Chapter 1 Data Collection

Section 1.1 Introduction to the Practice of Statistics

Objectives

1. Define statistics and statistical thinking
2. Explain the process of statistics
3. Distinguish between qualitative and quantitative variables
4. Distinguish between discrete and continuous variables
5. Determine the level of measurement of a variable

1 Define Statistics and Statistical Thinking

Statistics is the science of collecting, organizing, summarizing, and analyzing information to draw conclusions or answer questions. In addition, statistics is about providing a measure of confidence in any conclusions.

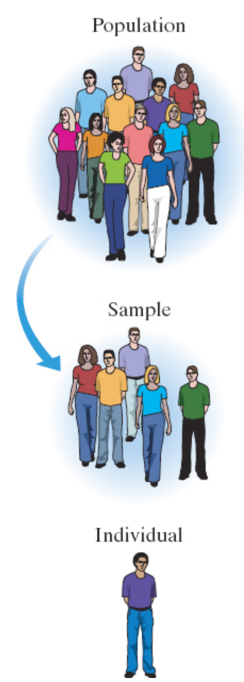
The information referred to in the definition is *data*. **Data** are a "fact or proposition used to draw a conclusion or make a decision." Data describe characteristics of an individual.

A key aspect of data is that they vary. Is everyone in your class the same height? No! Does everyone have the same hair color? No! So, among individuals there is variability.

In fact, data vary when measured on ourselves as well. Do you sleep the same number of hours every night? No! Do you consume the same number of calories every day? No!

One goal of statistics is to describe and understand sources of variability.

2 Explain the Process of Statistics



For most studies, it is unreasonable to be able to access of the individuals of interest in your study.

The entire group of individuals to be studied is called the **population**. An **individual** is a person or object that is a member of the population being studied. A **sample** is a subset of the population that is being studied.

Descriptive statistics consist of organizing and summarizing data. Descriptive statistics describe data through numerical summaries, tables, and graphs. A **statistic** is a numerical summary based on a sample.

Inferential statistics uses methods that take results from a sample, extends them to the population, and measures the reliability of the result.

A **parameter** is a numerical summary of a population.

EXAMPLE Parameter versus Statistic

Suppose the proportion of all students on your campus who have a job is 0.849. This value represents a parameter because it is a numerical summary of a population.

Suppose a sample of 250 students is obtained, and from this sample we find that the proportion who have a job is 0.864. This value represents a statistic because it is a numerical summary based on a sample.

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The Process of Statistics

1. *Identify the research objective.* A researcher must determine the question(s) he or she wants answered. The question(s) must clearly identify the population that is to be studied.
2. *Collect the data needed to answer the question(s) posed in (1).* Conducting research on an entire population is often difficult and expensive, so we typically look at a sample. This step is vital to the statistical process, because if the data are not collected correctly, the conclusions drawn are meaningless. Do not overlook the importance of appropriate data collection. We discuss this step in detail in Sections 1.2 through 1.6.
3. *Describe the data.* Descriptive statistics allow the researcher to obtain an overview of the data and can help determine the type of statistical methods the researcher should use. We discuss this step in detail in Chapters 2 through 4.
4. *Perform inference.* Apply the appropriate techniques to extend the results obtained from the sample to the population and report a level of reliability of the results. We discuss techniques for measuring reliability in Chapters 5 through 8 and inferential techniques in Chapters 9 through 15.

EXAMPLE Illustrating the Process of Statistics

Many studies evaluate batterer treatment programs, but there are few experiments designed to compare batterer treatment programs to non-therapeutic treatments, such as community service. Researchers designed an experiment in which 376 male criminal court defendants who were accused of assaulting their intimate female partners were randomly assigned into either a treatment group or a control group. The subjects in the treatment group entered a 40-hour batterer treatment program while the subjects in the control group received 40 hours of community service. After 6 months, the 376 male defendants were interviewed to determine if they had any further battering incidents, or not. It was reported that 21% of the males in the control group had further battering incidents, while 10% of the males in the treatment group had further battering incidents. The researchers concluded that the treatment was effective in reducing repeat battering offenses.

Source: *The Effects of a Group Batterer Treatment Program: A Randomized Experiment in Brooklyn by Bruce G. Taylor, et. al. Justice Quarterly, Vol. 18, No. 1, March 2001.*

SOLUTION

Step 1: Identify the research objective.

