idea' on Alcohol and Health" (Associated Press, April 19, 2005) reported that observational studies in recent years that have concluded that moderate drinking is associated with a reduction in the risk of heart disease may be misleading. The article refers to a study conducted by the Centers for Disease Control and Prevention that showed that moderate drinkers, as a group, tended to be better educated, wealthier, and more active than non-drinkers. Explain why the existence of these potentially confounding variables prevents drawing the conclusion that moderate drinking is the cause of reduced risk of heart disease.

2.8 An article titled "Guard Your Kids Against Allergies: Get Them a Pet" (*San Luis Obispo Tribune*, August 28, 2002) described a study that led researchers to conclude that "babies raised with two or more animals were about half as likely to have allergies by the time they turned six."

a. Do you think this study was an observational study or an experiment? Explain.
b. Describe a potential confounding variable that illustrates why it is unreasonable to conclude that being raised with two or more animals is the cause of the observed lower allergy rate.

2.9 Researchers at the Hospital for Sick Children in Toronto compared babies born to mothers with diabetes to babies born to mothers without diabetes ("Conditioning and Hyperanalgesia in Newborns Exposed to Repeated Heel Lances," *Journal of the American Medical Association* [2002]: 857–861). Babies born to mothers with diabetes have their heels pricked numerous times during the first 36 hours of life in order to obtain blood samples to monitor blood sugar level. The researchers noted that the babies born to diabetic mothers were more likely to grimace or cry when having blood drawn than the babies born to mothers without diabetes. This led the researchers to conclude that babies who experience pain early in life become highly sensitive to pain. Comment on the appropriateness of this conclusion.

2.10 Based on a survey conducted on the DietSı .com web site, investigators concluded that women regularly watched *Oprah* were only one-seventh as like crave fattening foods as those who watched other day talk shows (*San Luis Obispo Tribune*, October 14, 20

a. Is it reasonable to conclude that watching *Oprah* ca a decrease in cravings for fattening foods? Explain.
b. Is it reasonable to generalize the results of this su to all women in the United States? To all women watch daytime talk shows? Explain why or why r

2.11 ✦ A survey of affluent Americans (those wit comes of $75,000 or more) indicated that 57% w rather have more time than more money (*USA To* January 29, 2003).

a. What condition on how the data were colle would make the generalization from the sampl the population of affluent Americans reasonable
b. Would it be reasonable to generalize from the s ple to say that 57% of all Americans would ra have more time than more money? Explain.

2.12 Does living in the South cause high blood press Data from a group of 6278 whites and blacks questio in the Third National Health and Nutritional Exam tion Survey between 1988 and 1994 (see CNN.com site article of January 6, 2000, titled "High Blood P sure Greater Risk in U.S. South, Study Says") indi that a greater percentage of Southerners have high b pressure than do people in any other region of the U States. This difference in rate of high blood pressure found in every ethnic group, gender, and age cate studied. List at least two possible reasons we cannot clude that living in the South causes high blood pressu

Bold exercises answered in back ● Data set available online ✦ Video Solution available

2.2 Sampling

Many studies are conducted in order to generalize from a sample to the correspon population. As a result, it is important that the sample be representative of the pop tion. To be reasonably sure of this, we must carefully consider the way in which sample is selected. It is sometimes tempting to take the easy way out and gather da a haphazard way; but if a sample is chosen on the basis of convenience alone, it becc impossible to interpret the resulting data with confidence. For example, it migh easy to use the students in your statistics class as a sample of students at your univer However, not all majors include a statistics course in their curriculum, and most dents take statistics in their sophomore or junior year. The difficulty is that it is clear whether or how these factors (and others that we might not be aware of) affect conclusions based on information from such a sample.

There is no way to tell just by looking at a sample whether it is representative of the population from which it was drawn. Our only assurance comes from the method used to select the sample.

There are many reasons for selecting a sample rather than obtaining information from an entire population (a **census**). Sometimes the process of measuring the characteristics of interest is destructive, as with measuring the lifetime of flashlight batteries or the sugar content of oranges, and it would be foolish to study the entire population. But the most common reason for selecting a sample is limited resources. Restrictions on available time or money usually prohibit observation of an entire population.

Bias in Sampling

Bias in sampling is the tendency for samples to differ from the corresponding population in some systematic way. Bias can result from the way in which the sample is selected or from the way in which information is obtained once the sample has been chosen. The most common types of bias encountered in sampling situations are selection bias, measurement or response bias, and nonresponse bias.

Selection bias (sometimes also called undercoverage) is introduced when the way the sample is selected systematically excludes some part of the population of interest. For example, a researcher may wish to generalize from the results of a study to the population consisting of all residents of a particular city, but the method of selecting individuals may exclude the homeless or those without telephones. If those who are excluded from the sampling process differ in some systematic way from those who are included, the sample is virtually guaranteed to be unrepresentative of the population. If this difference between the included and the excluded occurs on a variable that is important to the study, conclusions based on the sample data may not be valid for the population of interest. Selection bias also occurs if only volunteers or self-selected individuals are used in a study, because those who choose to participate (for example, in a call-in telephone poll) may well differ from those who choose not to participate.

Measurement or response bias occurs when the method of observation tends to produce values that systematically differ from the true value in some way. This might happen if an improperly calibrated scale is used to weigh items or if questions on a survey are worded in a way that tends to influence the response. For example, a Gallup survey sponsored by the American Paper Institute (*Wall Street Journal,* May 17, 1994) included the following question: "It is estimated that disposable diapers account for less than 2 percent of the trash in today's landfills. In contrast, beverage containers, third-class mail and yard waste are estimated to account for about 21 percent of trash in landfills. Given this, in your opinion, would it be fair to tax or ban disposable diapers?" It is likely that the wording of this question prompted people to respond in a particular way.

Other things that might contribute to response bias are the appearance or behavior of the person asking the question, the group or organization conducting the study, and the tendency for people not to be completely honest when asked about illegal behavior or unpopular beliefs.

Although the terms *measurement bias* and *response bias* are often used interchangeably, the term *measurement bias* is usually used to describe systematic deviation from the true value as a result of a faulty measurement instrument (as with the improperly calibrated scale).

Nonresponse bias occurs when responses are not obtained from all individuals selected for inclusion in the sample. As with selection bias, nonresponse bias can distort

results if those who respond differ in important ways from those who do not resp
Although some level of nonresponse is unavoidable in most surveys, the biasing e
on the resulting sample is lowest when the response rate is high. To minimize no
sponse bias, it is critical that a serious effort be made to follow up with individuals
do not respond to an initial request for information.

The nonresponse rate for surveys or opinion polls varies dramatically, dependin
how the data are collected. Surveys are commonly conducted by mail, by phone, an
personal interview. Mail surveys are inexpensive but often have high nonresponse r
Telephone surveys can also be inexpensive and can be implemented quickly, but
work well only for short surveys and they can also have high nonresponse rates. Pers
interviews are generally expensive but tend to have better response rates. Some o
many challenges of conducting surveys are discussed in Section 2.5.

Types of Bias

Selection Bias

Tendency for samples to differ from the corresponding population as a result o
systematic exclusion of some part of the population.

Measurement or Response Bias

Tendency for samples to differ from the corresponding population because th
method of observation tends to produce values that differ from the true value

Nonresponse Bias

Tendency for samples to differ from the corresponding population because da
are not obtained from all individuals selected for inclusion in the sample.

AP* EXAM TIP

These types of bias are easily confused. When answering questions about bias, be sure to provide an explanation that shows your understanding of the bias problem in a particular situation.

It is important to note that bias is introduced by the way in which a sample is selected
the way in which the data are collected from the sample. Increasing the size of the sampl
though possibly desirable for other reasons, does nothing to reduce bias if the method of sele
the sample is flawed or if the nonresponse rate remains high. A good discussion of types of
appears in the sampling book by Lohr listed in the references in the back of the boo

Potential sources of bias are illustrated in the following examples.

EXAMPLE 2.1 Are Cell Phone Users Different?

Many surveys are conducted by telephone and participants are often selected f
phone books that include only landline telephones. For many years, it was thou
that this was not a serious problem because most cell phone users also had a lan
phone and so they still had a chance of being included in the survey. But the nu
of people with only cell phones is growing, and this trend is a concern for su
organizations. The article "Omitting Cell Phone Users May Affect Polls" (*Associ*
Press, September 25, 2008) described a study that examined whether people
only have a cell phone are different that those who have landline phones. One fin
from the study was that for people under the age of 30 with only a cell phone, 2
were Republicans compared to 36% of landline users. This suggests that researc
who use telephone surveys need to worry about how selection bias might influ
the ability to generalize the results of a survey if only landlines are used.

EXAMPLE 2.2 Think Before You Order That Burger!

The article "What People Buy from Fast-Food Restaurants: Caloric Content and Menu Item Selection" (*Obesity* [2009]: 1369–1374) reported that the average number of calories consumed at lunch in New York City fast food restaurants was 827. The researchers selected 267 fast food locations at random. The paper states that at each of these locations "adult customers were approached as they entered the restaurant and asked to provide their food receipt when exiting and to complete a brief survey." Approaching customers as they entered the restaurant and before they ordered may have influenced what they purchased. This introduces the potential for response bias. In addition, some people chose not to participate when approached. If those who chose not to participate differed from those who did participate, the researchers also need to be concerned about nonresponse bias. Both of these potential sources of bias limit the researchers' ability to generalize conclusions based on data from this study.

Random Sampling

Most of the inferential methods introduced in this text are based on the idea of random selection. The most straightforward sampling method is called simple random sampling. A **simple random sample** is a sample chosen using a method that ensures that each different possible sample of the desired size has an equal chance of being the one chosen. For example, suppose that we want a simple random sample of 10 employees chosen from all those who work at a large design firm. For the sample to be a simple random sample, each of the many different subsets of 10 employees must be equally likely to be the one selected. A sample taken from only full-time employees would not be a simple random sample of *all* employees, because someone who works part-time has no chance of being selected. Although a simple random sample may, by chance, include only full-time employees, it must be selected in such a way that each possible sample, and therefore *every* employee, has the same chance of inclusion in the sample. *It is the selection process, not the final sample, which determines whether the sample is a simple random sample*.

The letter n is used to denote sample size; it is the number of individuals or objects in the sample. For the design firm scenario of the previous paragraph, $n = 10$.

DEFINITION

A **simple random sample of size n** is a sample that is selected from a population in a way that ensures that every different possible sample of the desired size has the same chance of being selected.

The definition of a simple random sample implies that every individual member of the population has an equal chance of being selected. *However, the fact that every individual has an equal chance of selection, by itself, is not enough to guarantee that the sample is a simple random sample*. For example, suppose that a class is made up of 100 students, 60 of whom are female. A researcher decides to select 6 of the female students by writing all 60 names on slips of paper, mixing the slips, and then picking 6. She then selects 4 male students from the class using a similar procedure. Even though every student in the class has an equal chance of being included in the sample (6 of 60 females are selected and 4 of 40 males are chosen), the resulting sample is *not* a simple ranc sample because not all different possible samples of 10 students from the class have same chance of selection. Many possible samples of 10 students—for example, a s ple of 7 females and 3 males or a sample of all females—have no chance of being lected. The sample selection method described here is not necessarily a bad choice fact, it is an example of stratified sampling, to be discussed in more detail shortly), it does not produce a simple random sample, and this must be considered wh method is chosen for analyzing data resulting from such a sampling method.

Selecting a Simple Random Sample A number of different methods can be u to select a simple random sample. One way is to put the name or number of each m ber of the population on different but identical slips of paper. The process of thorou mixing the slips and then selecting *n* slips one by one yields a random sample of siz This method is easy to understand, but it has obvious drawbacks. The mixing mus adequate, and producing the necessary slips of paper can be extremely tedious, even relatively small populations.

A commonly used method for selecting a random sample is to first create a called a **sampling frame**, of the objects or individuals in the population. Each item the list can then be identified by a number, and a table of random digits or a rand number generator can be used to select the sample. A random number generator procedure that produces a sequence of numbers that satisfies properties associated w the notion of randomness. Most statistics software packages include a random num generator, as do many calculators. A small table of random digits can be found in pendix A, Table 1.

For example, suppose a list containing the names of the 427 customers who chased a new car during 2009 at a large dealership is available. The owner of dealership wants to interview a sample of these customers to learn about custo satisfaction. She plans to select a simple random sample of 20 customers. Becau would be tedious to write all 427 names on slips of paper, random numbers ca used to select the sample. To do this, we can use three-digit numbers, starting w 001 and ending with 427, to represent the individuals on the list.

The random digits from rows 6 and 7 of Appendix A, Table 1 are shown he

0 9 3 8 7 6 7 9 9 5 6 2 5 6 5 8 4 2 6 4
4 1 0 1 0 2 2 0 4 7 5 1 1 9 4 7 9 7 5 1

We can use blocks of three digits from this list (underlined in the lists above identify the individuals who should be included in the sample. The first bloc three digits is 093, so the 93rd person on the list will be included in the sam The next five blocks of three digits (876, 799, 562, 565, and 842) do not co spond to anyone on the list, so we ignore them. The next block that correspo to a person on the list is 410, so that person is included in the sample. This pro would continue until 20 people have been selected for the sample. We would nore any three-digit repeats since any particular person should only be selected o for the sample.

Another way to select the sample would be to use computer software or a gra ing calculator to generate 20 random numbers. For example, Minitab produced following when 20 random numbers between 1 and 427 were requested.

289	67	29	26	205	214	422	31	233	98
10	203	346	186	232	410	43	293	25	371

These numbers could be used to determine which 20 customers to include in sample.

When selecting a random sample, researchers can choose to do the sampling with or without replacement. **Sampling with replacement** means that after each successive item is selected for the sample, the item is "replaced" back into the population and may therefore be selected again at a later stage. In practice, sampling with replacement is rarely used. Instead, the more common method is to not allow the same item to be included in the sample more than once. After being included in the sample, an individual or object would not be considered for further selection. Sampling in this manner is called **sampling without replacement**.

DEFINITION

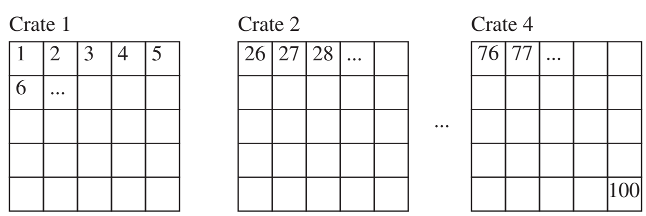
Sampling without replacement: Once an individual from the population is selected for inclusion in the sample, it may not be selected again in the sampling process. A sample selected without replacement includes n distinct individuals from the population.

Sampling with replacement: After an individual from the population is selected for inclusion in the sample and the corresponding data are recorded, the individual is placed back in the population and can be selected again in the sampling process. A sample selected with replacement might include any particular individual from the population more than once.

Although these two forms of sampling are different, when the sample size n is small relative to the population size, as is often the case, there is little practical difference between them. In practice, the two can be viewed as equivalent if the sample size is at most 10% of the population size.

EXAMPLE 2.3 Selecting a Random Sample of Glass Soda Bottles

Breaking strength is an important characteristic of glass soda bottles. Suppose that we want to measure the breaking strength of each bottle in a random sample of size $n = 3$ selected from four crates containing a total of 100 bottles (the population). Each crate contains five rows of five bottles each. We can identify each bottle with a number from 1 to 100 by numbering across the rows in each crate, starting with the top row of crate 1, as pictured:

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Using a random number generator from a calculator or statistical software package, we could generate three random numbers between 1 and 100 to determine which bottles would be included in our sample. This might result in bottles 15 (row 3 column 5 of crate 1), 89 (row 3 column 4 of crate 4), and 60 (row 2 column 5 of crate 3) being selected.

Step-by-Step technology instructions available online

The goal of random sampling is to produce a sample that is likely to be representativ
of the population. Although random sampling does not *guarantee* that the sample w
be representative, it does allow us to assess the risk of an unrepresentative sample.
is the ability to quantify this risk that will enable us to generalize with confidence fro
a random sample to the corresponding population.

An Important Note Concerning Sample Size

It is a common misconception that if the size of a sample is relatively small comp to the population size, the sample cannot possibly accurately reflect the populat Critics of polls often make statements such as, "There are 14.6 million registered ers in California. How can a sample of 1000 registered voters possibly reflect pu opinion when only about 1 in every 14,000 people is included in the sample?" T critics do not understand the power of random selection!

Consider a population consisting of 5000 applicants to a state university, and pose that we are interested in math SAT scores for this population. A dotplot of values in this population is shown in Figure 2.1(a). Figure 2.1(b) shows dotplots o math SAT scores for individuals in five different random samples from the populat ranging in sample size from $n = 50$ to $n = 1000$. Notice that the samples tend t flect the distribution of scores in the population. If we were interested in using

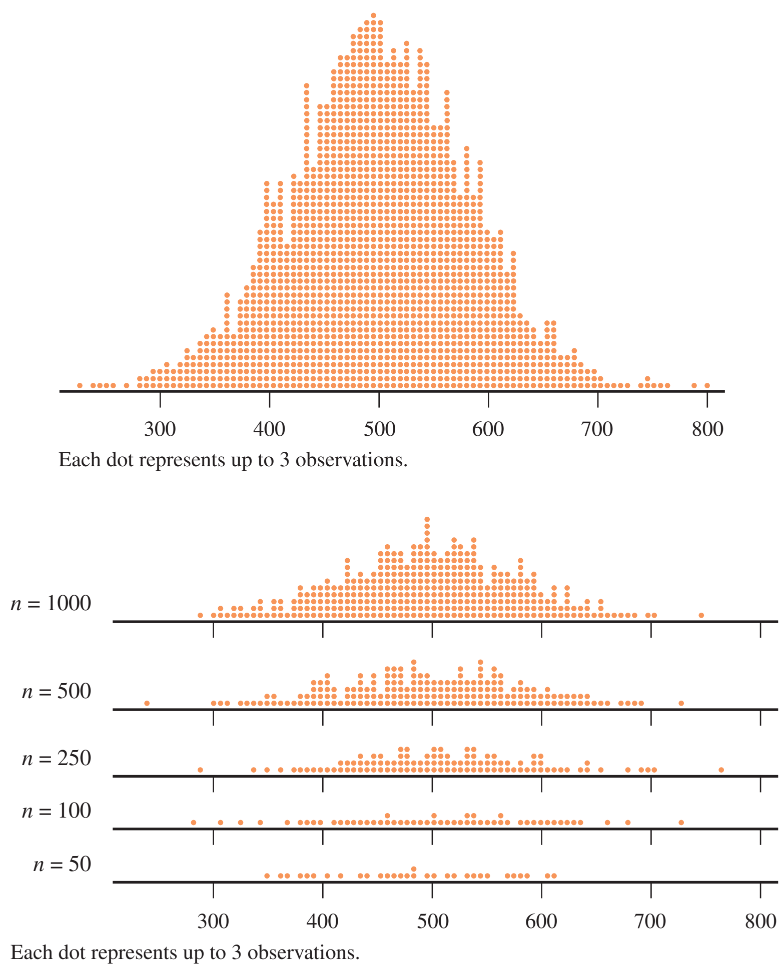


FIGURE 2.1
(a) Dotplot of math SAT scores for the entire population. (b) Dotplots of math SAT scores for random samples of sizes 50, 100, 250, 500, and 1000.

sample to estimate the population average or to say something about the variability in SAT scores, even the smallest of the samples ($n = 50$) pictured would provide reliable information. Although it is possible to obtain a simple random sample that does not do a reasonable job of representing the population, this is likely only when the sample size is very small, and unless the population itself is small, this risk does not depend on what fraction of the population is sampled. The random selection process allows us to be confident that the resulting sample adequately reflects the population, even when the sample consists of only a small fraction of the population.

Other Sampling Methods

Simple random sampling provides researchers with a sampling method that is objective and free of selection bias. In some settings, however, alternative sampling methods may be less costly, easier to implement, and sometimes even more accurate.

Stratified Random Sampling

When the entire population can be divided into a set of nonoverlapping subgroups, a method known as **stratified sampling** often proves easier to implement and more cost-effective than simple random sampling. In stratified random sampling, separate simple random samples are independently selected from each subgroup. For example, to estimate the average cost of malpractice insurance, a researcher might find it convenient to view the population of all doctors practicing in a particular metropolitan area as being made up of four subpopulations: (1) surgeons, (2) internists and family practitioners, (3) obstetricians, and (4) a group that includes all other areas of specialization. Rather than taking a random simple sample from the population of all doctors, the researcher could take four separate simple random samples—one from the group of surgeons, another from the internists and family practitioners, and so on. These four samples would provide information about the four subgroups as well as information about the overall population of doctors.

