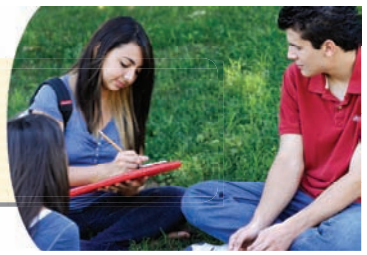
6.5 Compare Surveys, Experiments, and Observational Studies



Before You studied sampling methods for collecting data using a survey.

Now You will learn how studies are used to collect data.

Why So you can design a study to collect data, as in Ex. 16.

Key Vocabulary

- **biased questions**
- **experiment**
- **observational study**
- **controlled experiment**
- **control group**
- **treatment group**
- **randomized comparative experiment**

COMMON CORE

CC.9-12.S.IC.3 Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.*

SURVEYS Previously, you learned that in choosing a sample of a population to survey, you should do your best to select an unbiased sample to help ensure that the survey data represent the population. Random samples are preferred since they are less likely to be biased.

In designing a survey, it is also very important to word survey questions carefully. Answers to poorly worded questions may not accurately reflect the opinions or actions of those being surveyed. Questions that are flawed in a way that leads to inaccurate results are called **biased questions**. Questions may be biased in several ways:

- The wording of the question may encourage or pressure the respondent to answer in a particular way.
- The question may be perceived as too sensitive to answer truthfully.
- The question may not provide the respondent with enough information to give an accurate opinion.

Bias may also be introduced in survey questioning in other ways, such as by the order in which questions are asked or by respondents giving answers they believe will please the questioner.

EXAMPLE 1 Identify and correct bias in survey questioning

Tell why the question may be biased or otherwise introduce bias into the survey. Describe a way to correct the flaw.

a. A reporter asks parents:

Do you agree with the school board's proposal for new technology in our schools?

b. A dentist asks patients:

Do you brush your teeth at least twice per day and floss every day?

Solution

a. This question assumes that the respondent is familiar with the proposal. To get accurate results that lead to valid conclusions, state the proposal clearly using neutral language before asking the question.

b. Patients who brush less than twice per day or do not floss daily may be afraid to admit this since the dentist is asking the question. One improvement would be to have patients answer questions about dental hygiene on paper and put the paper anonymously into a box.

EXPERIMENTS AND OBSERVATIONAL STUDIES You have seen that surveys are one way to collect data, but different situations and purposes require different data gathering techniques. For example, many studies are designed to try to determine whether a quantity that varies can be associated with measured differences in two different groups of individuals.

An **experiment** imposes a treatment on individuals in order to collect data on their response to the treatment. The treatment may be a medical treatment, or it can be any action that might affect a variable in the experiment, such as adding methanol to gasoline and then measuring its effect on fuel efficiency.

In some cases, it may be difficult to control or isolate the variable being studied, or it may be unethical to subject people to a certain treatment or to withhold it from them. In this case, an *observational study* is used. An **observational study** observes individuals and measures variables without controlling the individuals or their environment.

EXAMPLE 2 Identify experiments and observational studies

Determine whether each situation is an example of an experiment or an observational study. Explain.

a. A researcher asks college students how many hours of sleep they get on an average night and examines whether the number of hours of sleep affects students' grades.

b. A Parks Department employee wants to know if latex paint is more durable than non-latex paint. She has 50 park benches painted with latex paint and has 50 park benches painted with non-latex paint.

Solution

a. The researcher gathers data without controlling the individuals or applying a treatment. The situation is an observational study.

b. A treatment (painting benches with latex paint) is applied to some of the individuals (benches) in the study. The situation is an experiment.

GUIDED PRACTICE for Examples 1 and 2

1. Tell whether the survey question below may be biased or otherwise introduce bias into the survey. *Explain.*

"Do you, like most people your age, enjoy watching the latest music videos?"

2. Determine whether the situation described in the research summary shown at the right is an example of an experiment or an observational study. *Explain.*

...TECH NOTES...

A Faster Web Site

To test the redesign of its Web site, an online bookseller assembled 96 users of the site and randomly divided them into two groups. One group used the new Web site to make an online purchase and one group used the old Web site to do the same transaction. Users of the new site were able to complete the purchase 22% faster.

CONTROLLED EXPERIMENTS In a **controlled experiment**, two groups are studied under identical conditions with the exception of one variable. The group under ordinary conditions is the **control group**. The group that is subjected to the treatment is the **treatment group**.

In a **randomized comparative experiment**, individuals are randomly assigned to the control group or the treatment group. The comparison of the control group and the treatment group makes it possible to determine any effects of the treatment.