To determine whether males accused of battering their intimate female partners that were assigned into a 40-hour batter treatment program are less likely to batter again compared to those assigned to 40-hours of community service.

Step 2: Collect the information needed to answer the question.

The researchers randomly divided the subjects into two groups. Group 1 participants received the 40-hour batterer program, while group 2 participants received 40 hours of community service. Six months after the program ended, the percentage of males that battered their intimate female partner was determined.

Step 3: Describe the data - Organize and summarize the information.

The demographic characteristics of the subjects in the experimental and control group were similar. After the six month treatment, 21% of the males in the control group had any further battering incidents, while 10% of the males in the treatment group had any further battering incidents.

Step 4: Draw conclusions from the data.

We extend the results of the 376 males in the study to all males who batter their intimate female partner. That is, males who batter their female partner and participate in a batter treatment program are less likely to batter again.

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❸ Distinguish between Qualitative and Quantitative Variables

Variables are the characteristics of the individuals within the population.

Key Point: Variables vary. Consider the variable height. If all individuals had the same height, then obtaining the height of one individual would be sufficient in knowing the heights of all individuals. Of course, this is not the case. As researchers, we wish to identify the factors that influence variability.

Qualitative, or categorical, variables allow for classification of individuals based on some attribute or characteristic.

Quantitative variables provide numerical measures of individuals. The values of a quantitative variable can be added or subtracted and provide meaningful results.

Example Qualitative versus Quantitative Variables

Classify each of the following variables as qualitative or quantitative. Determine whether the quantitative variables are discrete or continuous. In addition, specify the level of measurement for each variable.

a. Education level

b. Today's high temperature

c. Daily intake of whole grains (measured in grams per day)

d. Number of vending machines at a school

e. Whether a student is prepared for class

f. Number of days per week a student eats lunch

g. Name of a university

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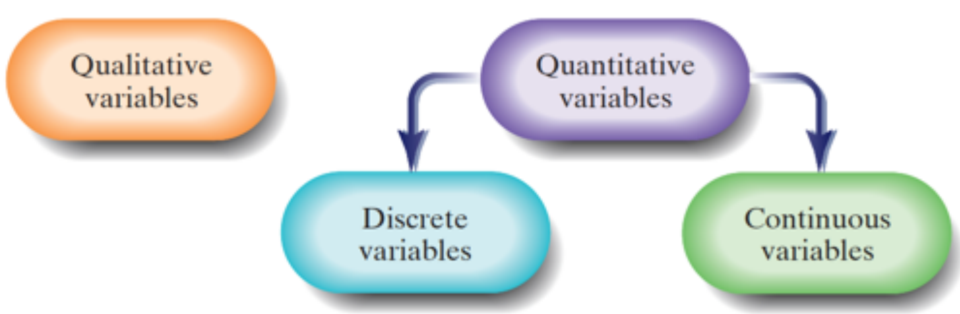
❹ Distinguish between Discrete and Continuous Variables

A **discrete variable** is a quantitative variable that has either a finite number of possible values or a countable number of possible values. The term *countable* means that the values result from counting, such as 0, 1, 2, 3, and so on. A discrete variable cannot take on every possible value between any two possible values.

A **continuous variable** is a quantitative variable that has an infinite number of possible values that are not countable. A continuous variable may take on every possible value between any two values.



EXAMPLE   Discrete Versus Continuous Variables

Classify each of the following variables as qualitative or quantitative. Determine whether the quantitative variables are discrete or continuous.

a. Gender

b. Income status (i.e. middle income, low income, etc.)

c. Income

d. Grade earned in Algebra

e. Response to the question "Working with numbers upsets me," where the responses are given as strongly agree, agree, disagree, or strongly disagree)

f. Number of children in a classroom

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The list of observations a variable assumes is called **data.**

While gender is a variable, the observations, male or female, are data.

Qualitative data are observations corresponding to a qualitative variable.

Quantitative data are observations corresponding to a quantitative variable.

- **Discrete data** are observations corresponding to a discrete variable.
- **Continuous data** are observations corresponding to a continuous variable.

For example, manufacturer of car is a qualitative variable. Qualitative data would be Ford, Chevrolet, BMW, and so on. Gas mileage is a quantitative (continuous) variable. Quantitative data would be 13 mpg, 21 mpg, and so on.