When the population is divided in this way, the subgroups are called **strata** and each individual subgroup is called a stratum (the singular of strata). Stratified sampling entails selecting a separate simple random sample from each stratum. Stratified sampling can be used instead of simple random sampling if it is important to obtain information about characteristics of the individual strata as well as of the entire population, although a stratified sample is not required to do this—subgroup estimates can also be obtained by using an appropriate subset of data from a simple random sample.

The real advantage of stratified sampling is that it often allows us to make more accurate inferences about a population than does simple random sampling. In general, it is much easier to produce relatively accurate estimates of characteristics of a homogeneous group than of a heterogeneous group. For example, even with a small sample, it is possible to obtain an accurate estimate of the average grade point average (GPA) of students graduating with high honors from a university. The individual GPAs of these students are all quite similar (a homogeneous group), and even a sample of three or four individuals from this subpopulation should be representative. On the other hand, producing a reasonably accurate estimate of the average GPA of *all* seniors at the university, a much more diverse group of GPAs, is a more difficult task. Thus, if a varied population can be divided into strata, with each stratum being much more homogeneous than the population with respect to the characteristic of interest, then a stratified random sample can produce more accurate estimates of population characteristics than a simple random sample of the same size.

Cluster Sampling

Sometimes it is easier to select groups of individuals from a population than it is to select individuals themselves. **Cluster sampling** involves dividing the population of interest into nonoverlapping subgroups, called **clusters**. Clusters

are then selected at random, and then *all* individuals in the selected clusters are inclu
in the sample. For example, suppose that a large urban high school has 600 senior
dents, all of whom are enrolled in a first period homeroom. There are 24 senior ho
rooms, each with approximately 25 students. If school administrators wanted to se
a sample of roughly 75 seniors to participate in an evaluation of the college and ca
placement advising available to students, they might find it much easier to select t
of the senior homerooms at random and then include all the students in the sele
homerooms in the sample. In this way, an evaluation survey could be administered t
students in the selected homerooms at the same time—certainly easier logistically t
randomly selecting 75 students and then administering the survey to those indivi
seniors.

Because whole clusters are selected, the ideal situation for cluster sampling is w
each cluster mirrors the characteristics of the population. When this is the case, a s
number of clusters results in a sample that is representative of the population. If
not reasonable to think that the variability present in the population is reflected in e
cluster, as is often the case when the cluster sizes are small, then it becomes impor
to ensure that a large number of clusters are included in the sample.

Be careful not to confuse clustering and stratification. Even though both of these s pling strategies involve dividing the population into subgroups, both the way in whic subgroups are sampled and the optimal strategy for creating the subgroups are differen stratified sampling, we sample from every stratum, whereas in cluster sampling, we inc only selected whole clusters in the sample. Because of this difference, to increase the chan obtaining a sample that is representative of the population, we want to create homogen groups for strata and heterogeneous (reflecting the variability in the population) group clusters.

AP* EXAM TIP

When describing a sampling plan, be sure to convey your understanding of the sampling procedure and give a complete description of how the sample will be selected.

Systematic Sampling **Systematic sampling** is a procedure that can be used w
it is possible to view the population of interest as consisting of a list or some othe
quential arrangement. A value k is specified (for example, $k = 50$ or $k = 200$). T
one of the first k individuals is selected at random, after which every kth individu
the sequence is included in the sample. A sample selected in this way is called a **1
systematic sample**.

For example, a sample of faculty members at a university might be selected f
the faculty phone directory. One of the first $k = 20$ faculty members listed coul
selected at random, and then every 20th faculty member after that on the list wo
also be included in the sample. This would result in a 1 in 20 systematic sample.

The value of k for a 1 in k systematic sample is generally chosen to achie
desired sample size. For example, in the faculty directory scenario just describe
there were 900 faculty members at the university, the 1 in 20 systematic sample
scribed would result in a sample size of 45. If a sample size of 100 was desired, a
9 systematic sample could be used (because $900/100 = 9$).

As long as there are no repeating patterns in the population list, systematic s
pling works reasonably well. However, if there are such patterns, systematic samp
can result in an unrepresentative sample. For example, suppose that workers at
entry station of a state park have recorded the number of visitors to the park each
for the past 10 years. In a 1 in 70 systematic sample of days from this list, we wo
pick one of the first 70 days at random and then every 70th day after that. But if
first day selected happened to be a Wednesday, *every* day selected in the entire sam
would also be a Wednesday (because there are 7 days a week and 70 is a multipl
7). It is unlikely that such a sample would be representative of the entire collectio
days. The number of visitors is likely to be higher on weekend days, and no Satur
or Sundays would be included in the sample.

Convenience Sampling: Don't Go There! It is often tempting to resort to "convenience" sampling—that is, using an easily available or convenient group to form a sample. This is a recipe for disaster! Results from such samples are rarely informative, and it is a mistake to try to generalize from a convenience sample to any larger population.

One common form of convenience sampling is sometimes called **voluntary response sampling**. Such samples rely entirely on individuals who volunteer to be a part of the sample, often by responding to an advertisement, calling a publicized telephone number to register an opinion, or logging on to an Internet site to complete a survey. It is extremely unlikely that individuals participating in such voluntary response surveys are representative of any larger population of interest.

EXERCISES 2.13 - 2.32

2.13 As part of a curriculum review, the psychology department would like to select a simple random sample of 20 of last year's 140 graduates to obtain information on how graduates perceived the value of the curriculum. Describe two different methods that might be used to select the sample.

2.14 A petition with 500 signatures is submitted to a university's student council. The council president would like to determine the proportion of those who signed the petition who are actually registered students at the university. There is not enough time to check all 500 names with the registrar, so the council president decides to select a simple random sample of 30 signatures. Describe how this might be done.

2.15 During the previous calendar year, a county's small claims court processed 870 cases. Describe how a simple random sample of size $n = 50$ might be selected from the case files to obtain information regarding the average award in such cases.

2.16 The financial aid advisor of a university plans to use a stratified random sample to estimate the average amount of money that students spend on textbooks each term. For each of the following proposed stratification schemes, discuss whether it would be worthwhile to stratify the university students in this manner.

a. Strata corresponding to class standing (freshman, sophomore, junior, senior, graduate student)
b. Strata corresponding to field of study, using the following categories: engineering, architecture, business, other
c. Strata corresponding to the first letter of the last name: A–E, F–K, etc.

2.17 Suppose that a group of 1000 orange trees is laid out in 40 rows of 25 trees each. To determine the sugar content of fruit from a sample of 30 trees, researcher A suggests randomly selecting five rows and then randomly selecting six trees from each sampled row. Researcher B suggests numbering each tree on a map of the trees from 1 to 1000 and using random numbers to select 30 of the trees. Which selection method is preferred? Explain.

2.18 ✦ For each of the situations described, state whether the sampling procedure is simple random sampling, stratified random sampling, cluster sampling, systematic sampling, or convenience sampling.

a. All first-year students at a university are enrolled in 1 of 30 sections of a seminar course. To select a sample of freshmen at this university, a researcher selects four sections of the seminar course at random from the 30 sections and all students in the four selected sections are included in the sample.
b. To obtain a sample of students, faculty, and staff at a university, a researcher randomly selects 50 faculty members from a list of faculty, 100 students from a list of students, and 30 staff members from a list of staff.
c. A university researcher obtains a sample of students at his university by using the 85 students enrolled in his Psychology 101 class.
d. To obtain a sample of the seniors at a particular high school, a researcher writes the name of each senior on a slip of paper, places the slips in a box and mixes them, and then selects 10 slips. The students whose names are on the selected slips of paper are included in the sample.
e. To obtain a sample of those attending a basketball game, a researcher selects the 24th person through the door. Then, every 50th person after that is also included in the sample.

2.19 Of the 6500 students enrolled at a community college, 3000 are part time and the other 3500 are full time. The college can provide a list of students that is sorted so that all full-time students are listed first, followed by the part-time students.

a. Describe a procedure for selecting a stratified random sample that uses full-time and part-time students as the two strata and that includes 10 students from each stratum.

b. Does every student at this community college have the same chance of being selected for inclusion in the sample? Explain.

2.20 Briefly explain why it is advisable to avoid the use of convenience samples.

2.21 A sample of pages from this book is to be obtained, and the number of words on each selected page will be determined. For the purposes of this exercise, equations are not counted as words and a number is counted as a word only if it is spelled out—that is, *ten* is counted as a word, but *10* is not.

a. Describe a sampling procedure that would result in a simple random sample of pages from this book.

b. Describe a sampling procedure that would result in a stratified random sample. Explain why you chose the specific strata used in your sampling plan.

c. Describe a sampling procedure that would result in a systematic sample.

d. Describe a sampling procedure that would result in a cluster sample.

e. Using the process you gave in Part (a), select a simple random sample of at least 20 pages, and record the number of words on each of the selected pages. Construct a dotplot of the resulting sample values, and write a sentence or two commenting on what it reveals about the number of words on a page.

f. Using the process you gave in Part (b), select a stratified random sample that includes a total of at least 20 selected pages, and record the number of words on each of the selected pages. Construct a dotplot of the resulting sample values, and write a sentence or two commenting on what it reveals about the number of words on a page.

2.22 In 2000, the chairman of a California ballot initiative campaign to add "none of the above" to the list of ballot options in all candidate races was quite critical of a Field poll that showed his measure trailing by 10 percentage points. The poll was based on a random sample of 1000 registered voters in California. He is quoted by the Associated Press (January 30, 2000) as say "Field's sample in that poll equates to one out of 17 voters," and he added that this was so dishonest Field should get out of the polling business! If worked on the Field poll, how would you respond to criticism?

2.23 The authors of the paper "Digital Inequa Differences in Young Adults' Use of the Inter (*Communication Research* [2008]: 602–621) were terested in determining if people with higher level education use the Internet in different ways than t who do not have as much formal education. To an this question, they used data from a national teleph survey. Approximately 1300 households were sele for the survey, and 270 of them completed the interv What type of bias should the researchers be concer about and why?

2.24 The authors of the paper "Illicit Use of Psyc stimulants among College Students" (*Psychol Health & Medicine* [2002]: 283–287) surveyed co students about their use of legal and illegal stimula The sample of students surveyed consisted of stud enrolled in a psychology class at a small, competitive lege in the United States.

a. Was this sample a simple random sample, a strat sample, a systematic sample, or a convenience s ple? Explain.

b. Give two reasons why the estimate of the propor of students who reported using illegal stimul based on data from this survey should not be ge alized to all U.S. college students.

2.25 The paper "Deception and Design: The Im of Communication Technology on Lying Behav (*Computer-Human Interaction* [2009]: 130–136) scribes an investigation into whether lying is less c mon in face-to-face communication than in other fo of communication such as phone conversations or e-r Participants in this study were 30 students in an up division communications course at Cornell Unive who received course credit for participation. Particip were asked to record all of their social interactions f week, making note of any lies told. Based on data f these records, the authors of the paper concluded students lie more often in phone conversations tha face-to-face conversations and more often in face-to- conversations than in e-mail. Discuss the limitatior this study, commenting on the way the sample wa lected and potential sources of bias.

2.26 The authors of the paper "Popular Video Games: Quantifying the Presentation of Violence and its Context" (*Journal of Broadcasting & Electronic Media* [2003]: 58–76) investigated the relationship between video game rating—suitable for everyone (E), suitable for 13 years of age and older (T), and suitable for 17 years of age and older (M)—and the number of violent interactions per minute of play. The sample of games examined consisted of 60 video games—the 20 most popular (by sales) for each of three game systems. The researchers concluded that video games rated for older children had significantly more violent interactions per minute than did those games rated for more general audiences.

a. Do you think that the sample of 60 games was selected in a way that makes it reasonable to think it is representative of the population of all video games?
b. Is it reasonable to generalize the researchers' conclusion to all video games? Explain why or why not.

2.27 Participants in a study of honesty in online dating profiles were recruited through print and online advertisements in the *Village Voice,* one of New York City's most prominent weekly newspapers, and on Craigslist New York City ("The Truth About Lying in Online Dating Profiles," *Computer-Human Interaction* [2007]: 1–4). The actual height, weight, and age of the participants were compared to what appeared in their online dating profiles. The resulting data was then used to draw conclusions about how common deception was in online dating profiles. What concerns do you have about generalizing conclusions based on data from this study to the population of all people who have an online dating profile? Be sure to address at least two concerns and give the reason for your concern.

2.28 The report "Undergraduate Students and Credit Cards in 2004: An Analysis of Usage Rates and Trends" (Nellie Mae, May 2005) estimated that 21% of undergraduates with credit cards pay them off each month and that the average outstanding balance on undergraduates' credit cards is $2169. These estimates were based on an online survey that was sent to 1260 students. Responses were received from 132 of these students. Is it reasonable to generalize the reported estimates to the population of all undergraduate students? Address at least two possible sources of bias in your answer.

2.29 Suppose that you were asked to help design a survey of adult city residents in order to estimate the proportion that would support a sales tax increase. The plan is to use a stratified random sample, and three stratification schemes have been proposed.

Scheme 1: Stratify adult residents into four strata based on the first letter of their last name (A–G, H–N, O–T, U–Z).

Scheme 2: Stratify adult residents into three strata: college students, nonstudents who work full time, nonstudents who do not work full time.

Scheme 3: Stratify adult residents into five strata by randomly assigning residents into one of the five strata.

Which of the three stratification schemes would be best in this situation? Explain.

2.30 The article "High Levels of Mercury Are Found in Californians" (*Los Angeles Times,* February 9, 2006) describes a study in which hair samples were tested for mercury. The hair samples were obtained from more than 6000 people who voluntarily sent hair samples to researchers at Greenpeace and The Sierra Club. The researchers found that nearly one-third of those tested had mercury levels that exceeded the concentration thought to be safe. Is it reasonable to generalize this result to the larger population of U.S. adults? Explain why or why not.

2.31 ✦ Whether or not to continue a Mardi Gras Parade through downtown San Luis Obispo, CA, is a hotly debated topic. The parade is popular with students and many residents, but some celebrations have led to complaints and a call to eliminate the parade. The local newspaper conducted online and telephone surveys of its readers and was surprised by the results. The survey web site received more than 400 responses, with more than 60% favoring continuing the parade, while the telephone response line received more than 120 calls, with more than 90% favoring banning the parade (*San Luis Obispo Tribune,* March 3, 2004). What factors may have contributed to these very different results?

2.32 The article "Gene's Role in Cancer May Be Overstated" (*San Luis Obispo Tribune,* August 21, 2002) states that "early studies that evaluated breast cancer risk among gene mutation carriers selected women in families where sisters, mothers, and grandmothers all had breast cancer. This created a statistical bias that skewed risk estimates for women in the general population." Is the bias described here selection bias, measurement bias, or nonresponse bias? Explain.

2.3 Simple Comparative Experiments

Sometimes the questions we are trying to answer deal with the effect of certair planatory variables on some response. Such questions are often of the form, "W happens when . . . ?" or "What is the effect of . . . ?" For example, an industrial gineer may be considering two different workstation designs and might want to k whether the choice of design affects work performance. A medical researcher want to determine how a proposed treatment for a disease compares to a stan treatment. Experiments provide a way to collect data to answer these type questions.

DEFINITION

An **experiment** is a study in which one or more explanatory variables are ma nipulated in order to observe the effect on a response variable.

The **explanatory variables** are those variables that have values that are con trolled by the experimenter. Explanatory variables are also called **factors.**

The **response variable** is a variable that is not controlled by the experimente and that is measured as part of the experiment.

An **experimental condition** is any particular combination of values for the ex planatory variables. Experimental conditions are also called **treatments.**

Suppose we are interested in determining the effect of room temperature performance on a first-year calculus exam. In this case, the explanatory variab room temperature (it can be manipulated by the experimenter). The response vari is exam performance (the variable that is not controlled by the experimenter and will be measured).

In general, we can identify the explanatory variables and the response vari easily if we can describe the purpose of the experiment in the following terms:

The purpose is to assess the effect of ______________ on ______________

explanatory variable	response variable

Let's return to the example of an experiment to assess the effect of room temp ture on exam performance. We might decide to use two room temperature setti 65° and 75°. This would result in an experiment with two experimental condit (or equivalently, two treatments) corresponding to the two temperature settings.

Suppose that there are 10 sections of first-semester calculus that have agree participate in our study. We might design an experiment in this way: Set the r temperature (in degrees Fahrenheit) to 65° in five of the rooms and to 75° in the o five rooms on test day, and then compare the exam scores for the 65° group and 75° group. Suppose that the average exam score for the students in the 65° group noticeably higher than the average for the 75° group. Could we conclude that increased temperature resulted in a lower average score? Based on the informa given, the answer is no because many other factors might be related to exam sc Were the sections at different times of the day? Did they have the same instruc Different textbooks? Did the sections differ with respect to the abilities of the dents? Any of these other factors could provide a plausible explanation (having n ing to do with room temperature) for why the average test score was different for two groups. It is not possible to separate the effect of temperature from the effec these other factors. As a consequence, simply setting the room temperatures as described makes for a poorly designed experiment.

A well-designed experiment requires more than just manipulating the explanatory variables; the design must also eliminate other possible explanations or the experimental results will not be conclusive.

The goal is to design an experiment that will allow us to determine the effects of the explanatory variables on the chosen response variable. To do this, we must take into consideration any extraneous variables that, although not of interest in the current study, might also affect the response variable.

DEFINITION

An **extraneous variable** is one that is not one of the explanatory variables in the study but is thought to affect the response variable.

A well-designed experiment copes with the potential effects of extraneous variables by using random assignment to experimental conditions and sometimes also by incorporating direct control and/or blocking into the design of the experiment. Each of these strategies—random assignment, direct control, and blocking—is described in the paragraphs that follow.

A researcher can **directly control** some extraneous variables. In the calculus test example, the textbook used is an extraneous variable because part of the differences in test results might be attributed to this variable. We could control this variable directly, by requiring that all sections use the same textbook. Then any observed differences between temperature groups could not be explained by the use of different textbooks. The extraneous variable *time of day* might also be directly controlled in this way by having all sections meet at the same time.

The effects of some extraneous variables can be filtered out by a process known as **blocking**. Extraneous variables that are addressed through blocking are called *blocking variables*. Blocking creates groups (called blocks) that are similar with respect to blocking variables; then all treatments are tried in each block. In our example, we might use *instructor* as a blocking variable. If five instructors are each teaching two sections of calculus, we would make sure that for each instructor, one section was part of the 65° group and the other section was part of the 75° group. With this design, if we see a difference in exam scores for the two temperature groups, the extraneous variable *instructor* can be ruled out as a possible explanation, because all five instructors' students were present in each temperature group. (Had we controlled the instructor variable by choosing to have only one instructor, that would be an example of direct control. Of course we can't directly control both time of day and instructor.) If one instructor taught all the 65° sections and another taught all the 75° sections, we would be unable to distinguish the effect of temperature from the effect of the instructor. In this situation, the two variables (temperature and instructor) are said to be **confounded**.

Two variables are **confounded** if their effects on the response variable cannot be distinguished from one another.

If an extraneous variable is confounded with the explanatory variables (w define the treatments), it is not possible to draw an unambiguous conclusion al the effect of the treatment on the response. Both direct control and blocking ar fective in ensuring that the controlled variables and blocking variables are not founded with the variables that define the treatments.