Randomization minimizes bias and produces groups of individuals that are theoretically similar in all ways before the treatment is applied. Conclusions drawn from an experiment that is not a randomized comparative experiment may not be valid.

EXAMPLE 3 Evaluate a published report

Determine whether the study described in the health bulletin below is a randomized comparative experiment. If it is, describe the treatment, the treatment group, and the control group. If it is not, explain why not and discuss whether the conclusions drawn from the study are valid.

Health Watch!

Milk Fights Cavities

At Ashland Middle School, students were given the choice of drinking milk or other beverages at lunch. Fifty students who chose milk were monitored for one year, as were 50 students who chose other beverages. At the end of the year, students in the "milk" group had 15% fewer cavities than students in the other group.

Solution

The study is not a randomized comparative experiment because the individuals were not randomly assigned to a control group and a treatment group. (In fact, the study is an observational study, not an experiment, since no treatment is imposed.)

The study's conclusion that milk fights cavities may or may not be valid. There may be other reasons why students who chose milk had fewer cavities. For example, students who voluntarily choose milk at lunch may be more likely to have other healthy eating or dental care habits that could affect the number of cavities they have.

GUIDED PRACTICE for Example 3

3. Determine whether the study described in the research summary for Guided Practice Exercise 2 is a randomized comparative experiment. If it is, describe the treatment, the treatment group, and the control group. If it is not, explain why not and discuss whether the conclusions drawn from the study are valid.

WELL-DESIGNED STUDIES Randomization is a key element of well-designed studies. How randomization applies to different kinds of studies varies, as shown below.

Sample survey	Observational study	Experiment
A random sample is selected to be surveyed from the population studied.	As possible, random samples can be selected for the groups being studied.	Individuals are assigned at random to the treatment group or the control group.

Surveys do not compare groups, and so do not address cause and effect. Good observational studies and experiments are designed to be comparative—to compare data from two or more groups looking for a relationship between variables. But only a well-designed experiment can determine a cause-and-effect relationship.

KEY CONCEPT *For Your Notebook*

Comparative Studies and Causality

- An observational study can identify *correlation* between variables, but not *causality*. Variables other than what is being measured may be affecting the results. For example, vigorous exercise in older people correlates with longer life, but comparing groups only on exercise and lifespan ignores other factors, such as that people who are unhealthy to begin with may not be able to exercise vigorously.
- A rigorous randomized comparative experiment, by eliminating sources of variation other than the controlled variable, can make valid cause-and-effect conclusions possible.

EXAMPLE 4 Design an experiment or observational study

Explain whether the following research topic is best investigated through an experiment or an observational study. Then explain how you would design the experiment or observational study.

You want to know if listening to music using earphones for more than one hour per day affects a person's hearing.

Solution

The treatment (listening to music using earphones for more than one hour a day) may affect an individual's hearing, so it is not ethical to assign individuals to a control or treatment group. Use an observational study.

Randomly choose one group of individuals who already listen to music using earphones for more than one hour per day.

Randomly choose one group of individuals who do not listen to music using earphones for more than one hour per day.

Monitor the hearing of the individuals in both groups at regular intervals.

6.5 EXERCISES

HOMEWORK KEY

◯ = See **WORKED-OUT SOLUTIONS** Exs. 5 and 15

★ = **STANDARDIZED TEST PRACTICE** Exs. 2 and 9

SKILL PRACTICE

1. **VOCABULARY** Copy and complete: An ___?___ observes individuals and measures variables without controlling the individuals or their environment.

2. ★ **WRITING** *Describe* the difference between an experiment and an observational study.

EXAMPLE 1 for Exs. 3–6

IDENTIFYING BIASED SURVEY QUESTIONS **Tell why the question may be biased or otherwise introduce bias into the survey. Describe a way to correct the flaw.**

3. "Do you agree with all of the budget cuts proposed by the mayor?"

4. "Would you rather watch the latest award-winning movie or just read some book?

5. "The tap water coming from our western water supply contains twice the level of arsenic of water from our eastern supply. Do you think the government should address this health problem?"

6. A child with an adult asks, "Will you vote for our school bond issue?"

EXAMPLE 2 for Exs. 7–9

CLASSIFYING STUDIES **Determine whether each situation is an example of an *experiment* or an *observational study*. *Explain*.**

7. A researcher compares incomes of people who live in rural areas with incomes of people who live in large cities.

8. A farmer wants to know if a new fertilizer affects the weight of the fruit produced by strawberry plants. She applies the fertilizer to 10 rows of plants and does not apply the fertilizer to 10 other rows of plants.