1.2 Observational Studies Versus Designed Experiments
Objectives

1. Distinguish between an observational study and an experiment

2. Explain the various types of observational studies

❶ Distinguish between an Observational Study and an Experiment

Consider the following two studies.

EXAMPLE Cellular Phones and Brain Tumors

Researchers Joachim Schüz and associates wanted "to investigate cancer risk among Danish cellular phone users who were followed for up to 21 years." To do so, they kept track of 420,095 people whose first cellular telephone subscription was between 1982 and 1995. In 2002, they recorded the number of people out of the 420,095 people who had a brain tumor and compared the rate of brain tumors in this group to the rate of brain tumors in the general population. They found no significant difference in the rate of brain tumors between the two groups. The researchers concluded "cellular telephone was not associated with increased risk for brain tumors." (Source: Joachim Schüz et al. "Cellular Telephone Use and Cancer Risk: Update of a Nationwide Danish Cohort," *Journal of the National Cancer Institute* 98(23): 1707-1713, 2006)

EXAMPLE Cellular Phones and Brain Tumors

Researchers Joseph L. Roti and associates examined "whether chronic exposure to radio frequency (RF) radiation at two common cell phone signals–835.62 megahertz, a frequency used by analogue cell phones, and 847.74 megahertz, a frequency used by digital cell phones–caused brain tumors in rats. The rats in group 1 were exposed to the analogue cell phone frequency; the rats in group 2 were exposed to the digital frequency; the rats in group 3 served as controls and received no radiation. The exposure was done for 4 hours a day, 5 days a week for 2 years. The rats in all three groups were treated the same, except for the RF exposure. After 505 days of exposure, the researchers reported the following after analyzing the data. "We found no statistically significant increases in any tumor type, including brain, liver, lung or kidney, compared to the control group." (Source: M. La Regina, E. Moros, W. Pickard, W. Straube, J. L. Roti Roti. "The Effect of Chronic Exposure to 835.62 MHz FMCW or 847.7 MHz CDMA on the incidence of Spontaneous Tumors in Rats." Bioelectromagnetic Society Conference, June 25, 2002.)

In both studies, the goal of the research was to determine if radio frequencies from cell phones increase the risk of contracting brain tumors. Whether or not brain cancer was contracted is the **response variable**. The level of cell phone usage is the **explanatory variable**.

In research, we wish to determine how varying the amount of an **explanatory variable** affects the value of a **response variable**.

An **observational study** measures the value of the response variable without attempting to influence the value of either the response or explanatory variables. That is, in an observational study, the researcher observes the behavior of the individuals without trying to influence the outcome of the study.

If a researcher randomly assigns the individuals in a study to groups, intentionally manipulates the value of an explanatory variable and controls other explanatory variables at fixed values, and then records the value of the response variable for each individual, the study is a **designed experiment**.

EXAMPLE Observational Study or Designed Experiment? Do Flu shots Benefit Seniors?

Researchers wanted to determine the long-term benefits of the influenza vaccine on seniors aged 65 years and older. The researchers looked at records of over 36,000 seniors for 10 years. The seniors were divided into two groups. Group 1 were seniors who chose to get a flu vaccination shot, and group 2 were seniors who chose not to get a flu vaccination shot. After observing the seniors for 10 years, it was determined that seniors who get flu shots are 27% less likely to be hospitalized for pneumonia or influenza and 48% less likely to die from pneumonia or influenza. (Source: Kristin L. Nichol, MD, MPH, MBA, James D. Nordin, MD, MPH, David B. Nelson, PhD, John P. Mullooly, PhD, Eelko Hak, PhD. "Effectiveness of Influenza Vaccine in the Community-Dwelling Elderly," New England Journal of Medicine 357:1373–1381, 2007)

Based on the results of this study, would you recommend that all seniors go out and get a flu shot?

The study may have flaws! Namely, **confounding**.

Confounding in a study occurs when the effects of two or more explanatory variables are not separated. Therefore, any relation that may exist between an explanatory variable and the response variable may be due to some other variable or variables not accounted for in the study.

A **lurking variable** is an explanatory variable that was not considered in a study, but that affects the value of the response variable in the study. In addition, lurking variables are typically related to explanatory variables considered in the study.

State some potential lurking variables in the influenza study.

Even after accounting for potential lurking variables, the authors of the study concluded that getting an influenza shot is **associated** with a lower risk of being hospitalized or dying from influenza.