We can directly control some extraneous variables by holding them constant, we can use blocking to create groups that are similar to essentially filter out the e of others. But what about variables, such as student ability in our calculus test exam which cannot be controlled by the experimenter and which would be difficult to u blocking variables? These extraneous variables are handled by the use of **random signment** to experimental groups. Random assignment ensures that our experin does not systematically favor one experimental condition over any other and atter to create experimental groups that are as much alike as possible. For example, i students requesting calculus could be assigned to one of the ten available sections u a random mechanism, we would expect the resulting groups to be similar with res to student ability as well as with respect to other extraneous variables that are no rectly controlled or used as a basis for blocking. Note that random assignment i experiment is different from random selection of subjects. The ideal situation w be to have both random selection of subjects and random assignment of subjec experimental conditions, as this would allow conclusions from the experiment t generalized to a larger population. *For many experiments the random selection of sub is not possible. As long as subjects are assigned at random to experimental conditions, still possible to assess treatment effects.*

To get a sense of how random assignment tends to create similar groups, sup that 50 college freshmen are available to participate as subjects in an experimer investigate whether completing an online review of course material before an e improves exam performance. The 50 subjects vary quite a bit with respect to achi ment, which is reflected in their math and verbal SAT scores, as shown in Figure

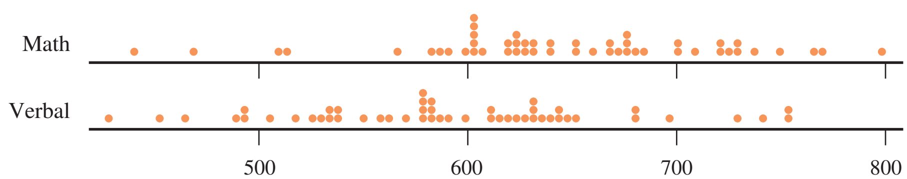


FIGURE 2.2
Dotplots of math and verbal SAT scores for 50 freshmen.

If these 50 students are to be assigned to the two experimental groups (one will complete the online review and one that will not), we want to make sure tha assignment of students to groups does not favor one group over the other by ten to assign the higher achieving students to one group and the lower achieving stud to the other.

Creating groups of students with similar achievement levels in a way that co ers both verbal and math SAT scores simultaneously would be difficult, so we rel random assignment. Figure 2.3(a) shows the math SAT scores of the student signed to each of the two experimental groups (one shown in orange and one sh in blue) for each of three different random assignments of students to groups. Fi 2.3(b) shows the verbal SAT scores for the two experimental groups for each o same three random assignments. Notice that each of the three random assignm produced groups that are similar with respect to *both* verbal and math SAT scores if any of these three assignments were used and the two groups differed on e performance, we could rule out differences in math or verbal SAT scores as pos competing explanations for the difference.

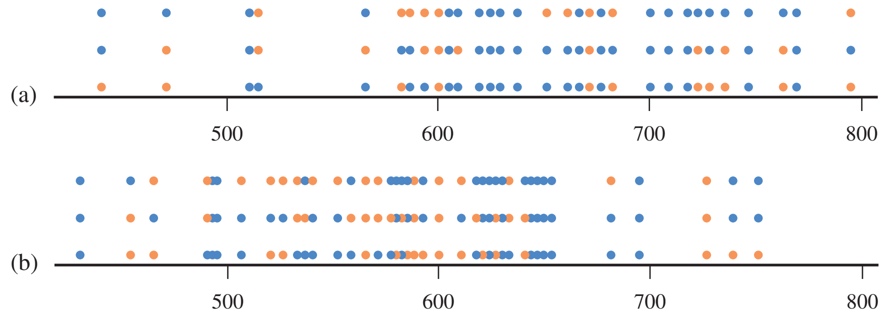


FIGURE 2.3
Dotplots for three different random assignments to two groups, one shown in orange and one shown in blue: (a) math SAT score; (b) verbal SAT score.

Not only will random assignment tend to create groups that are similar with respect to verbal and math SAT scores, but it will also tend to even out the groups with respect to other extraneous variables. *As long as the number of subjects is not too small, we can rely on the random assignment to produce comparable experimental groups. This is the reason that random assignment is a part of all well-designed experiments.*

Not all experiments require the use of human subjects. For example, a researcher interested in comparing three different gasoline additives with respect to gasoline mileage might conduct an experiment using a single car with an empty tank. One gallon of gas with one of the additives will be put in the tank, and the car will be driven along a standard route at a constant speed until it runs out of gas. The total distance traveled on the gallon of gas could then be recorded. This could be repeated a number of times—10, for example—with each additive.

The experiment just described can be viewed as consisting of a sequence of trials. Because a number of extraneous variables (such as variations in environmental conditions like wind speed or humidity and small variations in the condition of the car) might have an effect on gas mileage, it would not be a good idea to use additive 1 for the first 10 trials, additive 2 for the next 10 trials, and so on. A better approach would be to randomly assign additive 1 to 10 of the 30 planned trials, and then randomly assign additive 2 to 10 of the remaining 20 trials. The resulting plan for carrying out the experiment might look as follows:

Trial	1	2	3	4	5	6	7	. . .	30
Additive	2	2	3	3	2	1	2	. . .	1

When an experiment can be viewed as a sequence of trials, random assignment involves the random assignment of treatments to trials. *Remember that random assignment—either of subjects to treatments or of treatments to trials—is a critical component of a good experiment*.

Random assignment can be effective only if the number of subjects or observations in each experimental condition (treatment) is large enough for each experimental group to reliably reflect variability in the population. For example, if there were only 20 students requesting calculus, it is unlikely that we would get equivalent groups for comparison, even with random assignment to the ten sections. **Replication** is the design strategy of making multiple observations for each experimental condition. Together, replication and random assignment allow the researcher to be reasonably confident of comparable experimental groups.

To illustrate the design of a simple experiment, consider the dilemma of Anna, a waitress in a local restaurant. She would like to increase the amount of her tips, and her strategy is simple: She will write "Thank you" on the back of some of the checks before giving them to the patrons and on others she will write nothing. She plans to calculate the percentage of the tip as her measure of success (for example, a 15% tip is common). She will compare the average percentage of the tips calculated from

Key Concepts in Experimental Design

Random Assignment

Random assignment (of subjects to treatments or of treatments to trials) t ensure that the experiment does not systematically favor one experimental cor dition (treatment) over another.

Blocking

Using extraneous variables to create groups (blocks) that are similar. All exper mental conditions (treatments) are then tried in each block.

Direct Control

Holding extraneous variables constant so that their effects are not confounde with those of the experimental conditions (treatments).

Replication

Ensuring that there is an adequate number of observations for each experimer tal condition.

checks with and without the handwritten "Thank you." If writing "Thank you" not produce higher tips, she may try a different strategy.

Anna is untrained in the art of planning experiments, but already she has ta some common sense steps in the right direction to answer her question—Will wri "Thank you" produce the desired outcome of higher tips? Anna has defined a man able problem, and collecting the appropriate data is feasible. It should be easy to ga data as a normal part of her work. Anna wonders whether writing "Thank you" or customers' bills will have an effect on the amount of her tip. In the language of ex mentation, we would refer to the writing of "Thank you" and the not writin "Thank you" as **treatments** (the two experimental conditions to be compared ir experiment). The two treatments together are the possible values of the **explana variable**. The tipping percentage is the **response variable**. The idea behind this te nology is that the tipping percentage is a *response* to the treatments *writing "Thank* or *not writing "Thank you."* Anna's experiment may be thought of as an attemp explain the variability in the response variable in terms of its presumed cause, the ability in the explanatory variable. That is, as she manipulates the explanatory vari she expects the response by her customers to vary. Anna has a good start, but now must consider the four fundamental design principles.

Replication. Anna cannot run a successful experiment by gathering tipping formation on only one person for each treatment. There is no reason to be that any single tipping incident is representative of what would happen in o incidents, and therefore it would be impossible to evaluate the two treatm with only two subjects. To interpret the effects of a particular treatment, she r **replicate** each treatment in the experiment.

Blocking. Suppose that Anna works on both Thursdays and Fridays. Bec day of the week might affect tipping behavior, Anna should block on day of week and make sure that observations for both treatments are made on eac the two days.

Direct Control and Random Assignment. There are a number of extraneous variables that might have an effect on the size of tip. Some restaurant patrons will be seated near the window with a nice view; some will have to wait for a table, whereas others may be seated immediately; and some may be on a fixed income and cannot afford a large tip. Some of these variables can be directly controlled. For example, Anna may choose to use only window tables in her experiment, thus eliminating table location as a potential confounding variable. Other variables, such as length of wait and customer income, cannot be easily controlled. As a result, it is important that Anna use random assignment to decide which of the window tables will be in the "Thank you" group and which will be in the "No thank you" group. She might do this by flipping a coin as she prepares the check for each window table. If the coin lands with the head side up, she could write "Thank you" on the bill, omitting the "Thank you" when a tail is observed.

The accompanying box summarizes how experimental designs deal with extraneous variables.

Taking Extraneous Variables into Account

Extraneous variables are variables other than the explanatory variables in an experiment that may also have an effect on the response variable. There are several strategies for dealing with extraneous variables in order to avoid confounding.

Extraneous variables that we know about and choose to incorporate into the experimental design:

Strategies

Direct control—holds extraneous variables fixed so that they can't affect the response variable
Blocking—allows for valid comparisons because each treatment is tried in each block

Extraneous variables that we don't know about or choose not to incorporate into the experimental design through direct control or blocking:

Strategy

Random assignment

Extraneous variables that are not incorporated into the design of the experiment are sometimes called **lurking variables.***

*For more on lurking variables, see "Lurking Variables: Some Examples" (*The American Statistician* [1981]: 227–233).

A Note on Random Assignment

There are several strategies that can be used to perform random assignment of subjects to treatments or treatments to trials. Two common strategies are:

- Write the name of each subject or a unique number that corresponds to a subject on a slip of paper. Place all of the slips in a container and mix well. Then draw out the desired number of slips to determine those that will be assigned to the first treatment group. This process of drawing slips of paper then continues until all treatment groups have been determined.

- Assign each subject a unique number from 1 to *n,* where *n* represents the t number of subjects. Use a random number generator or table of random n bers to obtain numbers that will identify which subjects will be assigned to first treatment group. This process would be repeated, ignoring any rand numbers generated that correspond to subjects that have already been assigne a treatment group, until all treatment groups have been formed.

The two strategies above work well and can be used for experiments in which desired number of subjects in each treatment group has been predetermined.

Another strategy that is sometimes employed is to use a random mechar (such as tossing a coin or rolling a die) to determine which treatment will be assig to a particular subject. For example, in an experiment with two treatments, you m toss a coin to determine if the first subject is assigned to treatment 1 or treatmer This could continue for each subject—if the coin lands H, the subject is assigne treatment 1, and if the coin lands T, the subject is assigned to treatment 2. strategy is fine, but may result in treatment groups of unequal size. For exampl an experiment with 100 subjects, 53 might be assigned to treatment 1 and 4 treatment 2. If this is acceptable, the coin flip strategy is a reasonable way to as subjects to treatments.

But, suppose you want to ensure that there is an equal number of subjects in treatment group. Is it acceptable to use the coin flip strategy until one treatm group is complete and then just assign all of the remaining subjects to groups tha not yet full? The answer to this question is that it is probably not acceptable. example, suppose a list of 20 subjects is in order by age from youngest to oldest that we want to form two treatment groups each consisting of 10 subjects. Tossi coin to make the assignments might result in the following (based on using the row of random digits in Appendix A, Table 1, with an even number representin and an odd number representing T):

Subject	Random Number	Coin Toss Equivalent	Treatment Grou
1	4	H	1
2	5	T	2
3	1	T	2
4	8	H	1
5	5	T	2
6	0	H	1
7	3	T	2
8	3	T	2
9	7	T	2
10	1	T	2
11	2	H	1
12	8	H	1
13	4	H	1
14	5	T	2
15	1	T	2
16	Treatment group 2 filled. Assign all others to treatment group 1.		1
17			1
18			1
19			1
20			1

If the list of subjects was ordered by age, treatment group 1 would end up with a disproportionate number of older people. This strategy usually results in one treatment group drawing disproportionately from the end of the list. So, the only time the strategy of assigning at random until groups fill up and then assigning the remaining subjects to the group that is not full is reasonable is if you can be sure that the list is in random order with respect to all variables that might be related to the response variable. Because of this, it is best to avoid this strategy. Activity 2.5 investigates potential difficulties with this type of strategy.

On the other hand, if the number of subjects is large, it may not be important that every treatment group has exactly the same number of subjects. If this is the case, it is reasonable to use a coin flip strategy (or other strategies of this type) that does not involve stopping assignment of subjects to a group that becomes full.

Evaluating an Experimental Design

The key concepts of experimental design provide a framework for evaluating an experimental design, as illustrated in the following examples.

EXAMPLE 2.4 Revenge Is Sweet

The article "The Neural Basis of Altruistic Punishment" (*Science*, August 27, 2004) described a study that examined motivation for revenge. Subjects in the study were all healthy, right-handed men. Subjects played a game with another player in which they could both earn money by trusting each other or one player could double-cross the other player and keep all of the money. In some cases the double cross was required by the rules of the game in certain circumstances, while in other cases the double cross was the result of a deliberate choice. The victim of a double cross was then given the opportunity to retaliate by imposing a fine, but sometimes the victim had to spend some of his own money in order to impose the fine. This study was an experiment with four experimental conditions or treatments:

1. double cross not deliberate (double cross dictated by the rules of the game) and no cost to the victim to retaliate
2. double cross deliberate and no cost to the victim to retaliate
3. double cross not deliberate and a cost to the victim to retaliate
4. double cross deliberate and a cost to the victim to retaliate

All subjects chose revenge (imposed a fine on the double-crosser) when the double cross was deliberate and retaliation was free, and 86% of the subjects chose revenge when the double cross was deliberate, even if it cost them money. Only 21% imposed a fine if the double cross was dictated by the rules of the game and was not deliberate.

Assuming that the researchers randomly assigned the subjects to the four experimental conditions, this study is an experiment that incorporated random assignment, direct control (controlled sex, health, and handedness by using only healthy, right-handed males as subjects), and replication (many subjects assigned to each experimental condition).

EXAMPLE 2.5 Subliminal Messages

The article "The Most Powerful Manipulative Messages Are Hiding in Plain Si (*Chronicle of Higher Education,* January 29, 1999) reported the results of an in esting experiment on priming—the effect of subliminal messages on how we beh In the experiment, subjects completed a language test in which they were aske construct a sentence using each word in a list of words. One group of subject ceived a list of words related to politeness, and a second group was given a lis words related to rudeness. Subjects were told to complete the language test and come into the hall and find the researcher so that he could explain the next pa the test. When each subject came into the hall, he or she found the researcher eng in conversation. The researcher wanted to see whether the subject would interrup conversation. The researcher found that 63% of those primed with words relate rudeness interrupted the conversation, whereas only 17% of those primed with w related to politeness interrupted.

If we assume that the researcher randomly assigned the subjects to the groups, then this study is an experiment that compares two treatments (primed words related to rudeness and primed with words related to politeness). The sponse variable, *politeness*, has the values *interrupted conversation* and *did not in rupt conversation*. The experiment uses replication (many subjects in each treatn group) and random assignment to control for extraneous variables that might a the response.

Many experiments compare a group that receives a particular treatment to a **c trol group** that receives no treatment.

EXAMPLE 2.6 Chilling Newborns? Then You Need a Control Group...

Researchers for the National Institute of Child Health and Human Developn studied 208 infants whose brains were temporarily deprived of oxygen as a re of complications at birth (*The New England Journal of Medicine,* Octobe 2005). These babies were subjects in an experiment to determine if reducing b temperature for three days after birth improved their chances of surviving with brain damage. The experiment was summarized in a paper that stated "inf were randomly assigned to usual care (control group) or whole-body cooli Including a control group in the experiment provided a basis for compariso death and disability rates for the proposed cooling treatment and those for u care. Some extraneous variables that might also affect death and disability ra such as the duration of oxygen deprivation, could not be directly controlled, s ensure that the experiment did not unintentionally favor one experimental co tion over the other, random assignment of the infants to the two groups was c cal. Because this was a well-designed experiment, the researchers were able to the resulting data and statistical methods that you will see in Chapter 11 to c clude that cooling did reduce the risk of death and disability for infants depr of oxygen at birth.

Visualizing the Underlying Structure of Some Common Experimental Designs

Simple diagrams are sometimes used to highlight important features of some common experimental designs. The structure of an experiment that is based on random assignment of experimental units (the units to which treatments are assigned, usually subjects or trials) to one of two treatments is displayed in Figure 2.4. The diagram can be easily adapted for an experiment with more than two treatments. In any particular setting, we would also want to customize the diagram by indicating what the treatments are and what response will be measured. This is illustrated in Example 2.7.

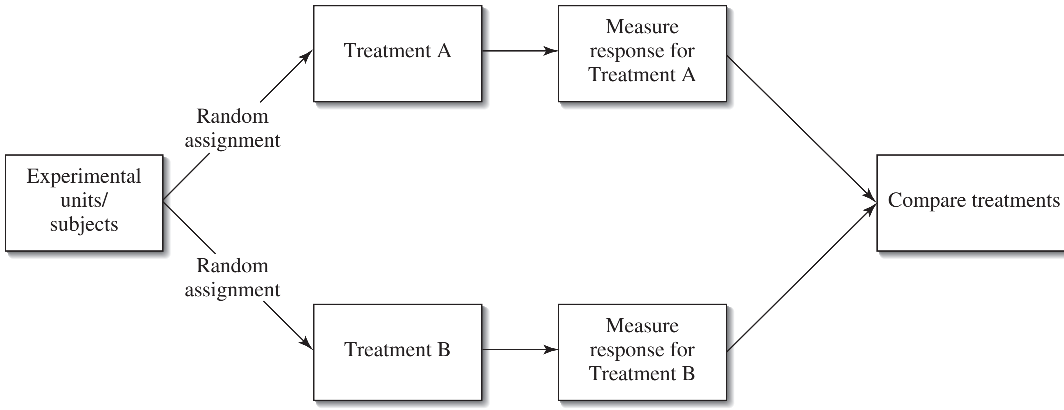


FIGURE 2.4
Diagram of an experiment with random assignment of experimental units to two treatments.

EXAMPLE 2.7 A Helping Hand

Can moving their hands help children learn math? This is the question investigated by the authors of the paper "Gesturing Gives Children New Ideas about Math" (*Psychological Science* [2009]: 267–272). An experiment was conducted to compare two different methods for teaching children how to solve math problems of the form 3 + 2 + 8 = ____ + 8. One method involved having students point to the 3 + 2 on the left side of the equal sign with one hand and then point to the blank on the right side of the equal sign before filling in the blank to complete the equation. The other method did not involve using these hand gestures. The paper states that the study used children ages 9 and 10 who were given a pretest containing six problems of the type described above. Only children who answered all six questions incorrectly became subjects in the experiment. There were a total of 128 subjects.

To compare the two methods, the 128 children were assigned at random to the two experimental conditions. Children assigned to one experimental condition were taught a method that used hand gestures and children assigned to the other experimental condition were taught a similar strategy that did not involve using hand gestures. Each child then took a test with six problems and the number correct was determined for each child. The researchers used the resulting data to reach the conclusion that the average number correct for children who used the method that incorporated hand gestures was significantly higher than the average number correct for children who were taught the method that did not use hand gestures.

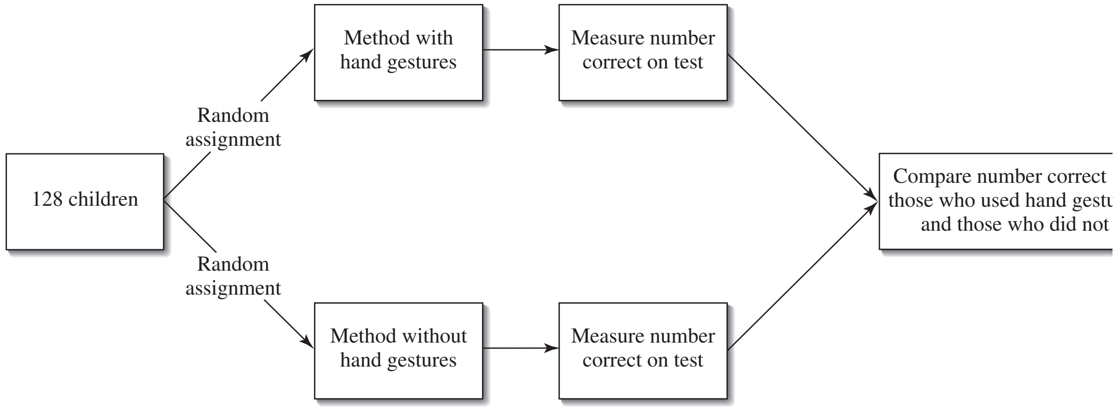


FIGURE 2.5
Diagram for the experiment of Example 2.7.