9. ★ **MULTIPLE CHOICE** A doctor studies the effects of nicotine on a person's health by monitoring the health of 100 randomly selected smokers and 100 randomly selected nonsmokers. This is an example of what type of study?

   (A) experiment (B) observational study

   (C) sample survey (D) none of the above

EXAMPLE 3 for Exs. 10, 11

ERROR ANALYSIS *Describe* and correct the error in describing the study given below.

A company's researchers want to study the effects of adding shea butter to their existing hair conditioner. They monitor the hair quality of 50 randomly selected volunteers using the old conditioner and 50 randomly selected volunteers using the new shea butter conditioner.

10. The control group is volunteers who do not use either of the conditioners.

11. The study is a comparative observational study.

12. **CHALLENGE** *Explain* why observational studies, rather than experiments, are usually used in astronomy.

◯ = See **WORKED-OUT SOLUTIONS** in Student Resources

★ = **STANDARDIZED TEST PRACTICE**

PROBLEM SOLVING

EXAMPLE 4 for Exs. 13–15

Explain whether the research topic is best addressed through an *experiment* or an *observational study*. Then explain how you would design the experiment or the observational study.

13. You want to know if homes that are close to parks or schools have higher property values than other homes.

14. You want to know if flowers sprayed twice a day with a mist of water stay fresh longer than flowers that are not sprayed.

15. Determine whether the study described in the report is a randomized comparative experiment. If it is, describe the treatment, the treatment group, and the control group. If it is not, explain why not and discuss whether the conclusions drawn from the study are valid.

Early Birds Make Better Drivers

A recent study shows that adults who rise before 6:30 A.M. are better drivers than other adults. The study monitored the driving records of 140 volunteers who always wake up before 6:30 and 140 volunteers who never wake up before 6:30. The early risers had 12% fewer accidents.

16. Describe how you would set up a randomized, controlled experiment to investigate the hypothesis below. Include any precautions you would take to ensure that your conclusions are valid.

Dog food with added Omega-3 fatty acids will give dogs a shiny coat.

17. MEDICINE A researcher studied the effect of fiber supplements on heart disease. She identified 175 people who take fiber supplements and 175 people who do not take fiber supplements. She found that those who took the supplements had 19% fewer heart attacks those who did not. She concluded that taking fiber supplements reduces the incidence of heart attacks.

a. *Explain* why the researcher's conclusion may not be valid.

b. *Describe* how the researcher could have conducted the study differently to produce valid results.

18. CHALLENGE Will replicating an experiment on many individuals produce data that is more likely to accurately represent a population than performing the experiment only once? *Explain*.

QUIZ

A normal distribution has a mean of 47 and a standard deviation of 6. Find the probability that a randomly selected x-value is in the given interval.

1. Between 35 and 65 **2.** At least 41 **3.** At most 29

Find the sample size required to achieve the given margin of error. Round your answer to the nearest whole number.

4. ±3% **5.** ±7% **6.** ±4.5% **7.** ±0.8%

8. ★ WRITING *Explain* why a randomized comparative experiment should be used to collect data whenever possible.

Simulate an Experimental Difference

MATERIALS • index cards • scissors • small paper bag • graphing calculator

MATHEMATICAL PRACTICES
Use appropriate tools strategically.

QUESTION How can you test a hypothesis about an experiment?

When you perform a randomized comparative experiment and measure a difference between the control and treatment groups, how do you know if the difference is from the treatment or if it's just a chance result of the choice of the groups? One way is to *resample*: combine all the measurements from both groups, and repeatedly create new "control" and "treatment" groups at random from the measurements. Then see how often you get chance differences between the new groups that are at least as large as the one you measured.

EXPLORE 1 Resample data

A randomized experiment tests whether a soil supplement affects the total yield (in kilograms) of cherry tomato plants. The table below shows the results. How does the difference in the means of the control and treatment groups compare with differences resulting from chance?

	Total Yield of Tomato Plants (kilograms)									
Control group	1.4	0.9	1.2	1.3	2.0	1.2	0.7	1.9	1.4	1.7
Treatment group	1.4	0.9	1.5	1.8	1.6	1.8	2.4	1.9	1.9	1.7

STEP 1 Calculate means Find the mean yield of the control group, $\overline{x}_{control}$, and the mean yield of the treatment group, $\overline{x}_{treatment}$. Then find the difference $\overline{x}_{treatment} - \overline{x}_{control}$. Note that the difference can be positive or negative, and is 0 when $\overline{x}_{treatment} = \overline{x}_{control}$.

STEP 2 Combine measurements and resample Working in pairs, cut index cards to make 20 equal-sized pieces, and write one yield measurement on each. Place the pieces in a bag, shake, and randomly choose 10. Call this the "treatment" group, and call the 10 pieces in the bag the "control" group. Find the mean for each group, record $\overline{x}_{treatment} - \overline{x}_{control}$, and return the pieces to the bag.