Observational studies do not allow a researcher to claim causation, only association.

While lurking variables tend to exist in observational studies, *confounding variables* tend to exist in designed experiments.

A **confounding variable** is an explanatory variable that was considered in a study whose effect cannot be distinguished from a second explanatory variable in the study.

2 Explain the Various Types of Observational Studies

There are three major categories of observational studies.

Cross-sectional Studies Observational studies that collect information about individuals at a specific point in time, or over a very short period of time.

Case-control Studies These studies are **retrospective**, meaning that they require individuals to look back in time or require the researcher to look at existing records. In case-control studies, individuals who have certain characteristics are matched with those that do not.

Cohort Studies A cohort study first identifies a group of individuals to participate in the study (the cohort). The cohort is then observed over a long period of time. Over this time period, characteristics about the individuals are recorded. Because the data is collected over time, cohort studies are **prospective**.

EXAMPLE Observational Study or Designed Experiment?

Determine whether each of the following studies depict an observational study or an experiment. If the researchers conducted an observational study, determine the type of the observational study.

a. Researchers wanted to assess the long-term psychological effects on children evacuated during World War II. They obtained a sample of 169 former evacuees and a control group of 43 people who were children during the war but were not evacuated. The subjects' mental states were evaluated using questionnaires. It was determined that the psychological well being of the individuals was adversely affected by evacuation. (Source: Foster D, Davies S, and Steele H (2003) The evacuation of British children during World War II: a preliminary investigation into the long-term psychological effects. Aging & Mental Health (7)5.)

b. Xylitol has proven effective in preventing dental caries (cavities) when included in food or gum. A total of 75 Peruvian children were given milk with and without xylitol and were asked to evaluate the taste of each. Overall, the children preferred the milk flavored with xylitol. (Source: Castillo JL, et al (2005) Children's acceptance of milk with xylitol or sorbitol for dental caries prevention. BMC Oral Health (5)6.)

c. A total of 974 homeless women in the Los Angeles area were surveyed to determine their level of satisfaction with the healthcare provided by shelter clinics versus the healthcare provided by government clinics. The women reported greater quality satisfaction with the shelter and outreach clinics compared to the government clinics. (Source: Swanson KA, Andersen R, Gelberg L (2003) Patient satisfaction for homeless women. Journal of Women's Health (12)7.)

d. Hypertension (or high blood pressure) can lead to cardiovascular problems and even death. A group of 1006 adolescents with prehypertension (moderately high blood pressure) were tracked over several years to assess which health factors lead to hypertension. (Source: Redwine KM, et al (2011) Development of hypertension in adolescents with pre-hypertension. The Journal of Pediatric, in press.)

A **census** is a list of all individuals in a population along with certain characteristics of each individual.

Section 1.3 Simple Random Sampling

Objective

1. Obtain a Simple Random Sample

Random sampling is the process of using chance to select individuals from a population to be included in the sample.

If convenience is used to obtain a sample, the results of the survey are meaningless.

1 Obtain a Simple Random Sample

A sample of size n from a population of size N is obtained through **simple random sampling** if every possible sample of size n has an equally likely chance of occurring. The sample is then called a **simple random sample**.

Steps for Obtaining a Simple Random Sample

1) Obtain a frame that lists all the individuals in the population of interest. Number the individuals in the frame 1 to N.
2) Use a random number table, graphing calculator, or statistical software to randomly generate n numbers where n is the desired sample size.

EXAMPLE Obtaining a Simple Random Sample

The House of Representatives has 435 members. Explain how to conduct a simple random sample of 5 members to attend a Presidential luncheon. Then obtain the sample using StatCrunch.

1.4 Other Effective Sampling Methods

Objectives

1. Obtain a stratified sample

2. Obtain a systematic sample

3. Obtain a cluster sample

❶ Obtain a Stratified Sample

A **stratified sample** is obtained by separating the population into nonoverlapping groups called *strata* and then obtaining a simple random sample from each stratum. The individuals within each stratum should be homogeneous (or similar) in some way.

EXAMPLE Obtaining a Stratified Sample

The 115th United States Congress is comprised of members of the Senate and House of Representative. The 115th Congress begins January 3, 2017. In the 115th Congress, the United States Senate had 52 Republicans, 46 Democrats, and 2 Independents. The president wants to have a luncheon with 4 Republicans, 4 Democrats and 1 Independent. Obtain a stratified sample in order to select members who will attend the luncheon.