The basic structure of this experiment can be diagramed as shown in Figure This type of diagram provides a nice summary of the experiment, but notice several important characteristics of the experiment are not captured in the diag For example, the diagram does not show that some extraneous variables were cor ered by the researchers and directly controlled. In this example, both age and p math knowledge were directly controlled by using only children who were 9 10 years old and who were not able to solve any of the questions on the pretest rectly. *So, be aware that while a diagram of an experiment may be a useful tool, it usu cannot stand alone in describing an experimental design.*

Some experiments consist of a sequence of trials, and treatments are assigne random to the trials. The diagram in Figure 2.6 illustrates the underlying structu such an experiment. Example 2.8 shows how this diagram can be customized to scribe a particular experiment.

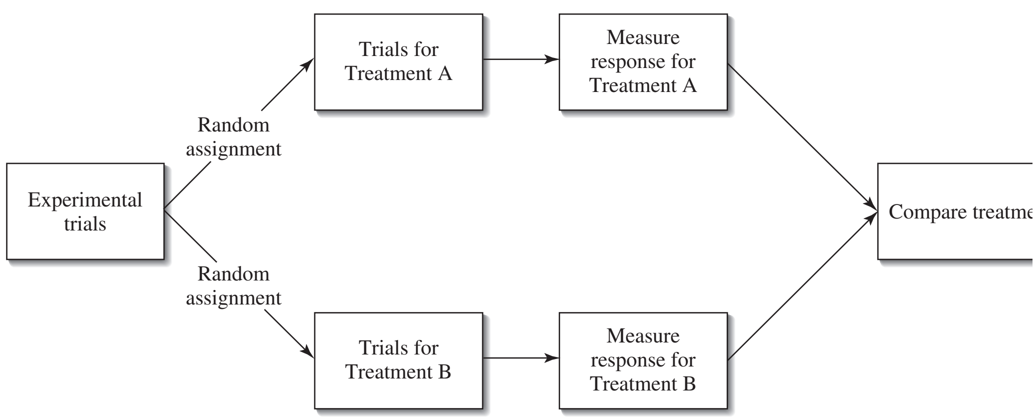


FIGURE 2.6
Diagram of an experiment with random assignment of treatments to trials.

EXAMPLE 2.8 Distracted? Watch Out for Those Cars!

The paper "Effect of Cell Phone Distraction on Pediatric Pedestrian Injury Risk" (*Pediatrics* [2009]: e179–e185) describes an experiment to investigate whether pedestrians who are talking on a cell phone are at greater risk of an accident when crossing the street than when not talking on a cell phone. No children were harmed in this experiment—a virtual interactive pedestrian environment was used! One possible way of conducting such an experiment would be to have a person cross 20 streets in this virtual environment. The person would talk on a cell phone for some crossings and would not use the cell phone for others. It would be important to randomly assign the two treatments (talking on the phone, not talking on the phone) to the 20 trials (the 20 simulated street crossings). This would result in a design that did not favor one treatment over the other because the pedestrian became more careful with experience or more tired and, therefore, easily distracted over time. The basic structure of this experiment is diagramed in Figure 2.7.

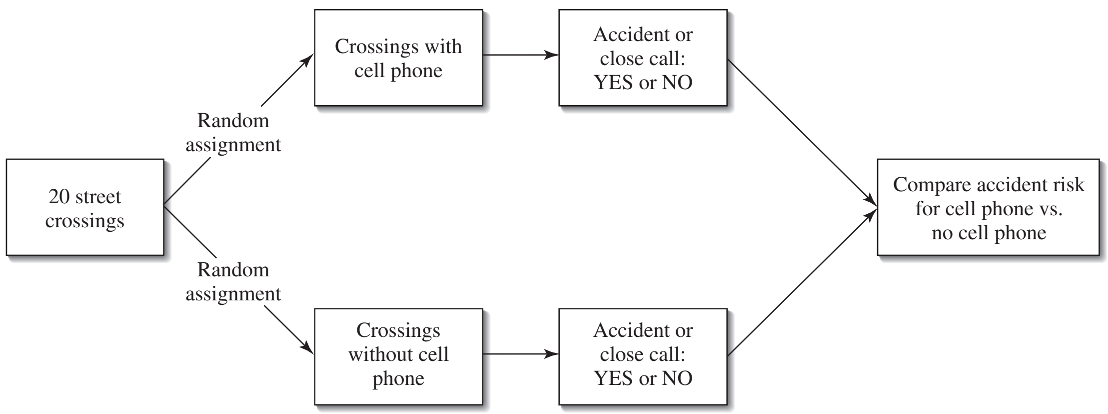


FIGURE 2.7
Diagram for the experiment of Example 2.8 with random assignment to trials.

The actual experiment conducted by the authors of the paper was a bit more sophisticated than the one just described. In this experiment, 77 children age 10 and 11 each performed simulated crossings with and without a cell phone. Random assignment was used to decide which children would cross first with the cell phone followed by no cell phone and which children could cross first with no cell phone. The structure of this experiment is diagramed in Figure 2.8.

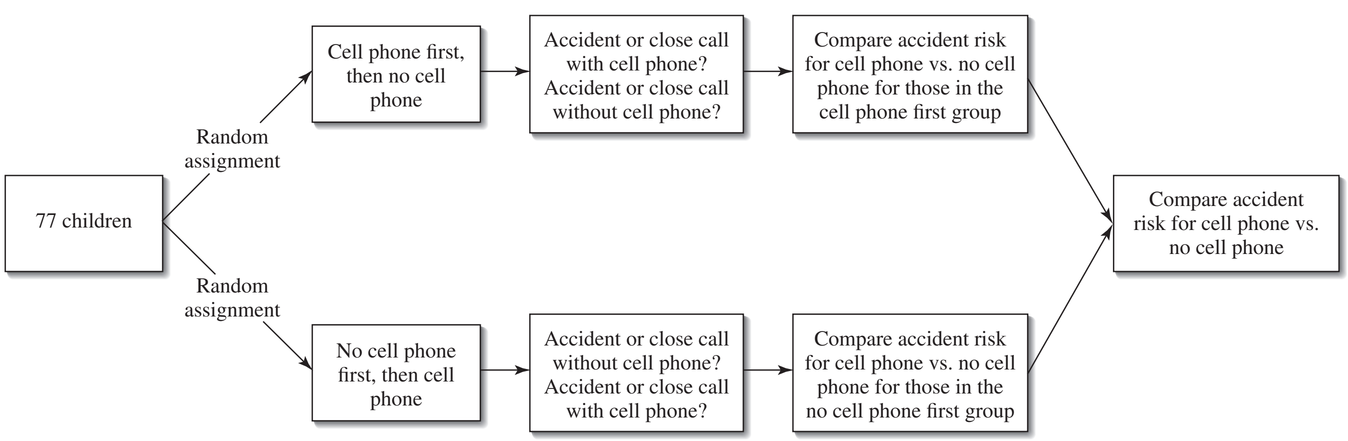


FIGURE 2.8
Diagram for the Experiment of Example 2.8 with 77 children.

As was the case in Example 2.7, note that while the diagram is informative itself, it does not capture all of the important aspects of the design. In particula does not capture the direct control of age (only children age 10 and 11 were use subjects in the experiment).

Experimental designs in which experimental units are assigned at randor treatments or in which treatments are assigned at random to trials (like those of experiments in Examples 2.7 and 2.8) are called **completely randomized desig**

Diagrams are also useful for highlighting the structure of experiments that blocking. This is illustrated in Example 2.9.

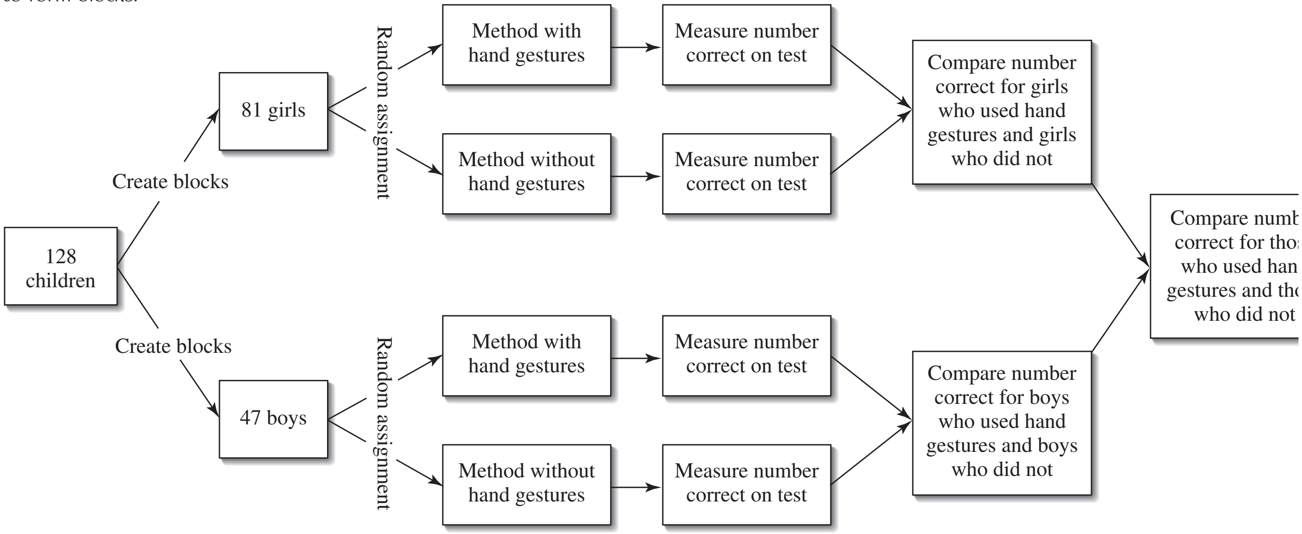
EXAMPLE 2.9 A Helping Hand Revisited

Let's return to the experiment described in Example 2.7. Take a minute to go back re-read that example. The experiment described in Example 2.7, a completely rand ized design with 128 subjects, was used to compare two different methods for teac kids how to solve a particular type of math problem. Age and prior math knowledge extraneous variables that the researchers thought might be related to performance or math test given at the end of the lesson, so the researchers chose to directly control t variables. The 128 children were assigned at random to the two experimental condit (treatments). The researchers relied on random assignment to create treatment gr that would be roughly equivalent with respect to other extraneous variables.

But suppose that we were worried that gender might also be related to pe mance on the math test. One possibility would be to use direct control of gend that is, we might use only boys or only girls as subjects in the experiment. Then i saw a difference in test performance for the two teaching methods, it could no due to one experimental group containing more boys and fewer girls than the o group. The downside to this strategy is that if we use only boys in the experim there is no basis for also generalizing any conclusions from the experiment to gi

Another strategy for dealing with extraneous variables is to incorporate blocking the design. In the case of gender, we could create two blocks, one consisting of girls one consisting of boys. Then, once the blocks are formed, we would randomly assig girls to the two treatments and randomly assign the boys to the two treatments. Ir actual study, the group of 128 children included 81 girls and 47 boys. A diagram that sh the structure of an experiment that includes blocking using gender is shown in Figure

FIGURE 2.9
Diagram for the experiment of Example 2.9 using gender to form blocks.



When blocking is used, the design is called a **randomized block design**. Note that one difference between the diagram that describes the experiment in which blocking is used (Figure 2.9) and the diagram of the original experiment (Figure 2.5) is at what point the random assignment occurs. *When blocking is incorporated in an experiment, the random assignment to treatments occurs after the blocks have been formed and is done separately for each block.*

Before proceeding with an experiment, you should be able to give a satisfactory answer to each of the following 10 questions.

1. What is the research question that data from the experiment will be used to answer?
2. What is the response variable?
3. How will the values of the response variable be determined?
4. What are the explanatory variables for the experiment?
5. For each explanatory variable, how many different values are there, and what are these values?
6. What are the treatments for the experiment?
7. What extraneous variables might influence the response?
8. How does the design incorporate random assignment of subjects to treatments (or treatments to subjects) or random assignment of treatments to trials?
9. For each extraneous variable listed in Question 7, how does the design protect against its potential influence on the response through blocking, direct control, or random assignment?
10. Will you be able to answer the research question using the data collected in this experiment?

EXERCISES 2.33 - 2.47

2.33 The head of the quality control department at a printing company would like to carry out an experiment to determine which of three different glues results in the greatest binding strength. Although they are not of interest in the current investigation, other factors thought to affect binding strength are the number of pages in the book and whether the book is being bound as a paperback or a hardback.

a. What is the response variable in this experiment?
b. What explanatory variable will determine the experimental conditions?
c. What two extraneous variables are mentioned in the problem description? Are there other extraneous variables that should be considered?

2.34 A study of college students showed a temporary gain of up to 9 IQ points after listening to a Mozart piano sonata. This conclusion, dubbed the Mozart effect, has since been criticized by a number of researchers who have been unable to confirm the result in similar studies. Suppose that you wanted to see whether there is a Mozart effect for students at your school.

a. Describe how you might design an experiment for this purpose.
b. Does your experimental design include direct control of any extraneous variables? Explain.
c. Does your experimental design use blocking? Explain why you did or did not include blocking in your design.
d. What role does random assignment play in your design?

Bold exercises answered in back ● Data set available online ✦ Video Solution available

2.35 The following is from an article titled "After the Workout, Got Chocolate Milk?" that appeared in the *Chicago Tribune* (January 18, 2005):

> Researchers at Indiana University at Bloomington have found that chocolate milk effectively helps athletes recover from an intense workout. They had nine cyclists bike, rest four hours, then bike again, three separate times. After each workout, the cyclists downed chocolate milk or energy drinks Gatorade or Endurox (two to three glasses per hour); then, in the second workout of each set, they cycled to exhaustion. When they drank chocolate milk, the amount of time they could cycle until they were exhausted was similar to when they drank Gatorade and longer than when they drank Endurox.

The article is not explicit about this, but in order for this to have been a well-designed experiment, it must have incorporated random assignment. Briefly explain where the researcher would have needed to use random assign in order for the conclusion of the experiment to be valid.

2.36 The report "Comparative Study of Two Computer Mouse Designs" (Cornell Human Factors Laboratory Technical Report RP7992) included the following description of the subjects used in an experiment:

> Twenty-four Cornell University students and staff (12 males and 12 females) volunteered to participate in the study. Three groups of 4 men and 4 women were selected by their stature to represent the 5th percentile (female 152.1 ± 0.3 cm, male 164.1 ± 0.4 cm), 50th percentile (female 162.4 ± 0.1 cm, male 174.1 ± 0.7 cm), and 95th percentile (female 171.9 ± 0.2 cm, male 185.7 ± 0.6 cm) ranges . . . All subjects reported using their right hand to operate a computer mouse.

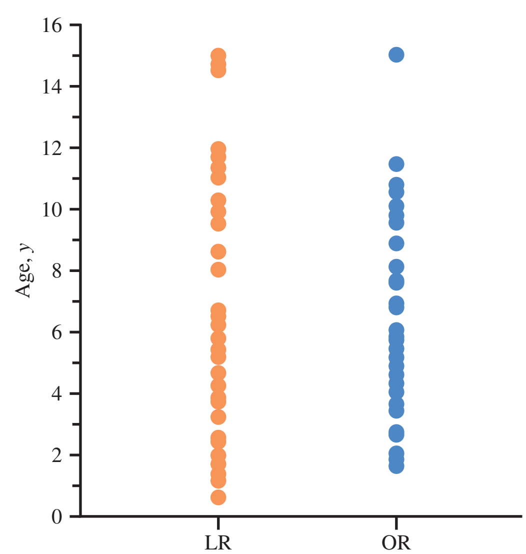
This experimental design incorporated direct control and blocking.

a. Are the potential effects of the extraneous variable stature (height) addressed by blocking or direct control?

b. Whether the right or left hand is used to operate the mouse was considered to be an extraneous variable. Are the potential effects of this variable addressed by blocking or direct control?

2.37 The Institute of Psychiatry at Kings College I don found that dealing with "infomania" has a ten rary, but significant derogatory effect on IQ (*Disc* November 2005). In this experiment, researchers vided volunteers into two groups. Each subject too IQ test. One group had to check e-mail and respon instant messages while taking the test, and the sec group took the test without any distraction. The tracted group had an average score that was 10 p lower than the average for the control group. Exp why it is important that the researchers created the experimental groups in this study by using ran assignment.

2.38 In an experiment to compare two different s cal procedures for hernia repair ("A Single-Blinded, R domized Comparison of Laparoscopic Versus O Hernia Repair in Children," *Pediatrics* [2009]: 3 336), 89 children were assigned at random to one o two surgical methods. The researchers relied on the dom assignment of subjects to treatments to create c parable groups with respect to extraneous variables they did not control. One such extraneous variable age. After random assignment to treatments, the searchers looked at the age distribution of the childre each of the two experimental groups (laparoscopic re (LR) and open repair (OR)). The accompanying figu from the paper.



Based on this figure, has the random assignment of jects to experimental groups been successful in crea groups that are similar with respect to the ages of children in the groups? Explain.

2.39 In many digital environments, users are allowed to choose how they are represented visually online. Does how people are represented online affect online behavior? This question was examined by the authors of the paper "The Proteus Effect: The Effect of Transformed Self-Representation on Behavior" (*Human Communication Research* [2007]: 271–290). Participants were randomly assigned either an attractive avatar (a graphical image that represents a person) to represent them or an unattractive avatar.

a. The researchers concluded that when interacting with a person of the opposite gender in an online virtual environment, those assigned an attractive avatar moved significantly closer to the other person than those who had been assigned an unattractive avatar. This difference was attributed to the attractiveness of the avatar. Explain why the researchers would not have been able to reach this conclusion if participants had been allowed to choose one of the two avatars (attractive, unattractive) to represent them online.

b. Construct a diagram to represent the underlying structure of this experiment.

2.40 To examine the effect of exercise on body composition, healthy women age 35 to 50 were classified as either active (9 hours or more of physical activity per week) or sedentary ("Effects of Habitual Physical Activity on the Resting Metabolic Rates and Body Composition of Women aged 35 to 50 Years," *Journal of the American Dietetic Association* [2001]: 1181–1191). Percent body fat was measured and the researchers found that percent body fat was significantly lower for women who were active than for sedentary women.

a. Is the study described an experiment? If so, what are the explanatory variable and the response variable? If not, explain why it is not an experiment.

b. From this study alone, is it reasonable to conclude that physical activity is the cause of the observed difference in body fat percentage? Justify your answer.

2.41 Does playing action video games provide more than just entertainment? The authors of the paper "Action-Video-Game Experience Alters the Spatial Resolution of Vision" (*Psychological Science* [2007]: 88–94) concluded that spatial resolution, an important aspect of vision, is improved by playing action video games. They based this conclusion on data from an experiment in which 32 volunteers who had not played action video games were "equally and randomly divided between the experimental and control groups." Subjects in each group played a video game for 30 hours over a period of 6 weeks. Those in the experimental group played Unreal Tournament 2004, an action video game. Those in the control group played the game Tetris, a game that does not require the user to process multiple objects at once. Explain why the random assignment to the two groups is an important aspect of this experiment.

2.42 Construct a diagram to represent the subliminal messages experiment of Example 2.5.

2.43 Construct a diagram to represent the gasoline additive experiment described on page 52.

2.44 An advertisement for a sweatshirt that appeared in *SkyMall Magazine* (a catalog distributed by some airlines) stated the following: "This is not your ordinary hoody! Why? Fact: Research shows that written words on containers of water can influence the water's structure for better or worse depending on the nature and intent of the word. Fact: The human body is 70% water. What if positive words were printed on the inside of your clothing?" For only $79, you could purchase a hooded sweatshirt that had over 200 positive words (such as hope, gratitude, courage and love) in 15 different languages printed on the inside of the sweatshirt so that you could benefit from being surrounded by these positive words. The reference to the "fact" that written words on containers of water can influence the water's structure appears to be based on the work of Dr. Masaru Emoto who typed words on paper, pasted the words on bottles of water, and observed how the water reacted to the words by seeing what kind of crystals were formed in the water. He describes several of his experiments in his self-published book, *The Message from Water*. If you were going to interview Dr. Emoto, what questions would you want to ask him about his experiment?