To obtain the stratified sample, conduct a simple random sample within each group. That is, obtain a simple random sample of 4 Republicans (from the 52), a simple random sample of 4 Democrats (from the 46), and a simple random sample of 1 Independent from the 2. Be sure to use a different seed for each stratum.

2 Obtain a Systematic Sample

A **systematic sample** is obtained by selecting every *k*th individual from the population. The first individual selected corresponds to a random number between 1 and *k*.

EXAMPLE Obtaining a Systematic Sample

A quality control engineer wants to obtain a systematic sample of 25 bottles coming off a filling machine to verify the machine is working properly. Design a sampling technique that can be used to obtain a sample of 25 bottles.

Steps in Systematic Sampling

1. If possible, approximate the population size, N.
2. Determine the sample size desired, n.
3. Compute $\frac{N}{n}$ and round down to the nearest integer. This value is k.
4. Randomly select a number between 1 and k. Call this number p.
5. The sample will consist of the following individuals:

$$p, p + k, p + 2k, \ldots, p + (n - 1)k$$

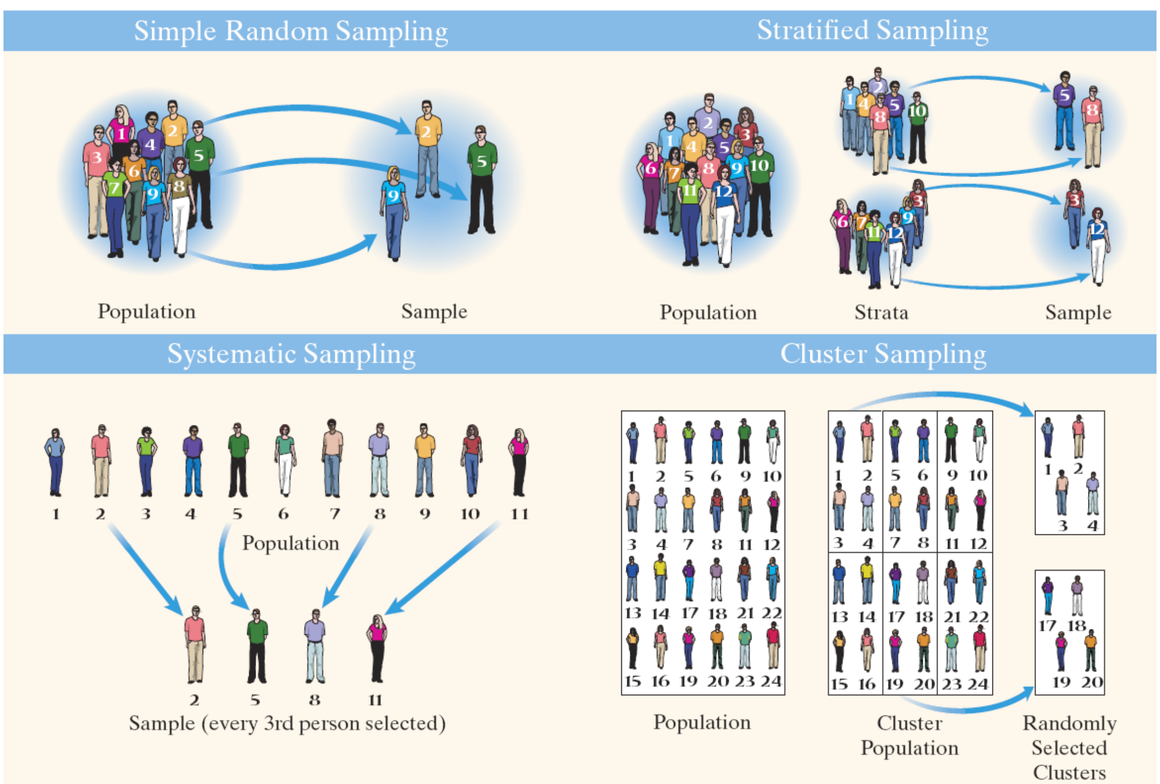
③ Obtain a Cluster Sample

A **cluster sample** is obtained by selecting all individuals within a randomly selected collection or group of individuals.

EXAMPLE Obtaining a Cluster Sample

A school administrator wants to obtain a sample of students in order to conduct a survey.

She randomly selects 10 classes and administers the survey to all the students in the class.



Note: Stratified and cluster samples are different. In a stratified sample, we divide the population into two or more homogeneous groups. Then we obtain a simple random sample from each group. In a cluster sample, we divide the population into groups, obtain a simple random sample of some of the groups, and survey **all** individuals in the selected groups.

A **convenience sample** is a sample in which the individuals are easily obtained and not based on randomness.

EXAMPLE Determine the Sampling Method

1. a. A study was conducted at a university in Cairo, Egypt to determine the relationship between road risk perception and pedestrian injuries. The sample was taken from the list of student IDs. Every 40th student was selected, after starting with a randomly chosen number. What sampling
scheme was used? (Source: JM Ibrahim JM (2011) Road risk-perception and pedestrian injuries among students at Ain Shams University, Cairo, Egypt. Journal of Injury and Volence Research (4)2.)

b. In a study of the health condition of residents of nursing homes, a simple random sample of all nursing homes in the city of Wenzhou was taken. All residents of the randomly selected nursing homes were interviewed. What sampling scheme was employed? (Source: Ireson J and Hallam S
(2011) Survey of elderly health condition in Wenzhou city nursing home. Chinese Journal of Gerontology (8).)

c. In a study of lung function, a simple random sample was taken from three groups of children: (i) children who live on a farm, (ii) children with intermediate farm exposure, and (iii) children with no farm exposure. Which sampling scheme was used? (Source: Ireson J and Hallam S (2005) Pupil's liking for school. British Journal of Educational Psychology (75).)

1.5 Bias in Sampling

Objective

1. Explain the Sources of Bias in Sampling

If the results of the sample are not representative of the population, then the sample has **bias**.

Three Sources of bias

1. Sampling bias
2. Nonresponse bias
3. Response bias

Sampling bias means that the technique used to obtain the individuals to be in the sample tends to favor one part of the population over another.

Undercoverage results in sampling bias. **Undercoverage** occurs when the proportion of one segment of the population is lower in a sample than it is in the population.

Nonresponse bias exists when individuals selected to be in the sample who do not respond to the survey have different opinions from those who do.

Nonresponse can be improved through the use of callbacks or rewards/incentives.

Response bias exists when the answers on a survey do not reflect the true feelings of the respondent.

Types of Response Bias

1. Interviewer error
2. Misrepresented answers
3. Wording of questions
4. Order of questions or words

Data-entry Error

Although not technically a result of response bias, data-entry error will lead to results that are not representative of the population. Once data are collected, the results may need to be entered into a computer, which could result in input errors. Or, a respondant may make a data entry error. For example, 39 may be entered as 93. It is imperative that data be checked for accuracy. In this text, we present some suggestions for checking for data error.

Nonsampling errors are errors that result from sampling bias, nonresponse bias, response bias, or data-entry error. Such errors could also be present in a complete census of the population.

Sampling error is an error that results from using a sample to estimate information about a population. This type of error occurs because a sample gives incomplete information about a population.

According to Martin Boon of ICM Limited, a polling firm in Britain, in 1995 it took 3000 to 4000 calls to obtain a sample size of 2000. Today, it takes over 30,000 calls. To reduce costs, more polling is done using robocalls and Internet-based polling. Robocalling to cellular telephones is illegal. How do these methods potentially lead to non-sampling error? What types of non-sampling error do you think this may lead to?

1.6 The Design of Experiments
Objectives

1. Describe the characteristics of an experiment
2. Explain the steps in designing an experiment
3. Explain the completely randomized design
4. Explain the matched-pairs design
5. Explain the randomized block design We Do Not Cover This Objective

❶ Describe the Characteristics of an Experiment

An **experiment** is a controlled study conducted to determine the effect varying one or more explanatory variables or **factors** has on a response variable. Any combination of the values of the factors is called a **treatment**.

The **experimental unit** (or **subject**) is a person, object or some other well-defined item upon which a treatment is applied.

A **control group** serves as a baseline treatment that can be used to compare to other treatments.

A second method for defining the control group is through the use of a *placebo*. A **placebo** is an innocuous medication, such as a sugar tablet, that looks, tastes, and smells like the experimental medication. A placebo might also be a procedure that follows the same steps as the experimental procedure, but leaves out a key intervention. For example, a procedure called vertebroplasty where medical cement is pumped into a spine fracture was tested through a designed experiment. All subjects went through a surgery to repair the spine, but only half received the medical cement.