2.45 An experiment was carried out to assess the effect of Sweet Talk, a text messaging support system for patients with diabetes ("A Randomized Controlled Trial of Sweet Talk," *Diabetic Medicine* [2006]: 1332–1338). Participants in the experiment were 92 patients, age 8 to 18, with type I diabetes who had been on conventional insulin treatment for at least one year. Participants were assigned at random to one of three experimental groups:

Group 1: continued conventional insulin therapy
Group 2: continued conventional insulin therapy with Sweet Talk support
Group 3: followed a new intensive insulin therapy with Sweet Talk support

One response variable was a measure of glucose concentration in the blood. There was no significant difference in glucose concentration between groups 1 and 2, but group 3 showed a significant improvement in this measure compared to groups 1 and 2.

a. Explain why it is not reasonable to attribute the observed improvement in group 3 compared to group 1 to the use of Sweet Talk, even though subjects were randomly assigned to the three experimental groups.
b. How would you modify this experiment so that you could tell if improvement in glucose concentration was attributable to the intensive insulin therapy, the use of Sweet Talk, or a combination of the two?
c. Draw a diagram showing the structure of the modified experiment from Part (b).

2.46 The Pew Research Center conducted a study of gender bias. The report "Men or Women: Who is the Better Leader? A Paradox in Public Attitudes" (www.pewsocialtrends.org, August 28, 2008) describes how the study was conducted:

> In the experiment, two separate random samples of more than 1000 registered voters were asked to read a profile sent to them online of a hypothetical candidate for U.S. Congress in their district. One random sample of 1161 respondents read a profile of Ann Clark, described as a lawyer, a churchgoer, a member of the local Chamber of Commerce, an environmentalist and a member of the same party as the survey respondent. They were then asked what they liked and didn't like about her, whether they considered her qualified and whether they were inclined to vote for her. There was no indi tion that this was a survey about gender or genc bias. A second random sample of 1139 registere voters was asked to read a profile of Andrew Cla who—except for his gender—was identical in e way to Ann Clark. These respondents were ther asked the same questions.

a. What are the two treatments in this experiment
b. What are the response variables in this experime
c. Explain why "taking two separate random samp has the same benefits as random assignment to two treatments in this experiment.

2.47 Red wine contains flavonol, an antioxi thought to have beneficial health effects. But to hav effect, the antioxidant must be absorbed into the bl The article "Red Wine is a Poor Source of Bioavail Flavonols in Men" (*The Journal of Nutrition* [20 745–748) describes a study to investigate three sourc dietary flavonol—red wine, yellow onions, and b tea—to determine the effect of source on absorpt The article included the following statement:

> We recruited subjects via posters and local news pers. To ensure that subjects could tolerate the a cohol in the wine, we only allowed men with a consumption of at least seven drinks per week t participate ... Throughout the study, the subjec consumed a diet that was low in flavonols.

a. What are the three treatments in this experimer
b. What is the response variable?
c. What are three extraneous variables that the searchers chose to control in the experiment?

2.4 More on Experimental Design

The previous section covered basic principles for designing simple compara experiments—control, blocking, random assignment, and replication. The goal c experimental design is to provide a method of data collection that (1) minimize traneous sources of variability in the response so that any differences in respons various experimental conditions can be more easily assessed and (2) creates exp mental groups that are similar with respect to extraneous variables that canno controlled either directly or through blocking.

In this section, we look at some additional considerations that you may nee think about when planning an experiment.

Use of a Control Group

If the purpose of an experiment is to determine whether some treatment has an effect, it is important to include an experimental group that does not receive the treatment. Such a group is called a **control group**. The use of a control group allows the experimenter to assess how the response variable behaves when the treatment is not used. This provides a baseline against which the treatment groups can be compared to determine whether the treatment had an effect.

EXAMPLE 2.10 Comparing Gasoline Additives


Stockbyte/Getty Images

Suppose that an engineer wants to know whether a gasoline additive increases fuel efficiency (miles per gallon). Such an experiment might use a single car (to eliminate car-to-car variability) and a sequence of trials in which 1 gallon of gas is put in an empty tank, the car is driven around a racetrack at a constant speed, and the distance traveled on the gallon of gas is recorded.

To determine whether the additive increases gas mileage, it would be necessary to include a control group of trials in which distance traveled was measured when gasoline without the additive was used. The trials would be assigned *at random* to one of the two experimental conditions (additive or no additive).

Even though this experiment consists of a sequence of trials all with the same car, random assignment of trials to experimental conditions is still important because there will always be uncontrolled variability. For example, temperature or other environmental conditions might change over the sequence of trials, the physical condition of the car might change slightly from one trial to another, and so on. Random assignment of experimental conditions to trials will tend to even out the effects of these uncontrollable factors.

AP* EXAM TIP

The experimental design terminology introduced in this section (such as *control group*, *placebo*, and *blinding*) is very important in describing experimental designs. You should be able to both read and write with understanding using these terms.

Although we usually think of a control group as one that receives no treatment, in experiments designed to compare a new treatment to an existing standard treatment, the term control group is sometimes also used to describe the group that receives the current standard treatment.

Not all experiments require the use of a control group. For example, many experiments are designed to compare two or more conditions—an experiment to compare density for three different formulations of bar soap or an experiment to determine how oven temperature affects the cooking time of a particular type of cake. However, sometimes a control group is included even when the ultimate goal is to compare two or more different treatments. An experiment with two treatments and no control group might allow us to determine whether there is a difference between the two treatments and even to assess the magnitude of the difference if one exists, but it would not allow us to assess the individual effect of either treatment. For example, without a control group, we might be able to say that there is no difference in the increase in mileage for two different gasoline additives, but we would not be able to tell if this was because both additives increased gas mileage by a similar amount or because neither additive had any effect on gas mileage.

Use of a Placebo

In experiments that use human subjects, use of a control group may not be enough to determine whether a treatment really does have an effect. People sometimes respond merely to the power of suggestion! For example, suppose a study designed to determine whether a particular herbal supplement is effective in promoting weight loss uses ar perimental group that takes the herbal supplement and a control group that takes n ing. It is possible that those who take the herbal supplement and believe that they taking something that will help them to lose weight may be more motivated and unconsciously change their eating behavior or activity level, resulting in weight loss.

Although there is debate about the degree to which people respond, many stu have shown that people sometimes respond to treatments with no active ingredi and that they often report that such "treatments" relieve pain or reduce sympto So, if an experiment is to enable researchers to determine whether a treatment r has an effect, comparing a treatment group to a control group may not be eno To address the problem, many experiments use what is called a placebo.

DEFINITION

A **placebo** is something that is identical (in appearance, taste, feel, etc.) to th treatment received by the treatment group, except that it contains no activ ingredients.

For example, in the herbal supplement experiment, rather than using a con group that received *no* treatment, the researchers might want to include a placebo gr Individuals in the placebo group would take a pill that looked just like the herbal sup ment but did not contain the herb or any other active ingredient. As long as the sub did not know whether they were taking the herb or the placebo, the placebo group w provide a better basis for comparison and would allow the researchers to deterr whether the herbal supplement had any real effect over and above the "placebo effe

Single-Blind and Double-Blind Experiments

Because people often have their own personal beliefs about the effectiveness of var treatments, it is desirable to conduct experiments in such a way that subjects do know what treatment they are receiving. For example, in an experiment compa four different doses of a medication for relief of headache pain, someone who kn that he is receiving the medication at its highest dose may be subconsciously in enced to report a greater degree of headache pain reduction. By ensuring that sub are not aware of which treatment they receive, we can prevent the subjects' pers perceptions from influencing the response.

An experiment in which subjects do not know what treatment they have rece is described as *single-blind.* Of course, not all experiments can be made single-bl For example, in an experiment to compare the effect of two different types of exe on blood pressure, it is not possible for participants to be unaware of whether are in the swimming group or the jogging group! However, when it is poss "blinding" the subjects in an experiment is generally a good strategy.

In some experiments, someone other than the subject is responsible for mea ing the response. To ensure that the person measuring the response does no personal beliefs influence the way in which the response is recorded, the researc should make sure that the measurer does not know which treatment was given to particular individual. For example, in a medical experiment to determine wheth new vaccine reduces the risk of getting the flu, doctors must decide whether a part lar individual who is not feeling well actually has the flu or some other unrelated ness. If the doctor knew that a participant with flu-like symptoms had received new flu vaccine, she might be less likely to determine that the participant had th and more likely to interpret the symptoms as being the result of some other illn

There are two ways in which blinding might occur in an experiment. One involves blinding the subjects, and the other involves blinding the individuals who measure the response. If subjects do not know which treatment was received *and* those measuring the response do not know which treatment was given to which subject, the experiment is described as **double-blind.** If only one of the two types of blinding is present, the experiment is single-blind.

DEFINITION

A **double-blind** experiment is one in which neither the subjects nor the individuals who measure the response know which treatment was received.

A **single-blind** experiment is one in which the subjects do not know which treatment was received but the individuals measuring the response do know which treatment was received, or one in which the subjects do know which treatment was received but the individuals measuring the response do not know which treatment was received.

Experimental Units and Replication

An **experimental unit** is the smallest unit to which a treatment is applied. In the language of experimental design, treatments are assigned at random to experimental units, and replication means that each treatment is applied to more than one experimental unit.

Replication is necessary for random assignment to be an effective way to create similar experimental groups and to get a sense of the variability in the values of the response for individuals who receive the same treatment. As we will see in Chapters 9–15, this enables us to use statistical methods to decide whether differences in the responses in different treatment groups can be attributed to the treatment received or whether they can be explained by chance variation (the natural variability seen in the responses to a single treatment).

Be careful when designing an experiment to ensure that there is replication. For example, suppose that children in two third-grade classes are available to participate in an experiment to compare two different methods for teaching arithmetic. It might at first seem reasonable to select one class at random to use one method and then assign the other method to the remaining class. But what are the experimental units here? If treatments are randomly assigned to classes, classes are the experimental units. Because only one class is assigned to each treatment, this is an experiment with no replication, even though there are many children in each class. We would *not* be able to determine whether there was a difference between the two methods based on data from this experiment, because we would have only one observation per treatment.

One last note on replication: Do not confuse replication in an experimental design with replicating an experiment. Replicating an experiment means conducting a new experiment using the same experimental design as a previous experiment; it is a way of confirming conclusions based on a previous experiment, but it does not eliminate the need for replication in each of the individual experiments themselves.

Using Volunteers as Subjects in an Experiment

Although the use of volunteers in a study that involves collecting data through sampling is never a good idea, it is a common practice to use volunteers as subjects in an experiment. Even though the use of volunteers limits the researcher's ability to generalize to a larger population, random assignment of the volunteers to treatments should result in comparable groups, and so treatment effects can still be assessed.

EXERCISES 2.48 - 2.59

2.48 Explain why some studies include both a control group and a placebo treatment. What additional comparisons are possible if both a control group and a placebo group are included?

2.49 Explain why blinding is a reasonable strategy in many experiments.

2.50 Give an example of an experiment for each of the following:

a. Single-blind experiment with the subjects blinded
b. Single-blind experiment with the individuals measuring the response blinded
c. Double-blind experiment
d. An experiment for which it is not possible to blind the subjects

2.51 ✦ Swedish researchers concluded that viewing and discussing art soothes the soul and helps relieve medical conditions such as high blood pressure and constipation (AFP International News Agency, October 14, 2005). This conclusion was based on a study in which 20 elderly women gathered once a week to discuss different works of art. The study also included a control group of 20 elderly women who met once a week to discuss their hobbies and interests. At the end of 4 months, the art discussion group was found to have a more positive attitude, to have lower blood pressure, and to use fewer laxatives than the control group.

a. Why would it be important to determine if the researchers assigned the women participating in the study at random to one of the two groups?
b. Explain why you think that the researchers included a control group in this study.

2.52 In an experiment to compare two different surgical procedures for hernia repair ("A Single-Blinded, Randomized Comparison of Laparoscopic Versus Open Hernia Repair in Children," *Pediatrics* [2009]: 332–336), 89 children were assigned at random to one of the two surgical methods. The methods studied were laparoscopic repair and open repair. In laparoscopic repair, three small incisions are made and the surgeon works through these incisions with the aid of a small camera that is inserted through one of the incisions. In the open repair, a larger incision is used to open the abdomen. One of the response variables in this study was the amount of medication that was given after the surgery for the control of pain and nausea. The paper states "For postoperative pain, rescue fentanyl (1 μg/kg) and nausea, ondansetron (0.1 mg/kg) were given as juc necessary by the attending nurse blinded to the opera approach."

a. Why do you think it was important that the n who administered the medications did not k which type of surgery was performed?
b. Explain why it was not possible for this experin to be double-blind.

2.53 The article "Placebos Are Getting More Ef tive. Drug Makers Are Desperate to Know W (*Wired Magazine*, August 8, 2009) states that "acc ing to research, the color of a tablet can boost the e tiveness even of genuine meds—or help convince a tient that a placebo is a potent remedy." Describe you would design an experiment to investigate if ad color to Tylenol tablets would result in greater perce pain relief. Be sure to address how you would select jects, how you would measure pain relief, what co you would use, and whether or not you would inclu control group in your experiment.

2.54 A novel alternative medical treatment for h attacks seeds the damaged heart muscle with cells f the patient's thigh muscle ("Doctors Mend Dama Hearts with Cells from Muscles," *San Luis Obispo bune*, November 18, 2002). Doctor Dib from the zona Heart Institute evaluated the approach on 16 tients with severe heart failure. The article states "ordinarily, the heart pushes out more than hal blood with each beat. Dib's patients had such se heart failure that their hearts pumped just 23 perc After bypass surgery and cell injections, this impro to 36 percent, although it was impossible to say much, if any, of the new strength resulted from extra cells."

a. Explain why it is not reasonable to generalize to population of all heart attack victims based on data from these 16 patients.
b. Explain why it is not possible to say whether an the observed improvement was due to the cell in tions, based on the results of this study.
c. Describe a design for an experiment that woul low researchers to determine whether bypass sur plus cell injections was more effective than by surgery alone.

Bold exercises answered in back ● Data set available online ✦ Video Solution available

2.55 ✦ The article "Doctor Dogs Diagnose Cancer by Sniffing It Out" (*Knight Ridder Newspapers*, January 9, 2006) reports the results of an experiment described in the journal *Integrative Cancer Therapies*. In this experiment, dogs were trained to distinguish between people with breast and lung cancer and people without cancer by sniffing exhaled breath. Dogs were trained to lay down if they detected cancer in a breath sample. After training, dogs' ability to detect cancer was tested using breath samples from people whose breath had not been used in training the dogs. The paper states "The researchers blinded both the dog handlers and the experimental observers to the identity of the breath samples." Explain why this blinding is an important aspect of the design of this experiment.

2.56 An experiment to evaluate whether vitamins can help prevent recurrence of blocked arteries in patients who have had surgery to clear blocked arteries was described in the article "Vitamins Found to Help Prevent Blocked Arteries" (Associated Press, September 1, 2002). The study involved 205 patients who were given either a treatment consisting of a combination of folic acid, vitamin B12, and vitamin B6 or a placebo for 6 months.

a. Explain why a placebo group was used in this experiment.
b. Explain why it would be important for the researchers to have assigned the 205 subjects to the two groups (vitamin and placebo) at random.
c. Do you think it is appropriate to generalize the results of this experiment to the population of all patients who have undergone surgery to clear blocked arteries? Explain.

2.57 Pismo Beach, California, has an annual clam festival that includes a clam chowder contest. Judges rate clam chowders from local restaurants, and the judging is done in such a way that the judges are not aware of which chowder is from which restaurant. One year, much to the dismay of the seafood restaurants on the waterfront, Denny's chowder was declared the winner! (When asked what the ingredients were, the cook at Denny's said he wasn't sure—he just had to add the right amount of nondairy creamer to the soup stock that he got from Denny's distribution center!)

a. Do you think that Denny's chowder would have won the contest if the judging had not been "blind?" Explain.
b. Although this was not an experiment, your answer to Part (a) helps to explain why those measuring the response in an experiment are often blinded. Using your answer in Part (a), explain why experiments are often blinded in this way.

2.58 The *San Luis Obispo Tribune* (May 7, 2002) reported that "a new analysis has found that in the majority of trials conducted by drug companies in recent decades, sugar pills have done as well as—or better than—antidepressants." What effect is being described here? What does this imply about the design of experiments with a goal of evaluating the effectiveness of a new medication?

2.59 The article "A Debate in the Dentist's Chair" (*San Luis Obispo Tribune*, January 28, 2000) described an ongoing debate over whether newer resin fillings are a better alternative to the more traditional silver amalgam fillings. Because amalgam fillings contain mercury, there is concern that they could be mildly toxic and prove to be a health risk to those with some types of immune and kidney disorders. One experiment described in the article used sheep as subjects and reported that sheep treated with amalgam fillings had impaired kidney function.

a. In the experiment, a control group of sheep that received no fillings was used but there was no placebo group. Explain why it is not necessary to have a placebo group in this experiment.
b. The experiment compared only an amalgam filling treatment group to a control group. What would be the benefit of also including a resin filling treatment group in the experiment?
c. Why do you think the experimenters used sheep rather than human subjects?

Bold exercises answered in back ● Data set available online ✦ Video Solution available

2.5 More on Observational Studies: Designing Surveys (Optional)

Designing an observational study to compare two populations on the basis of some easily measured characteristic is relatively straightforward, with attention focusing on choosing a reasonable method of sample selection. However, many observational

studies attempt to measure personal opinion or attitudes using responses to a sur
In such studies, both the sampling method and the design of the survey itself are c
cal to obtaining reliable information.

At first glance it might seem that a survey is a simple method for acquiring ir
mation. However, it turns out that designing and administering a survey is no
easy task. Great care must be taken in order to obtain good information fro
survey.

Survey Basics

A **survey** is a voluntary encounter between strangers in which an interviewer s
information from a respondent by engaging in a special type of conversation. '
conversation might take place in person, over the telephone, or even in the form
written questionnaire, and it is quite different from usual social conversations. I
the interviewer and the respondent have certain roles and responsibilities. The ir
viewer gets to decide what is relevant to the conversation and may ask questior
possibly personal or even embarrassing questions. The respondent, in turn, may re
to participate in the conversation and may refuse to answer any particular quest
But having agreed to participate in the survey, the respondent is responsible for
swering the questions truthfully. Let's consider the situation of the respondent.

The Respondent's Tasks

Understanding of the survey process has been improved in the past two decade
contributions from the field of psychology, but there is still much uncertainty al
how people respond to survey questions. Survey researchers and psychologists ge
ally agree that the respondent is confronted with a sequence of tasks when ask
question: comprehension of the question, retrieval of information from memory,
reporting the response.

Task 1: Comprehension

Comprehension is the single most important task facin
respondent, and fortunately it is the characteristic of a survey question that is most e
controlled by the question writer. Understandable directions and questions are chara
ized by (1) a vocabulary appropriate to the population of interest, (2) simple sent
structure, and (3) little or no ambiguity. Vocabulary is often a problem. As a rule,
best to use the simplest possible word that can be used without sacrificing clear mear

Simple sentence structure also makes it easier for the respondent to understanc
question. A famous example of difficult syntax occurred in 1993 when the Rope
ganization created a survey related to the Holocaust. One question in this survey

> "Does it seem possible or does it seem impossible to you that the Nazi exterm
> tion of the Jews never happened?"

The question has a complicated structure and a double negative—"impossible
never happened"—that could lead respondents to give an answer opposite to v
they actually believed. The question was rewritten and given a year later in an ot
wise unchanged survey:

> "Does it seem possible to you that the Nazi extermination of the Jews never l
> pened, or do you feel certain that it happened?"

This question wording is much clearer, and in fact the respondents' answers v
quite different, as shown in the following table (the "unsure" and "no opinion"
centages have been omitted):

Original Roper Poll		Revised Roper Poll	
Impossible	65%	Certain it happened	91%
Possible	12%	Possible it never happened	1%

It is also important to filter out ambiguity in questions. Even the most innocent and seemingly clear questions can have a number of possible interpretations. For example, suppose that you are asked, "When did you move to Cedar Rapids?" This would seem to be an unambiguous question, but some possible answers might be (1) "In 1971," (2) "When I was 23," and (3) "In the summer." The respondent must decide which of these three answers, if any, is the appropriate response. It may be possible to lessen the ambiguity with more precise questions:

1. In what year did you move to Cedar Rapids?
2. How old were you when you moved to Cedar Rapids?
3. In what season of the year did you move to Cedar Rapids?