An interesting outcome results from the vertebroplasty experiment. A subject in the placebo group found that the procedure resulted in complete abatement of the back pain even though she did not receive the medical cement! This type of phenomena in an experiment is referred to as the **placebo effect**. A book entitled *Cure* by Jo Marchant explores the placebo effect. In the book, she suggests that placebo treatments can have measurable effects. For example, in patients with Parkinson's disease placebos caused an increase of the neurotransmitter dopamine. In fact, in a study of 459 migraine sufferers, it was found that the placebo effect accounted for about 60% of the benefit of the drug Maxalt. Of course, the placebo effect will not account for improvements in someone with a tumor or replace insulin with someone with diabetes. However, the Maxalt study suggests that remedies for pain, nausea, or depression rely extensively on the placebo effect.

Blinding refers to nondisclosure of the treatment an experimental unit is receiving. There are two types of blinding: single blinding and double blinding.

In **single-blind** experiments, the experimental unit (or subject) does not know which treatment he or she is receiving. In **double-blind** experiments, neither the experimental unit nor the researcher in contact with the experimental unit knows which treatment the experimental unit is receiving.

EXAMPLE The Characteristics of an Experiment

Researchers conducted a double-blind, placebo-controlled, repeated-measures experiment to compare the effectiveness of a commercial caffeinated carbohydrate–electrolyte sports drink with a commercial noncaffeinated carbohydrate–electrolyte sports drink and a flavored-water placebo. Sixteen highly trained cyclists eachcompleted three trials of prolonged cycling in a warm environment: one while receiving the placebo, one while receiving the noncaffeinated sports drink, and one while receiving the caffeinated sports drink. For a given trial, one beverage treatment was administered throughout a 2-hour variable-intensity cycling bout followed by a 15-minute performance ride. Total work in kilojoules (kJ) performed during the final 15 minutes was used to measure performance. The beverage order for the individual subjects was randomly assigned. A period of at least 5 days separated the trials. All trials took place at approximately the same time of day in an environmental chamber at 28.5°C and 60% relative humidity with fan airflow of approximately 2.5 meters per second (m/s).

The researchers found that cycling performance, as assessed by the total work completed during the performance ride, was 23% greater for the caffeinated sports drink than for the placebo and 15% greater for the caffeinated sports drink than for the non-caffeinated sports drink. Cycling performances for the noncaffeinated sports drink and the placebo were not significantly different. The researchers concluded that the caffeinated carbohydrate–electrolyte sports drink substantially enhanced physical performance during prolonged exercise compared with the noncaffeinated carbohydrate–electrolyte sports drink and the placebo. *Source*: Kirk J. Cureton, Gordon L. Warren et al. "Caffeinated Sports Drink: Ergogenic Effects and Possible Mechanisms," *International Journal of Sport Nutrition and Exercise Metabolism*, 17(1):35–55, 2007

(a) What does it mean for the experiment to be placebo-controlled? The placebo is the flavored-water drink that looks and tastes like the sports drinks. The placebo serves as the baseline against which to compare the results when the non-caffeinated and caffeinated sports drinks are administered.

(b) What does it mean for the experiment to be double-blind? Why do you think it is necessary for the experiment to be double-blind? The cyclists and the researcher administering the treatments do not know when the cyclists have been given the caffeinated sports drink, the noncaffeinated sports drink, or the placebo.

(c) How is randomization used in this experiment? Randomization is used to determine the order of the treatments for each subject.

(d) What is the population for which this study applies? What is the sample? All athletes; 16 cyclists

(e) What are the treatments? Caffeinated sports drink, noncaffeinated sports drink, or flavored-water placebo

(f) What is the response variable? Total work

❷ Explain the Steps in Designing an Experiment

To **design** an experiment means to describe the overall plan in conducting the experiment.

Step 1 **Identify the Problem to Be Solved.** The statement of the problem should be as explicit as possible and should provide the experimenter with direction. The statement must also identify the response variable and the population to be studied. Often, the statement is referred to as the *claim*.

Step 2 **Determine the Factors That Affect the Response Variable.** The factors are usually identified by an expert in the field of study. In identifying the factors, ask, "What things affect the value of the response variable?" After the factors are identified, determine which factors to fix at some predetermined level, which to manipulate, and which to leave uncontrolled.