One way to find out whether or not a question is ambiguous is to field-test the question and to ask the respondents if they were unsure how to answer a question.

Ambiguity can also arise from the placement of questions as well as from their phrasing. Here is an example of ambiguity uncovered when the order of two questions differed in two versions of a survey on happiness. The questions were

1. Taken altogether, how would you say things are these days: Would you say that you are very happy, pretty happy, or not too happy?
2. Taking things altogether, how would you describe your marriage: Would you say that your marriage is very happy, pretty happy, or not too happy?

The proportions of responses to the general happiness question differed for the different question orders, as follows:

Response to General Happiness Question

	General Asked First	General Asked Second
Very happy	52.4%	38.1%
Pretty happy	44.2%	52.8%
Not too happy	3.4%	9.1%

If the goal in this survey was to estimate the proportion of the population that is generally happy, these numbers are quite troubling—they cannot both be right! What seems to have happened is that Question 1 was interpreted differently depending on whether it was asked first or second. When the general happiness question was asked after the marital happiness question, the respondents apparently interpreted it to be asking about their happiness in all aspects of their lives *except* their marriage. This was a reasonable interpretation, given that they had just been asked about their marital happiness, but it is a different interpretation than when the general happiness question was asked first. The troubling lesson here is that even carefully worded questions can have different interpretations in the context of the rest of the survey.

Task 2: Retrieval from Memory Retrieving relevant information from memor answer the question is not always an easy task, and it is not a problem limited to quest of fact. For example, consider this seemingly elementary "factual" question:

How many times in the past 5 years did you visit your dentist's office?

a. 0 times
b. 1–5 times
c. 6–10 times
d. 11–15 times
e. more than 15 times

It is unlikely that many people will remember with clarity every single visit to dentist in the past 5 years. But generally, people will respond to such a question answers consistent with the memories and facts they are able to reconstruct giver time they have to respond to the question. An individual may, for example, ha sense that he usually makes about two trips a year to the dentist's office, so he extrapolate the typical year and get 10 times in 5 years. Then there may be three ticularly memorable visits, say, for a root canal in the middle of winter. Thus, the recollection is now 13, and the respondent will choose Answer (d), 11–15 times. haps not exactly correct, but the best that can be reported under the circumstanc

What are the implications of this relatively fuzzy memory for those who const surveys about facts? First, the investigator should understand that most factual swers are going to be approximations of the truth. Second, events closer to the of a survey are easier to recall.

Attitude and opinion questions can also be affected in significant ways by th spondent's memory of recently asked questions. For example, one study contain survey question asking respondents their opinion about how much they followed tics. When that question was preceded by a factual question asking whether they k the name of the congressional representative from their district, the percentage reported they follow politics "now and then" or "hardly ever" jumped from 21% 39%! Respondents apparently concluded that, because they didn't know the answ the previous knowledge question, they must not follow politics as much as they m have thought otherwise. In a survey that asks for an opinion about the degree to w the respondent believes drilling for oil should be permitted in national parks, th sponse might be different if the question is preceded by questions about the high of gasoline than if the question is preceded by questions about the environment.

Task 3: Reporting the Response The task of formulating and reporting a resp can be influenced by the social aspects of the survey conversation. In general, if a respon agrees to take a survey, he or she will be motivated to answer truthfully. Therefore, i questions are not too difficult (taxing the respondent's knowledge or memory) and if t are not too many questions (taxing the respondent's patience), the answers to questions be reasonably accurate. However, it is also true that the respondents often wish to pre themselves in a favorable light. This desire leads to what is known as a social desirab bias. Sometimes this bias is a response to the particular wording in a question. In 1 the following questions were analyzed in two different forms of a survey (emphasis ad

1. Do you think the United States should *forbid* public speeches against democrac
2. Do you think the United States should *allow* public speeches against democra

It would seem logical that these questions are opposites and that the proportion would not allow public speeches against democracy should be equal to the propor who would forbid public speeches against democracy. But only 45% of those resp dents offering an opinion on Question 1 thought the United States should "forb whereas 75% of the respondents offering an opinion on Question 2 thought the United States should "not allow" public speeches against democracy. Most likely, respondents reacted negatively to the word *forbid,* as forbidding something sounds much harsher than not allowing it.

Some survey questions may be sensitive or threatening, such as questions about sex, drugs, or potentially illegal behavior. In this situation, a respondent not only will want to present a positive image but also will certainly think twice about admitting illegal behavior! In such cases, the respondent may shade the actual truth or may even lie about particular activities and behaviors. In addition, the tendency toward positive presentation is not limited to obviously sensitive questions. For example, consider the question about general happiness previously described. Several investigators have reported higher happiness scores in face-to-face interviews than in responses to a mailed questionnaire. Presumably, a happy face presents a more positive image of the respondent to the interviewer. On the other hand, if the interviewer was a clearly unhappy person, a respondent might shade answers to the less happy side of the scale, perhaps thinking that it is inappropriate to report happiness in such a situation.

It is clear that constructing surveys and writing survey questions can be a daunting task. Keep in mind the following three things:

1. Questions should be understandable by the individuals in the population being surveyed. Vocabulary should be at an appropriate level, and sentence structure should be simple.
2. Questions should, as much as possible, recognize that human memory is fickle. Questions that are specific will aid the respondent by providing better memory cues. The limitations of memory should be kept in mind when interpreting the respondent's answers.
3. As much as possible, questions should not create opportunities for the respondent to feel threatened or embarrassed. In such cases respondents may introduce a social desirability bias, the degree of which is unknown to the interviewer. This can compromise conclusions drawn from the survey data.

Constructing good surveys is a difficult task, and we have given only a brief introduction to this topic. For a more comprehensive treatment, we recommend the book by Sudman and Bradburn listed in the references in the back of the book.

EXERCISES 2.60 - 2.65

2.60 A tropical forest survey conducted by Conservation International included the following statements in the material that accompanied the survey:

"A massive change is burning its way through the earth's environment."

"The band of tropical forests that encircle the earth is being cut and burned to the ground at an alarming rate."

"Never in history has mankind inflicted such sweeping changes on our planet as the clearing of rain forest taking place right now!"

The survey that followed included the questions given in Parts (a)–(d) below. For each of these questions, identify a word or phrase that might affect the response and possibly bias the results of any analysis of the responses.

a. "Did you know that the world's tropical forests are being destroyed at the rate of 80 acres per minute?"
b. "Considering what you know about vanishing tropical forests, how would you rate the problem?"
c. "Do you think we have an obligation to prevent the man-made extinction of animal and plant species?"
d. "Based on what you know now, do you think there is a link between the destruction of tropical forests and changes in the earth's atmosphere?"

2.61 Fast-paced lifestyles, in which students balance the requirements of school, after-school activities, and jobs, are thought by some to lead to reduced sleep. Suppose that you are assigned the task of designing a survey that will provide answers to the accompanying questions. Write a set of survey questions that might be used. In some cases, you may need to write more than one question to adequately address a particular issue. For example, responses might be different for weekends and school nights. You may also have to define some terms to make the questions understandable to the target audience, which is adolescents.

Topics to be addressed:
How much sleep do the respondents get? Is this enough sleep?
Does sleepiness interfere with schoolwork?
If they could change the starting and ending times of the school day, what would they suggest?
(Sorry, they cannot reduce the total time spent in school during the day!)

2.62 Asthma is a chronic lung condition characterized by difficulty in breathing. Some studies have suggested that asthma may be related to childhood exposure to some animals, especially dogs and cats, during the first year of life ("Exposure to Dogs and Cats in the First Year of Life and Risk of Allergic Sensitization at 6 to 7 Years of Age," *Journal of the American Medical Association* [2002]: 963–972). Some environmental factors that trigger an asthmatic response are (1) cold air, (2) dust, (3) strong fumes, and (4) inhaled irritants.

a. Write a set of questions that could be used in a survey to be given to parents of young children suffering from asthma. The survey should include questions about the presence of pets in the first year of the child's life as well as questions about the presence of pets today. Also, the survey should include questions that address the four mentioned household environmental factors.
b. It is generally thought that low-income persons, who tend to be less well educated, have homes in environments where the four environmental factors are present. Mindful of the importance of comprehension, can you improve the questions in Part (a) by making your vocabulary simpler or by changing the wording of the questions?
c. One problem with the pet-related questions is reliance on memory. That is, parents may not actu remember when they got their pets. How might check the parents' memories about these pets?

2.63 In national surveys, parents consistently poi school safety as an important concern. One sourc violence in junior high schools is fighting ("Self-Repo Characterization of Seventh-Grade Student Figh *Journal of Adolescent Health* [1998]: 103–109). To struct a knowledge base about student fights, a sc administrator wants to give two surveys to students fights are broken up. One of the surveys is to be give the participants, and the other is to be given to stud who witnessed the fight. The type of information de includes (1) the cause of the fight, (2) whether or no fight was a continuation of a previous fight, (3) whe drugs or alcohol was a factor, (4) whether or not the f was gang related, and (5) the role of bystanders.

a. Write a set of questions that could be used in two surveys. Each question should include a se possible responses. For each question, indi whether it would be used on both surveys or jus one of the two.
b. How might the tendency toward positive presentation affect the responses of the fighter to survey questions you wrote for Part (a)?
c. How might the tendency toward positive presentation affect the responses of a bystande the survey questions you wrote for Part (a)?

2.64 Doctors have expressed concern about yo women drinking large amounts of soda and about t decreased consumption of milk ("Teenaged Girls, C bonated Beverage Consumption, and Bone F tures," *Archives of Pediatric and Adolescent Medi* [2000]: 610–613). In parts (a)–(d), construct two q tions that might be included in a survey of teenage g Each question should include possible responses f which the respondent can select. (Note: The questio written are vague. Your task is to clarify the question use in a survey, not just to change the syntax!)

a. How much "cola" beverage does the respond consume?
b. How much milk (and milk products) is consu by the respondent?
c. How physically active is the respondent?
d. What is the respondent's history of bone fractu

2.65 A survey described in the paper "The Adolescent Health Review: A Brief Multidimensional Screening Instrument" (*Journal of Adolescent Health* [2001]:131–139) attempted to address psychosocial factors thought to be of importance in preventive health care for adolescents. For each risk area in the following list, construct a question that would be comprehensible to students in grades 9–12 and that would provide information about the risk factor. Make your questions multiple-choice, and provide possible responses.

a. Lack of exercise
b. Poor nutrition
c. Emotional distress
d. Sexual activity
e. Cigarette smoking
f. Alcohol use

2.6 Interpreting and Communicating the Results of Statistical Analyses

Statistical studies are conducted to allow investigators to answer questions about characteristics of some population of interest or about the effect of some treatment. Such questions are answered on the basis of data, and how the data are obtained determines the quality of information available and the type of conclusions that can be drawn. As a consequence, when describing a study you have conducted (or when evaluating a published study), you must consider how the data were collected.

The description of the data collection process should make it clear whether the study is an observational study or an experiment. For observational studies, some of the issues that should be addressed are:

1. What is the population of interest? What is the sampled population? Are these two populations the same? If the sampled population is only a subset of the population of interest, **undercoverage** limits our ability to generalize to the population of interest. For example, if the population of interest is all students at a particular university, but the sample is selected from only those students who choose to list their phone number in the campus directory, undercoverage may be a problem. We would need to think carefully about whether it is reasonable to consider the sample as representative of the population of all students at the university. **Overcoverage** results when the sampled population is actually larger than the population of interest. This would be the case if we were interested in the population of all high schools that offer Advanced Placement (AP) Statistics but sampled from a list of all schools that offered an AP class in any subject. Both undercoverage and overcoverage can be problematic.
2. How were the individuals or objects in the sample actually selected? A description of the sampling method helps the reader to make judgments about whether the sample can reasonably be viewed as representative of the population of interest.
3. What are potential sources of bias, and is it likely that any of these will have a substantial effect on the observed results? When describing an observational study, you should acknowledge that you are aware of potential sources of bias and explain any steps that were taken to minimize their effect. For example, in a mail survey, nonresponse can be a problem, but the sampling plan may seek to minimize its effect by offering incentives for participation and by following up one or more times with those who do not respond to the first request. A common misperception is that increasing the sample size is a way to reduce bias in observational studies, but this is not the case. For example, if measurement bias is

present, as in the case of a scale that is not correctly calibrated and tends to w too high, taking 1000 measurements rather than 100 measurements cannot rect for the fact that the measured weights will be too large. Similarly, a la sample size cannot compensate for response bias introduced by a poorly wo question.

For experiments, some of the issues that should be addressed are:

1. What is the role of random assignment? All good experiments use random ass ment as a means of coping with the effects of potentially confounding varia that cannot easily be directly controlled. When describing an experimental sign, you should be clear about how random assignment (subjects to treatm treatments to subjects, or treatments to trials) was incorporated into the des
2. Were any extraneous variables directly controlled by holding them at fixed va throughout the experiment? If so, which ones and at which values?
3. Was blocking used? If so, how were the blocks created? If an experiment blocking to create groups of homogeneous experimental units, you should scribe the criteria used to create the blocks and their rationale. For example, might say something like "Subjects were divided into two blocks—those exercise regularly and those who do not exercise regularly—because it was lieved that exercise status might affect the responses to the diets."

Because each treatment appears at least once in each block, the block size r be at least as large as the number of treatments. Ideally, the block sizes should be e to the number of treatments, because this presumably would allow the experime to create small groups of extremely homogeneous experimental units. For exampl an experiment to compare two methods for teaching calculus to first-year co students, we may want to block on previous mathematics knowledge by using r SAT scores. If 100 students are available as subjects for this experiment, rather creating two large groups (above-average math SAT score and below-average r SAT score), we might want to create 50 blocks of two students each, the first con ing of the two students with the highest math SAT scores, the second containing two students with the next highest scores, and so on. We would then select one dent in each block at random and assign that student to teaching method 1. other student in the block would be assigned to teaching method 2.

A Word to the Wise: Cautions and Limitations

It is a big mistake to begin collecting data before thinking carefully about rese objectives and developing a plan. A poorly designed plan for data collection ma sult in data that do not enable the researcher to answer key questions of interest generalize conclusions based on the data to the desired populations of interest.

Clearly defining the objectives at the outset enables the investigator to deter whether an experiment or an observational study is the best way to proceed. W out for the following *inappropriate* actions:

1. Drawing a cause-and-effect conclusion from an observational study. Don' this, and don't believe it when others do it!
2. Generalizing results of an experiment that uses volunteers as subjects to a la population. This is not sensible without a convincing argument that the g of volunteers can reasonably be considered a representative sample from population.
3. Generalizing conclusions based on data from a sample to some populatio interest. This is sometimes a sensible thing to do, but on other occasions it is

reasonable. Generalizing from a sample to a population is justified only when there is reason to believe that the sample is likely to be representative of the population. This would be the case if the sample was a random sample from the population and there were no major potential sources of bias. If the sample was not selected at random or if potential sources of bias were present, these issues would have to be addressed before a judgment could be made regarding the appropriateness of generalizing the study results.

For example, the Associated Press (January 25, 2003) reported on the high cost of housing in California. The median home price was given for each of the 10 counties in California with the highest home prices. Although these 10 counties are a sample of the counties in California, they were not randomly selected and (because they are the 10 counties with the highest home prices) it would not be reasonable to generalize to all California counties based on data from this sample.

4. Generalizing conclusions based on an observational study that used voluntary response or convenience sampling to a larger population. This is almost never reasonable.

EXERCISES 2.66 - 2.69

2.66 The following paragraph appeared in *USA Today* (August 6, 2009):

> **Cement doesn't hold up to scrutiny**
>
> A common treatment that uses medical cement to fix cracks in the spinal bones of elderly people worked no better than a sham treatment, the first rigorous studies of a popular procedure reveal. Pain and disability were virtually the same up to six months later, whether patients had a real treatment or a fake one, shows the research in today's *New England Journal of Medicine.* Tens of thousands of Americans each year are treated with bone cement, especially older women with osteoporosis. The researchers said it is yet another example of a procedure coming into wide use before proven safe and effective. Medicare pays $1,500 to $2,100 for the outpatient procedure.

The paper referenced in this paragraph is "A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures" (*New England Journal of Medicine* [2009]: 557–568). Obtain a copy of this paper through your university library or your instructor. Read the following sections of the paper: the abstract on page 557; the study design section on page 558; the participants section on pages 558–559; the outcome assessment section on pages 559–560; and the discussion section that begins on page 564.

The summary of this study that appeared in *USA Today* consisted of just one paragraph. If the newspaper had allowed four paragraphs, other important aspects of the study could have been included. Write a four-paragraph summary that the paper could have used. Remember—you are writing for the *USA Today* audience, not for the readers of the *New England Journal of Medicine*!

2.67 The article "Effects of Too Much TV Can Be Undone" (*USA Today*, October 1, 2007) included the following paragraph:

> Researchers at Johns Hopkins Bloomberg School of Public Health report that it's not only how many hours children spend in front of the TV, but at what age they watch that matters. They analyzed data from a national survey in which parents of 2707 children were interviewed first when the children were 30–33 months old and again when they were $5\frac{1}{2}$, about their TV viewing and their behavior.

a. Is the study described an observational study or an experiment?

b. The article says that data from a sample of 2707 parents were used in the study. What other information about the sample would you want in order to evaluate the study?

Bold exercises answered in back ● Data set available online ✦ Video Solution available

c. The actual paper referred to by the *USA Today* article was "Children's Television Exposure and Behavioral and Social Outcomes at 5.5 years: Does Timing of Exposure Matter?" (*Pediatrics* [2007]: 762–769). The paper describes the sample as follows:

> The study sample included 2707 children whose mothers completed telephone interviews at both 30 to 33 months and 5.5 years and reported television exposure at both time points. Of those completing both interviewers, 41 children (1%) were excluded because of missing data on television exposure at one or both time points. Compared with those enrolled in the HS clinical trial, parents in the study sample were disproportionately older, white, more educate, and married.

The "HS clinical trial" referred to in the excerpt from the paper was a nationally representative sample used in the Healthy Steps for Young Children national evaluation. Based on the above description of the study sample, do you think that it is reasonable to regard the sample as representative of parents of all children at age 5.5 years? Explain.

d. The *USA Today* article also includes the following summary paragraph:

> The study did not examine what the children watched and can't show TV was the cause of later problems, but it does "tell parents that even if kids are watching TV early in life, and they stop, it could reduce the risk for behavioral and social problems later," Mistry says.

What potentially confounding variable is ident in this passage?

e. The passage in Part (d) says that the study car show that TV was the cause of later problems. Is quote from Kamila Mistry (one of the study auth in the passage consistent with the statement al cause? Explain.

2.68 The short article "Developing Science-Ba Food and Nutrition Information" (*Journal of the Am can Dietetic Association* [2001]: 1144–1145) includes s guidelines for evaluating a research paper. Obtain a cop this paper through your university library or your inst tor. Read this article and make a list of questions that be used to evaluate a research study.

2.69 An article titled "I Said, Not While You St Science Suggests Kids Can't Study and Groove at Same Time" appeared in the *Washington Post* (Sept ber 5, 2006). This provides an example of a repo summarizing the result of a scientific study in a way is designed to make it accessible to the newspaper's r ers. You can find the newspaper article online by searc on the title or by going to http://www.washingtonpost.c wp-dyn/content/article/2006/09/03/AR2006090300 .html. The study referenced in the newspaper article published in the *Proceedings of the National Acade of Science* and can be found at http://www.pnas. content/103/31/11778.full.

Read the newspaper article and then take a loo the published paper. Comment on whether you t that the author was successful in communicating findings of the study to the intended audience.

ACTIVITY 2.1 Facebook Friending

Background: The article "Professors Prefer Face Time to Facebook" appeared in the student newspaper at Cal Poly, San Luis Obispo (*Mustang Daily*, August 27, 2009). The article examines how professors and students felt about using Facebook as a means of faculty-student communication. The student who wrote this article got mixed opinions when she interviewed students to ask whether they wanted to become Facebook friends with their professors. Two student comments included in the article were

> "I think the younger the professor is, the more you can relate to them and the less awkward it would be if you were to become friends on Facebook. The older the professor, you just would have to won 'Why are they friending me?'"

and

> "I think becoming friends with professors on Fa book is really awkward. I don't want them bein able to see into my personal life, and frankly, I a not really interested in what my professors do in their free time."