Step 3 **Determine the Number of Experimental Units.** As a general rule, choose as many experimental units as time and money allow. Techniques (such as those in Sections 9.1 and 9.2) exist for determining sample size, provided certain information is available.

Step 4 **Determine the Level of Each Factor.** There are two ways to deal with the factors: control or randomize.

1. **Control:** There are two ways to control the factors.
   (a) Set the level of a factor at one value throughout the experiment (if you are *not* interested in its effect on the response variable).
   (b) Set the level of a factor at various levels (if you are interested in its effect on the response variable). The combinations of the levels of all varied factors constitute the treatments in the experiment.
2. **Randomize:** Randomly assign the experimental units to treatment groups. Because it is difficult, if not impossible, to identify all factors in an experiment, randomly assigning experimental units to treatment groups mutes the effect of variation attributable to factors (explanatory variables) not controlled.

Step 5 **Conduct the Experiment.**

(a) **Replication** occurs when each treatment is applied to more than one experimental unit. Using more than one experimental unit for each treatment ensures the effect of a treatment is not due to some characteristic of a single experimental unit. It is a good idea to assign an equal number of experimental units to each treatment.
(b) Collect and process the data. Measure the value of the response variable for each replication. Then organize the results. The idea is that the value of the response variable for each treatment group is the *same* before the experiment because of randomization. Then any *difference* in the value of the response variable among the different treatment groups is a result of differences in the level of the treatment.

Step 6 **Test the Claim.** This is the subject of inferential statistics. **Inferential statistics** is a process in which generalizations about a population are made on the basis of results obtained from a sample. Provide a statement regarding the level of confidence in the generalization. Methods of inferential statistics are presented in Chapters 9 through 15.

❸ Explain the Completely Randomized Design

A **completely randomized design** is one in which each experimental unit is randomly assigned to a treatment.

Example   A Completely Randomized Design

Researchers enrolled 247 women between the ages of 70 and 93 in a study. They women were randomly assigned into three groups. The individuals in Group 1 attended a computer class three times a week for 90 minutes each session; the individuals in Group 2 enrolled in an exercise program three times a week for 90 minutes each session; the individuals in Group 3 were told to stick to their normal routines. After six months, the women were issued a survey that results in an age-satisfaction score. The subjects in Group 2 had a significantly higher age-satisfaction score than the subjects in the other groups.
(a) Why is this a completely randomized design?

(b) How many levels of treatment are there? What are the treatments?

(c) What is the response variable in the study?

(d) What variables were controlled in the study?

(e) What variable was manipulated in the study?

(f) Explain the role of randomization in the study?

(g) To what population do the results of this study apply?

(h) Draw a figure that illustrates the experimental design.

4 Explain the Matched-Pairs Design

A **matched-pairs design** is an experimental design in which the experimental units are paired up. The pairs are selected so that they are related in some way (that is, the same person before and after a treatment, twins, husband and wife, same geographical location, and so on). There are only two levels of treatment in a matched-pairs design.

Example A Matched-Pairs Design

Xylitol has proven effective in preventing dental caries (cavities) when included in food or gum. A total of 75 Peruvian children were given milk with and without xylitol and were asked to evaluate the taste of each. The researchers measured the children's ratings of the two types of milk. (Source: Castillo JL, et al (2005) Children's acceptance of milk with xylitol or sorbitol for dental caries prevention. BMC Oral Health (5)6.)

a. What is the response variable in this experiment? The children's rating of each type of milk
b. Think of some of the factors in the study. Which are controlled? Which factor is manipulated? Answers will vary but could include age and gender of the children; Milk with and without xylitol is the factor that was manipulated.
c. What are the treatments? How many treatments are there? Milk with xylitol and milk without xylitol; 2
d. How are factors that are not controlled or manipulated dealt with? Random assignment
e. What type of experimental design is this? Matched-pairs design
f. Identify the subjects 75 Peruvian children
g. Draw a diagram to illustrate the design.

Random sampling versus random assignment.

In random sampling, individuals are randomly selected from some population. In random assignment, it is often individuals who happen to be available for a study who are then randomly assigned to one of *n* treatment groups.

When there is random selection of individuals from a population, inference allows conclusions that apply to the population to be made. When individuals are randomly assigned to a treatment group, causal inferences may be drawn.