Even if the students interviewed had expressed a con tent opinion, it would still be unreasonable to think represented general student opinion on this issue bec only four students were interviewed and it is not c from the article how these students were selected.

In this activity, you will work with a partner to develop a plan to assess student opinion about being Facebook friends with professors at your school.

1. Suppose you will select a sample of 50 students at your school to participate in a survey. Write one or more questions that you would ask each student in the sample.
2. Discuss with your partner whether you think it would be easy or difficult to obtain a simple random sample of 50 students at your school and to obtain the desired information from all the students selected for the sample. Write a summary of your discussion.
3. With your partner, decide how you might go about selecting a sample of 50 students from your school that reasonably could be considered representative of the population of interest even if it may not be a simple random sample. Write a brief description of your sampling plan, and point out the aspects of your plan that you think make it reasonable to argue that it will be representative.
4. Explain your plan to another pair of students. Ask them to critique your plan. Write a brief summary of the comments you received. Now reverse roles, and provide a critique of the plan devised by the other pair.
5. Based on the feedback you received in Step 4, would you modify your original sampling plan? If not, explain why this is not necessary. If so, describe how the plan would be modified.

ACTIVITY 2.2 An Experiment to Test for the Stroop Effect

Background: In 1935, John Stroop published the results of his research into how people respond when presented with conflicting signals. Stroop noted that most people are able to read words quickly and that they cannot easily ignore them and focus on other attributes of a printed word, such as text color. For example, consider the following list of words:

green blue red blue yellow red

It is easy to quickly read this list of words. It is also easy to read the words even if the words are printed in color, and even if the text color is different from the color of the word. For example, people can read the words in the list

green blue red blue yellow red

as quickly as they can read the list that isn't printed in color.

However, Stroop found that if people are asked to name the text colors of the words in the list (red, yellow, blue, green, red, green), it takes them longer. Psychologists believe that this is because the reader has to inhibit a natural response (reading the word) and produce a different response (naming the color of the text).

If Stroop is correct, people should be able to name colors more quickly if they do not have to inhibit the word response, as would be the case if they were shown the following:

1. Design an experiment to compare times to identify colors when they appear as text to times to identify colors when there is no need to inhibit a word response. Indicate how random assignment is incorporated into your design. What is your response variable? How will you measure it? How many subjects will you use in your experiment, and how will they be chosen?
2. When you are satisfied with your experimental design, carry out the experiment. You will need to construct your list of colored words and a corresponding list of colored bars to use in the experiment. You will also need to think about how you will implement the random assignment scheme.
3. Summarize the resulting data in a brief report that explains whether your findings are consistent with the Stroop effect.

ACTIVITY 2.3 McDonald's and the Next 100 Billion Burgers

Background: The article "Potential Effects of the Next 100 Billion Hamburgers Sold by McDonald's" (*American Journal of Preventative Medicine* [2005]: 379–381) estimated that 992.25 million pounds of saturated fat would be consumed as McDonald's sells its next 100 billion hamburgers. This estimate was based on the assumption that the average weight of a burger sold would be 2.4 oz. This is the average of the weight of a regular hamburger (1.6 oz.) and a Big Mac (3.2 oz.). The authors took this approach because

> McDonald's does not publish sales and profits of individual items. Thus, it is not possible to estimate how many of McDonald's first 100 billion beef burgers sold were 1.6 oz hamburgers, 3.2 oz. Big Macs (introduced in 1968), 4.0 oz. Quarter Pounders (introduced in 1973), or other sandwiches.

This activity can be completed as an individual or team. Your instructor will specify which approach (i vidual or team) you should use.

1. The authors of the article believe that the us 2.4 oz. as the average size of a burger sol McDonald's is "conservative," which would resu the estimate of 992.25 million pounds of satur fat being lower than the actual amount that w be consumed. Explain why the authors' belief m be justified.
2. Do you think it would be possible to collect that could lead to an estimate of the average bu size that would be better than 2.4 oz.? If so, exp how you would recommend collecting such dat not, explain why you think it is not possible.

ACTIVITY 2.4 Video Games and Pain Management

Background: Video games have been used for pain management by doctors and therapists who believe that the attention required to play a video game can distract the player and thereby decrease the sensation of pain. The paper "Video Games and Health" (*British Medical Journal* [2005]:122–123) states

> However, there has been no long term follow-up and no robust randomized controlled trials of such interventions. Whether patients eventually tire of such games is also unclear. Furthermore, it is not known whether any distracting effect depends simply on concentrating on an interactive task or whether the content of games is also an important factor as there have been no controlled trials comparing video games with other distracters. Further research should examine factors within games such as novelty, users' preferences, and relative levels of challenge and should compare video games with other potentially distracting activities.

1. Working with a partner, select one of the area potential research suggested in the passage from paper and formulate a specific question that coul addressed by performing an experiment.
2. Propose an experiment that would provide dat address the question from Step 1. Be specific a how subjects might be selected, what the experin tal conditions (treatments) would be, and wha sponse would be measured.
3. At the end of Section 2.3 there are 10 questions can be used to evaluate an experimental design. swer these 10 questions for the design propose Step 2.
4. After evaluating your proposed design, are t any changes you would like to make to your des Explain.

ACTIVITY 2.5 Be Careful with Random Assignment!

When individuals climb to high altitudes, a condition known as acute mountain sickness (AMS) may occur. AMS is brought about by a combination of reduced air pressure and lower oxygen concentration that occurs at high altitudes. Two standard treatments for AMS are a medication, acetazolamide (which stimulates breathing and reduces mild symptoms) and the use of portable hyperbaric chambers.

With increasing numbers of younger inexperienced mountaineers, it is important to re-evaluate these treatments for the 12 to 14 year age group. An experimental plan under consideration is to study the first 18 youngsters diagnosed with AMS at a high altitude park ranger station whose parents consent to participation in the experiment. Equal numbers of each treatment are desired and the researchers are considering the following strategy for random assignment of treatments: Assign the treatments using a coin flip until one treatment has been assigned nine times; then assign the other treatment to the remaining subjects.

The table below presents data on the first 18 young climbers whose parents consented to participation in the experiment.

Order	Gender	Age (yr)
1	male	12.90
2	female	13.34
3	male	12.39
4	male	13.95
5	male	13.63
6	male	13.62
7	female	12.55
8	female	13.54
9	male	12.34
10	female	13.74
11	female	13.78
12	male	14.05
13	female	14.22
14	female	13.91
15	male	14.39
16	female	13.54
17	female	13.85
18	male	14.11

1. Describe how you would implement a strategy equivalent to the one proposed by the researchers. Your plan should assign the treatments M (medicine) and H (hyperbaric chamber) to these climbers as they appear at the ranger station.
2. Implement your strategy in Step (1), assigning treatments to climbers 1–18.
3. Looking at which climbers were assigned to each of the two groups, do you feel that this method worked well? Why or why not?
4. Compute the proportion of females in the medicine group. How does this proportion compare to the proportion of females in the entire group of 18 subjects?
5. Construct two dotplots—one of the ages of those assigned to the medicine treatment and one of the ages of those assigned to the hyperbaric chamber treatment. Are the age distributions for the two groups similar?
6. Compute the average age of those assigned to the medicine group. How does it compare to the average age for the other treatment group?
7. Record the proportion of females in the medicine group, the average age of those assigned to the medicine group, and the average age of those assigned to the hyperbaric chamber group obtained by each student on your class.
8. Using the values from Step (6), construct a dotplot of each of the following: the proportion of females in the medicine group, the average age of those assigned to the medicine group, and the average age of those assigned to the hyperbaric chamber group.
9. Using the results of the previous steps, evaluate the success of this random assignment strategy. Write a short paragraph explaining to the researchers whether or not they should use the proposed strategy for random assignment and why.

Summary of Key Concepts and Formulas

TERM OR FORMULA	COMMENT
Observational study	A study that observes characteristics of an existing population.
Simple random sample	A sample selected in a way that gives every different sa ple of size *n* an equal chance of being selected.
Stratified sampling	Dividing a population into subgroups (strata) and the taking a separate random sample from each stratum.
Cluster sampling	Dividing a population into subgroups (clusters) and fo ing a sample by randomly selecting clusters and including all individuals or objects in the selected clus in the sample.
1 in *k* systematic sampling	A sample selected from an ordered arrangement of a p ulation by choosing a starting point at random from th first *k* individuals on the list and then selecting every *k* individual thereafter.
Confounding variable	A variable that is related both to group membership a to the response variable.
Measurement or response bias	The tendency for samples to differ from the populatio because the method of observation tends to produce va ues that differ from the true value.
Selection bias	The tendency for samples to differ from the populatio because of systematic exclusion of some part of the population.
Nonresponse bias	The tendency for samples to differ from the populatio because measurements are not obtained from all indivi als selected for inclusion in the sample.
Experiment	A procedure for investigating the effect of *experimenta conditions* (treatments) on a *response variable*.
Treatments	The experimental conditions imposed by the experimenter.
Extraneous variable	A variable that is not an explanatory variable in the stu but is thought to affect the response variable.
Direct control	Holding extraneous variables constant so that their eff are not confounded with those of the experimental conditions.
Blocking	Using extraneous variables to create groups that are si with respect to those variables and then assigning treat ments at random within each block, thereby filtering o the effect of the blocking variables.

TERM OR FORMULA	COMMENT
Random assignment	Assigning experimental units to treatments or treatments to trials at random.
Replication	A strategy for ensuring that there is an adequate number of observations on each experimental treatment.
Placebo treatment	A treatment that resembles the other treatments in an experiment in all apparent ways but that has no active ingredients.
Control group	A group that receives no treatment.
Single-blind experiment	An experiment in which the subjects do not know which treatment they received but the individuals measuring the response do know which treatment was received, or an experiment in which the subjects do know which treatment they received but the individuals measuring the response do not know which treatment was received.
Double-blind experiment	An experiment in which neither the subjects nor the individuals who measure the response know which treatment was received.

Chapter Review Exercises 2.70 - 2.85

2.70 A pollster for the Public Policy Institute of California explains how the Institute selects a sample of California adults ("It's About Quality, Not Quantity," *San Luis Obispo Tribune,* January 21, 2000):

> That is done by using computer-generated random residential telephone numbers with all California prefixes, and when there are no answers, calling back repeatedly to the original numbers selected to avoid a bias against hard-to-reach people. Once a call is completed, a second random selection is made by asking for the adult in the household who had the most recent birthday. It is as important to randomize who you speak to in the household as it is to randomize the household you select. If you didn't, you'd primarily get women and older people.

Comment on this approach to selecting a sample. How does the sampling procedure attempt to minimize certain types of bias? Are there sources of bias that may still be a concern?

2.71 Based on a survey of 4113 U.S. adults, researchers at Stanford University concluded that Internet use leads to increased social isolation. The survey was conducted by an Internet-based polling company that selected its samples from a pool of 35,000 potential respondents, all of whom had been given free Internet access and WebTV hardware in exchange for agreeing to regularly participate in surveys conducted by the polling company. Two criticisms of this study were expressed in an article that appeared in the *San Luis Obispo Tribune* (February 28, 2000). The first criticism was that increased social isolation was measured by asking respondents if they were talking less to family and friends on the phone. The second criticism was that the sample was selected only from a group that was induced to participate by the offer of free Internet service, yet the results were generalized to all U.S. adults. For each criticism, indicate what type of bias is being described and why it might make you question the conclusion drawn by the researchers.

Bold exercises answered in back ● Data set available online ✦ Video Solution available

2.72 The article "I'd Like to Buy a Vowel, Drivers Say" (*USA Today*, August 7, 2001) speculates that young people prefer automobile names that consist of just numbers and/or letters that do not form a word (such as Hyundai's XG300, Mazda's 626, and BMW's 325i). The article goes on to state that Hyundai had planned to identify the car that was eventually marketed as the XG300 with the name Concerto, until they determined that consumers hated it and that they thought XG300 sounded more "technical" and deserving of a higher price. Do the students at your school feel the same way? Describe how you would go about selecting a sample to answer this question.

2.73 A study in Florida is examining whether health literacy classes and using simple medical instructions that include pictures and avoid big words and technical terms can keep Medicaid patients healthier (*San Luis Obispo Tribune*, October 16, 2002). Twenty-seven community health centers are participating in the study. For 2 years, half of the centers will administer standard care. The other centers will have patients attend classes and will provide special health materials that are easy to understand. Explain why it is important for the researchers to assign the 27 centers to the two groups (standard care and classes with simple health literature) at random.

2.74 Is status related to a student's understanding of science? The article "From Here to Equity: The Influence of Status on Student Access to and Understanding of Science" (*Culture and Comparative Studies* [1999]: 577– 602) described a study on the effect of group discussions on learning biology concepts. An analysis of the relationship between status and "rate of talk" (the number of on-task speech acts per minute) during group work included gender as a blocking variable. Do you think that gender is a useful blocking variable? Explain.

2.75 The article "Tots' TV-Watching May Spur Attention Problems" (*San Luis Obispo Tribune*, April 5, 2004) describes a study that appeared in the journal *Pediatrics*. In this study, researchers looked at records of 2500 children who were participating in a long-term health study. They found that 10% of these children had attention disorders at age 7 and that hours of television watched at age 1 and age 3 was associated with an increased risk of having an attention disorder at age 7.

a. Is the study described an observational study or an experiment?

b. Give an example of a potentially confounding v able that would make it unwise to draw the con sion that hours of television watched at a young is the cause of the increased risk of atten disorder.

2.76 A study of more than 50,000 U.S. nurses fo that those who drank just one soda or fruit punch a tended to gain much more weight and had an 80% creased risk in developing diabetes compared to those drank less than one a month. (*The Washington Post*, gust 25, 2004). "The message is clear. . . . Anyone cares about their health or the health of their family w not consume these beverages," said Walter Willett o Harvard School of Public Health, who helped con the study. The sugar and beverage industries said tha study was fundamentally flawed. "These allegations inflammatory. Women who drink a lot of soda may ply have generally unhealthy lifestyles," said Ricl Adamson of the American Beverage Association.

a. Do you think that the study described was an ob vational study or an experiment?

b. Is it reasonable to conclude that drinking sod fruit punch causes the observed increased risk of betes? Why or why not?

2.77 "Crime Finds the Never Married" is the con sion drawn in an article from *USA Today* (June 2001). This conclusion is based on data from the Ju Department's National Crime Victimization Sur which estimated the number of violent crimes per 1 people, 12 years of age or older, to be 51 for the n married, 42 for the divorced or separated, 13 for mar individuals, and 8 for the widowed. Does being si cause an increased risk of violent crime? Describe a tential confounding variable that illustrates why unreasonable to conclude that a change in marital st causes a change in crime risk.

2.78 The article "Workers Grow More Dissatisf in the *San Luis Obispo Tribune* (August 22, 20 states that "a survey of 5000 people found that w most Americans continue to find their jobs interest and are even satisfied with their commutes, a bare ma ity like their jobs." This statement was based on the that only 51 percent of those responding to a mail su indicated that they were satisfied with their jobs. scribe any potential sources of bias that might limit researcher's ability to draw conclusions about wor Americans based on the data collected in this survey

2.79 According to the article "Effect of Preparation Methods on Total Fat Content, Moisture Content, and Sensory Characteristics of Breaded Chicken Nuggets and Beef Steak Fingers" (*Family and Consumer Sciences Research Journal* [1999]: 18–27), sensory tests were conducted using 40 college student volunteers at Texas Women's University. Give three reasons, apart from the relatively small sample size, why this sample may not be ideal as the basis for generalizing to the population of all college students.

2.80 Do ethnic group and gender influence the type of care that a heart patient receives? The following passage is from the article "Heart Care Reflects Race and Sex, Not Symptoms" (*USA Today*, February 25, 1999, reprinted with permission):

> Previous research suggested blacks and women were less likely than whites and men to get cardiac catheterization or coronary bypass surgery for chest pain or a heart attack. Scientists blamed differences in illness severity, insurance coverage, patient preference, and health care access. The researchers eliminated those differences by videotaping actors—two black men, two black women, two white men, and two white women—describing chest pain from identical scripts. They wore identical gowns, used identical gestures, and were taped from the same position. Researchers asked 720 primary care doctors at meetings of the American College of Physicians or the American Academy of Family Physicians to watch a tape and recommend care. The doctors thought the study focused on clinical decision making.

Evaluate this experimental design. Do you think this is a good design or a poor design, and why? If you were designing such a study, what, if anything, would you propose to do differently?

2.81 An article in the *San Luis Obispo Tribune* (September 7, 1999) described an experiment designed to investigate the effect of creatine supplements on the development of muscle fibers. The article states that the researchers "looked at 19 men, all about 25 years of age and similar in weight, lean body mass, and capacity to lift weights. Ten were given creatine—25 grams a day for the first week, followed by 5 grams a day for the rest of the study. The rest were given a fake preparation. No one was told what he was getting. All the men worked out under the guidance of the same trainer. The response variable measured was gain in fat-free mass (in percent)."

a. What extraneous variables are identified in the given statement, and what strategy did the researchers use to deal with them?
b. Do you think it was important that the men participating in the experiment were not told whether they were receiving creatine or the placebo? Explain.
c. This experiment was not conducted in a double-blind manner. Do you think it would have been a good idea to make this a double-blind experiment? Explain.

2.82 Researchers at the University of Houston decided to test the hypothesis that restaurant servers who squat to the level of their customers would receive a larger tip ("Effect of Server Posture on Restaurant Tipping," *Journal of Applied Social Psychology* [1993]: 678–685). In the experiment, the waiter would flip a coin to determine whether he would stand or squat next to the table. The waiter would record the amount of the bill and of the tip and whether he stood or squatted.
a. Describe the treatments and the response variable.
b. Discuss possible extraneous variables and how they could be controlled.
c. Discuss whether blocking would be necessary.
d. Identify possible confounding variables.
e. Discuss the role of random assignment in this experiment.

2.83 You have been asked to determine on what types of grasslands two species of birds, northern harriers and short-eared owls, build nests. The types of grasslands to be used include undisturbed native grasses, managed native grasses, undisturbed nonnative grasses, and managed nonnative grasses. You are allowed a plot of land 500 meters square to study. Explain how you would determine where to plant the four types of grasses. What role would random assignment play in this determination? Identify any confounding variables. Would this study be considered an observational study or an experiment? (Based on the article "Response of Northern Harriers and Short-Eared Owls to Grassland Management in Illinois," *Journal of Wildlife Management* [1999]: 517–523.)

2.84 A manufacturer of clay roofing tiles would like to investigate the effect of clay type on the proportion of tiles that crack in the kiln during firing. Two different types of clay are to be considered. One hundred tiles can be placed in the kiln at any one time. Firing temperature varies slightly at different locations in the kiln, and firing temperature may also affect cracking. Discuss the design of an experiment to collect information that could be used to decide between the two clay types. How does your proposed design deal with the extraneous variable *temperature*?

2.85 A mortgage lender routinely places advertisements in a local newspaper. The advertisements are of three different types: one focusing on low interest rates, one featuring low fees for first-time buyers, and one appealing to people who may want to refinance their homes. The lender would like to determine which advertisement format is most successful in attracting cust ers to call for more information. Describe an experin that would provide the information needed to make determination. Be sure to consider extraneous varia such as the day of the week that the advertisement pears in the paper, the section of the paper in which advertisement appears, or daily fluctuations in the in est rate. What role does random assignment play in y design?

Graphing Calculator Explorations

EXPLORATION 2.1 Calculators and the Study of Statistics

You must be able to use your calculator in order to be able to analyze data. In prev math classes you may have used your calculator for graphing functions, finding s tions to equations, and arithmetic calculations. In statistics you will use your calc tor differently and will also use new calculator keys and menu items. Graphing culator Explorations are intended to help you get maximum utility from y calculator. These explorations highlight some important features of your calcula In order to speak to the widest possible audience, the explorations will be gener nature, rather than showcasing a particular calculator.

Calculators vary in statistical capability and in the applications that can be do loaded from the web. The characteristics of a graphing calculator that are impor for the study of statistics are:

- Capability to perform elementary statistical calculations (computing means, s dard deviations, correlation coefficients, and regression equations)
- Capability to generate statistical graphs (boxplots, histograms, and scatterplo
- Row-and-column data entry format

EXPLORATION 2.2 Generating Random Integers

Procedures for generating random numbers have been around for a long time. earliest techniques for generating random numbers were throwing dice, dealing ca and selecting well-mixed numbered balls from a container. Today, computers calculators use algorithms to generate "random" numbers. These algorithms gene what are called "pseudo-random" numbers. For most purposes, the "random" n bers generated by today's computers and calculators are perfectly fine, and we refer to these numbers as random.

Generating random numbers is a built-in function of graphing calculators. learn the appropriate keystrokes for your calculator you will need to consult y calculator manual; look for "rand," or possibly "random" in the index. On s calculators the precision can be adjusted and in our discussions we will generally four digit accuracy. On most calculators, a single keystroke or a short sequenc keystrokes will produce a random number between 0 and 1. Locate that function then generate five random numbers using the procedures presented in your man Some calculators will repeat the process each time you press "enter" or "execute." pressing the enter/execute button four times after you get the first random num If a random number appears each time, smile—this will save many keystrokes!

numbers we obtained (yours will be different) are 0.5147, 0.4058, 0.7338, 0.0440, and 0.3394. Random number generators typically produce a random number, r, such that $0 \leq r < 1$. Your calculator may have additional random number functions, such as randInt() to generate integers. To see if you calculator has this built-in capability, look in the manual's index for something like "random integer." In the discussions that follow, we will *not* assume you have a random integer capability, but if you do, please use it!

If you do not have a built-in capability to generate random integers, the method in the box below will be helpful.

Converting Random Numbers to Integers, 1, 2, 3, . . . , *n*

To convert a calculator-generated decimal random number r, $0 \leq r < 1$, into a random integer in the range 1, 2, 3, . . . , n, multiply r by n, add 1, and ignore the digits to the right of the decimal.

This will involve a sequence of keystrokes something like the following, where we use "*rand*" to mean the keystrokes needed to generate r:

rand × *n* + 1.

Most scientific calculators have an "int" or "floor" function, which will truncate the decimal by "rounding down." If your calculator has this capability, you can accomplish the integer random number generation in one sequence of keystrokes:

int(*rand* × *n*) + 1.

Example: Generating Random Numbers Generate five random integers between 1 and 100 for purposes of sampling from a population with 100 individuals. The keystrokes to generate a random integer between 1 and 100 are:

int(*rand* × 100) + 1.

(Remember, *rand* stands for the sequence of keystrokes needed to get the random number between 0 and 1 and *int* stands for the keystrokes necessary to truncate a decimal to an integer.)

The numbers we obtained (though of course your numbers will differ) are

11 55 29 38 37

We would then include the individuals identified by these numbers in the sample. (Note that in this example we are sampling from a population. If we were sampling without replacement and the random number generated by the calculator resulted in two or more random integers that were the same, we would have ignored the duplicates and generated additional random integers as needed.)

Adding 1 in the formula above is not some sort of magic. Because the *rand* keystrokes return random numbers in the range $0 \leq r < 1$, it is possible for *rand* to deliver a 0. If you are not bothered by random integers starting at 0, you need not waste keystrokes by adding 1 each time. Also note that the arithmetic random number generators in calculators are shipped from the factory with a number called a "seed," needed to start the random number generation process. If two calculators in your class are "right out of the box" you may notice that the random numbers generated by these calculators are the same. This will not be a problem for very long; calculator users will typically press the *rand* sequence different numbers of times, and sequences will soon differ in actual classroom use.

EXPLORATION 2.3 Random Assignment to Treatments

The process of random assignment of subjects to treatments is critical in the pr design of an experiment. Random assignment can be accomplished using the gr ing calculator's capability to generate integers from 1, 2 . . . *n*. We will illustrate this can be done in some common experimental situations.

In the first experiment, we will assign subjects to treatments without trying t the same number of subjects in each treatment group. This experiment investi the effect of pizza on performance on a statistics exam. An instructor has decide use three types of pizza (the treatments): sausage pizza, mushroom pizza, and ch pizza. Twelve randomly selected students will take part in the experiment. The structor's strategy for assigning treatments is very simple: Generate 12 random i gers from the list {1, 2, 3}. *Before* any students are assigned, he arbitrarily ass mushroom pizza = 1, cheese pizza = 2, and sausage pizza = 3.

We now randomly generate integers between 1 and 3 using

$$\text{int}(rand \times 3) + 1.$$

Our results were (remember that yours will surely be different)

3, 1, 1, 1, 1, 3, 1, 2, 1, 3, 1, 3

These numbers are used to assign each student to a treatment (pizza type) in the periment, as shown. Entries in the table are student, treatment number, (treatment).

1	3 (Sausage)	2	1 (Mushroom)	3	1 (Mushroom)	4	1 (Mushro
5	1 (Mushroom)	6	3 (Sausage)	7	1 (Mushroom)	8	2 (Cheese)
9	1 (Mushroom)	10	3 (Sausage)	11	1 (Mushroom)	12	3 (Sausage)

We can quickly see some problems using this method of assignment: More 50% of the subjects were assigned to mushroom pizza, and there is no replicatio the cheese pizza treatment! What if we want to have equal-sized treatment gro We might try to achieve equal treatment group sizes by adding a rule to our pr dure: "Once any treatment group has four subjects assigned, do not assign any r subjects to that treatment." Unfortunately, this approach can cause problems (see discussion on random assignment in Section 2.3). Fortunately, we have ano strategy.

First, we number the subjects from 1–12. Then we generate 12 random num between 0 and 1, ignoring any repeats. The first four random numbers generated associated with treatment 1, the next four with treatment 2, and finally the last random numbers are associated with treatment 3. One possible result of this pro is shown below.

1	1	1	1	2	2	2	2	3	3	3	
.5441	.6379	.9295	.6742	.7980	.5522	.3377	.2187	.6217	.8811	.1243	.4

Finally, subject 1 is associated with the smallest of the 12 random numbers; sub 2 is associated with the second smallest random number, and so on. This would r in the following assignment of subjects to treatments.

1	1	1	1	2	2	2	2	3	3	3	
.5441	.6379	.9295	.6742	.7980	.5522	.3377	.2187	.6217	.8811	.1243	.4
5	8	12	9	10	6	3	2	7	11	1	

In this random assignment of subjects to treatments, subjects 5, 8, 12, and 9 get mushroom pizza; subjects 10, 6, 3, and 2 get cheese pizza; and the rest get sausage pizza.

Random Assignment to Treatments—with Blocking Random assignment in a situation in which the experimenter is using blocking to control an extraneous variable could also be implemented using random integers. Suppose the instructor in the previous example has some seats near the window and some seats that are not by the window. It is possible that students near the window might be distracted and that this might affect exam performance. Because of this, it would be reasonable to block by position in the room. Suppose that six students will participate in the experiment. We need to consider the blocking strategy as we assign treatments.

Our random assignment is restricted a bit compared to what we did earlier because now we need to have each treatment represented in each block. Suppose that the six students are seated for the exam in the arrangement shown in the table below.

Near Window	Not Near Window

We now want to assign treatments at random to the students within each block. A sequence of random integers between 1 and 3 can be used for this purpose. One possible sequence is:

3 3 2 1 1 3 1 2 1 1 3 2

The treatments are assigned as shown in the table below, starting with the "Near Window" block and then, once the assignment for the "Near Window" block is completed, moving to the "Not Near Window" block. Remember that mushroom pizza = 1, cheese pizza = 2, and sausage pizza = 3.

Random Integer	Decision
3	Assign student in row one of near window block to sausage pizza treatment
3	Ignore, as there is already a student assigned to sausage pizza in the nea window block
2	Assign student in row two of near window block to cheese pizza treatmen
—	Assign student in row three of near window block to mushroom pizza treatment (since that is the only treatment that has not already been assigned in this block)
1	Assign student in row one of not near window block to mushroom pizza treatment
1	Ignore, as there is already a student assigned to mushroom pizza in the near window block
3	Assign student in row two of not near window block to sausage pizza treatment
—	Assign student in row three of near window block to cheese pizza treat ment (since that is the only treatment that has not already been as- signed in this block)

The final assignment of treatments to subjects within each block is shown ir table below. Note that each treatment appears once in each block.

Near Window	Not Near Window
Sausage	Mushroom
Cheese	Sausage
Mushroom	Cheese

Now it's your turn to try it.

Acupuncture is a popular alternative treatment for chronic back pain. Does treatment work, or is it psychological? To try to find out, an experiment is plar at a local clinic. As the statistical expert of the day, you have been asked to assigr treatments (real or simulated acupuncture). Use the method discussed in this expl tion to assign 12 subjects to the two treatments.

EXPLORATION 2.4 Generating Random Real Numbers

In previous Explorations, we used the *rand* function to generate random num between 0 and 1 and then converted them to integers. In this Exploration, we use the *rand* function for generating random *real* numbers in some interval (a, b

The need for random real numbers sometimes arises in sampling situatior which it is not possible to make a list of the elements of the population. For exam suppose we want to study chemical residue from the use of pesticides on farm Iowa. A map of Iowa is overlaid with a grid of 1-mile by 1-mile squares. Pic squares at random in order to measure chemical residue would be a good start, within any randomly selected square the chemical residue measurement mus taken at some actual location in the square. To determine this location, imagi coordinate system with the origin in the southwest corner of a square of land. Since each square is 1 mile by 1 mile, generating a random point in a square of land is easy using the *rand* function: generate two random real numbers between 0 and 1, and use them as *x*- and *y*-coordinates for the square. Suppose the *rand* function generated 0.45059 and 0.98906. We would convert this to (0.45059, 0.98906), which would then determine the location where the measurement should be made.

Suppose now that we want to select random locations from a map of the wilds of Saskatchewan, Canada, in order to estimate the amount of a particular mineral in the soil. Here we can use the "natural" coordinates provided by the latitude and longitude of the map to determine location. Saskatchewan's latitudes range from 49 to 60N, and longitudes from 102 to 110W. For generating random points in Saskatchewan, we can use the *rand* function and a little algebra.

We approach this problem in stages. First, consider the problem of generating a random number between 0 and *b*. One solution is to generate a random number between 0 and 1, and multiply it by the positive real number, *b*. Algebraically we see that if *rand* represents the random number generated,

$$0 \leq rand < 1$$
$$b \times (0) \leq b \times (rand) < b \times (1)$$
$$0 \leq b \times (rand) < b$$

Our ability to generate random real numbers is not limited to intervals that begin at 0. To generate a random real number between any two real numbers, *a* and *b*, we can do a bit more algebra:

$$0 \leq rand < 1$$
$$(b - a) \times (0) \leq (b - a) \times (rand) < (b - a) \times (1)$$
$$0 \leq (b - a) \times (rand) < (b - a)$$
$$0 + a \leq (b - a) \times (rand) + a < (b - a) + a$$
$$a \leq (b - a) \times (rand) + a < b$$

Saskatchewan is located between the latitudes 49 and 60N and longitudes 102 and 110W. So,

$$102 \leq (110 - 102) \times (rand) + 102 < 110$$

generates a random longitude in Saskatchewan and

$$49 \leq (60 - 49) \times (rand) + 49 < 60$$

generates a random latitude in Saskatchewan.

For example, using *rand,* we might get: 0.6217 and 0.8811. Substituting these values into the formulas above results in this random location:

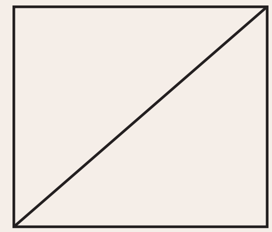
$$(110 - 102) \times (0.6217) + 102 = 106.97^{\circ} W$$
$$(60 - 49) \times (0.8811) + 49 = 58.69^{\circ} N$$

This random location is somewhere close to Fond du Lac, on Lake Athabasca, just down the road from Uranium City!

Now it's your turn to try it.

To provide some quick practice with generating random numbers using your calculator and also to learn about an interesting use of random numbers, we will find an area using what are known as "Monte Carlo" methods. We will learn something of the mathematics and statistics behind why this works in later chapters, but you can watch it unfold now.

Our story begins with a simple 1-inch by 1-inch square, and a diagonal line
ment as shown below. We will use random numbers to approximate the area in
the square and below the line. Of course, as we remember from geometry, the
will be 0.5 square inches. The really neat thing is that we can use this method w
the line turns into any mathematical function.



If we imagine a coordinate system with the origin at the lower left corner of
square, the line is: $y = x$. The Monte Carlo method of calculating an area hinge
this fact: If we generate random points inside the square, the proportion of the po
"below the line" will reflect the area under the line. (We made the area of the sq
equal one for easy calculation.) The more points we generate, the closer the pro
tion of points below the line will be to—in this case—0.5.

To see this unfold, generate 20 random numbers and fill in the table below
doesn't matter whether you go across or down as you fill the table.)

x										
y										

Now consider the ordered pairs (x, y) from the columns of the table. If x is less t
y, the point will be above the line. If x is greater than y, the point will be below
line. Approximately 5 of these points should be below the line! If you think y
results are just lucky random numbers, try another 10 points—how many of
20 points are below the line? If you are really suspicious, try another 20. If you
don't believe, keep adding points. Keep track of the proportion of points below
line after each additional 5 points—the proportion gets closer and closer to 0.5 as
number of points generated gets larger.

1. College students who reported being Internet users were surveyed, and data on the following attributes were recorded:

   I. number of times they accessed the Internet in the previous 24 hours
   II. length of the most recent Internet session
   III. purpose of the last Internet session (e-mail, shopping, downloading music, etc.)
   IV. approximate number of e-mails sent per day

   Which of these variables is/are numerical?

   (A) II only
   (B) III only
   (C) I and IV only
   (D) I, II, and IV only
   (E) I, III, and IV only

2. Which of the following numerical variable(s) are discrete?

   I. number of books in a student's backpack
   II. weight of a student's backpack
   III. number of students in a class who carry a backpack
   IV. thickness of the fabric used in making a student's backpack

   (A) I only
   (B) II only
   (C) I and III only
   (D) I and IV only
   (E) I, II, III, and IV are all discrete

3. The term used to describe the bias that occurs if some segment of a population is systematically excluded from a sample is

   (A) selection bias.
   (B) measurement bias.
   (C) response bias.
   (D) exclusion bias.
   (E) visibility bias.

4. Two variables are confounded if

   (A) their effects on the treatments cannot be ascertained.
   (B) their effects on the sampling design cannot be observed.
   (C) their effects on the response variable canno distinguished.
   (D) their effects on the experimental design car be justified.
   (E) their effects on the blocking factor canno measured.

5. In utilizing direct control, which of the following held constant?

   (A) values of an extraneous variable
   (B) values of a blocking variable
   (C) values of a response variable
   (D) values of an explanatory variable
   (E) values of a lurking variable

6. Fifty college students were asked what type of m they had seen most recently. The responses are s marized in the frequency distribution shown.

Type of Movie	Frequency
Comedy	23
Drama	9
Action	7
Western	4
Animated	4
Other	3
Total	50

   What is the relative frequency for the com category?

   (A) 23
   (B) 23/27
   (C) 0.23
   (D) 0.46
   (E) 46

7. In a study to determine if the color of the label m affect whether potential customers would buy a ticular brand of bottled tea, 100 volunteer sub were recruited. They were shown two different l designs and asked which design they would be r likely to purchase. One label was blue with a ph graph of a woman drinking the tea. The other l was green and did not include the photo. The volunteers were divided at random into two gro One group was shown the blue label first, followe the green label. The other group was shown the g

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label first followed by the blue label. Which of the following is confounded with the treatments?

(A) color of cover (blue or green)
(B) cover composition (photo or no photo)
(C) preferred label (which label the person was most likely to purchase)
(D) group membership (blue first or green first)
(E) There are no confounding variables.

8. In order to estimate the proportion of students at a college who spend more than 2 hours per day on Facebook, a random sample of students at the college is selected and each student is interviewed about his or her use of Facebook. The students conducting the survey are worried that people who spend a lot of time on Facebook might be embarrassed to admit it and that their responses to the survey might not be honest. What type of bias are the students conducting the survey worried about?

(A) selection bias
(B) nonresponse bias
(C) measurement or response bias
(D) bias due to confounding
(E) They shouldn't worry—there is no obvious source of bias.

9. To estimate the proportion of students who plan to purchase tickets to an upcoming school fundraiser, a high school decides to sample 100 students as they register for the spring semester. There are 2000 students at the school. Which of the following sampling plans would result in a stratified random sample?

(A) Number the students from 1 to 2000 and then use random numbers to select 100 students.
(B) Survey the first 100 students to register.
(C) Randomly select 100 students from a list of the 950 female students at the school.
(D) Divide the students into early registrants (the first 1000 to register) and late registrants (the last 1000 to register). Use random numbers to identify 50 of the early registrants and 50 of the late registrants to survey.
(E) Select one of the first 20 students to register using a random number table and then select every 20th student to register thereafter.

10. Which of the following describes a situation in which it is reasonable to reach a cause-and-effect conclusion based on data from a statistical study?

(A) The study is based on a random sample from a population of interest.
(B) The study is observational, and the sample used is not a convenience sample.
(C) The study is an experiment that uses random assignment to assign volunteers to experimental conditions (treatments).
(D) The study is observational, and the two samples used are not convenience samples.
(E) It is always reasonable to reach a cause-and-effect conclusion based on data from a statistical study.

11. A reporter for a local newspaper wants to survey county residents about their opinions on a proposal to raise property taxes to benefit the county library. He decides to ask 30 county residents whether they support this tax increase. He will select his sample by asking every third person entering the library starting at noon on a Friday. He will continue until he has asked a total of 30 county residents. Which type of bias is likely to be introduced by the way the sample will be selected?

(A) nonresponse bias
(B) response bias
(C) selection bias
(D) measurement bias
(E) No bias is introduced.

12. A random sample of 100 students at a particular college is to be selected, and each person selected will be asked how many times they went to a movie in a theater during the last year. The sample mean will then be used as an estimate of the mean number of times students at this college went to a movie in the last year. Which of the following is a reason to consider increasing the sample size for this study from 100 to 200?

(A) A larger sample size will reduce nonresponse bias.
(B) A larger sample size will reduce the response bias due to people not being able to accurately remember how many times they went to a movie in the last year.
(C) A larger sample size will reduce sampling variability—the differences in the sample mean that occur from sample to sample due to chance.
(D) It is less likely that one of the high values in the population (corresponding to a person who goes to a very large number of movies) will be included in a larger sample.
(E) All of the above are valid reasons to increase the sample size.

13. Researchers were interested in comparing students at private universities and students at public universities with respect to how much time they spent working in a typical week. They e-mailed a survey to 1000 students enrolled at a particular private university and to 2000 students enrolled at a particular public university. Data from the 400 private university students who responded to the survey and the 900 public university students who responded to the survey were used to determine that there was a significant difference in the mean number of hours worked in a typical week. Which of the following does *not* limit the researchers' ability to generalize to the two populations of interest?

(A) The two sample sizes are not equal.
(B) There may be bias introduced due to nonresponse.
(C) The samples were not randomly selected.
(D) All students in the private university sample attended the same university, and all students in the public university sample attended the same university.
(E) All of the above limit the researchers' ability to generalize to the populations of interest.

Use the following to answer questions 14–15.

One hundred volunteer subjects participated in a study to determine if room temperature affects people's ability to concentrate. Female volunteers were given 10 minutes to try to memorize the words on a list of 50 nonsense words. The room temperature was controlled at 65 degrees (a cold room) while they completed the task. Male volunteers were also given 10 minutes to try to memorize the same list of words, but for the males, room temperature was controlled at 85 degrees (a hot room). At the en the 10 minutes, each subject was asked to lis many of the words as he or she could remember, the number correct was recorded. The resulting were then used to determine if the mean numb words differed for the cold room and hot r conditions.

14. Which of the following is a confounding variab that is, which of the following is confounded the treatments?

(A) room temperature (cold or hot)
(B) gender (male or female)
(C) number of nonsense words recalled
(D) length of time given to memorize the words
(E) can't tell because volunteers were used

15. The poor design of this experiment results in a able that is confounded with the treatments. W of the following changes to the design would b fective in eliminating this confounding?

(A) Use only one room temperature.
(B) Use only male subjects in the study and as the males to one of the two room-tempera conditions at random.
(C) Assign the volunteers at random to one of two room-temperature conditions.
(D) Create two blocks by putting all of the fem in one block and all of the males in the o block. Then, within each block, assign sub at random to one of the room-tempera conditions.
(E) B, C, and D are all strategies that would effective.