Perform the resampling experiment 5 times, each time finding the difference of means. Sample results for 5 resamplings made by each of two pairs of students are shown at the right.

$\overline{x}_{treatment} - \overline{x}_{control}$:	
Pair 1:	−0.28, −0.24, −0.18, −0.12, 0.30
Pair 2:	−0.26, 0.00, 0.12, 0.18, 0.28

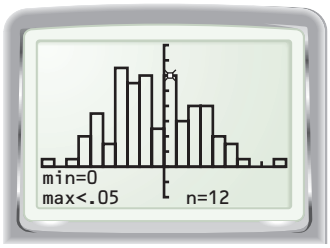
STEP 3 State the null hypothesis The *null hypothesis* is the assumption that measured differences between a treatment group and a control group are a result of chance. The null hypothesis for this activity is the following:

The soil nutrient has no effect on the yield of the cherry tomato plants.

EXPLORE 2 Evaluate the null hypothesis

To conclude that the treatment *is* responsible for the difference in yield, you need strong evidence to *reject* the null hypothesis. To evaluate the null hypothesis, compare the experimental difference of means with the resampling differences.

STEP 1 ***Collect and display results*** Collect all the differences $\overline{x}_{treatment} - \overline{x}_{control}$ calculated by pairs of students in the class in Explore 1. Display the differences in a histogram. A sample histogram for 50 resamplings made using a graphing calculator and an interval for the difference of means of 0.05 is shown at the right.



STEP 2 ***Analyze resampling data*** In Step 1 of Explore 1, you calculated the experimental difference of means. Draw a vertical line on your class histogram to represent this difference.

If the experimental difference of means lies in one of the tails of the resampling distribution, then resampling gave a difference of means at least as large as the experimental difference only rarely. This gives evidence for rejecting the null hypothesis. More specifically, the following are true:

- If the experimental difference of means falls outside of the middle 90% of the resampling differences of means, you can reject the null hypothesis at the 90% confidence level.
- If the experimental difference of means falls outside of the middle 95% of the resampling differences of means, you can reject the null hypothesis at the 95% confidence level.

STEP 3 ***Evaluate results*** Is your class able to reject the null hypothesis? *Explain*. What does this mean regarding the original experiment?

DRAW CONCLUSIONS Use your observations to complete these exercises

1. Find the mean of all of the resampling differences of means collected by all pairs of students in Step 1 of Explore 2. This mean should approximate the most likely result when the null hypothesis is true. Is the mean of the resampling differences of means for your class close to this value?
2. In Explore 1, how many resampling choices for the treatment and control groups are theoretically possible? Suppose that a computer is programmed to generate all possible control and treatment group assignments, to find the differences of means, and then to draw a histogram of the results. Would you prefer to make conclusions about the experiment using the histogram from the computer or the histogram for your class? *Explain*.
3. Suppose the company that produces the soil nutrient featured in the experiment described in Explore 1 advertises that growing tomato plants in soil enriched with the nutrient will increase the yield of the tomato plants. Is this an accurate statement? *Explain*.

MIXED REVIEW of Problem Solving

MATHEMATICAL PRACTICES Make sense of problems and persevere in solving them.

1. **MULTI-STEP PROBLEM** A fly fisher records in a table the weight of 20 Maine landlocked salmon he caught and finds they are normally distributed.

Fly fishing for salmon

1.9, 1.5, 2.0, 2.0, 2.1, 2.0, 1.8, 1.5, 2.2, 1.9, 1.8, 1.7, 2.1, 2.2, 1.7, 2.1, 2.0, 1.5, 1.8, 2.1

   a. Find the mean of the data set.

   b. Find the standard deviation of the data set.

   c. If all the fly fishers that come to the river in a year collectively catch 3000 fish, how many of the salmon caught do you expect weigh less than 1.443 lb?

2. **MULTI-STEP PROBLEM** In a survey of 1022 people who shop online, 73% said that they do so because of the convenience.

   a. What is the margin of error for the survey?

   b. Give an interval that is likely to contain the exact percent of all online shoppers who shop because of the convenience.

3. **GRIDDED ANSWER** At a tree nursery, the heights of scotch pine trees are normally distributed with a mean of 200 centimeters and a standard deviation of 20 centimeters. Find the percent of scotch pine trees that have a height of at least 220 centimeters. Round your answer to the nearest whole number.

4. **EXTENDED RESPONSE** Explain whether the following research topic is best investigated through an experiment or an observational study. Then explain how you would design the experiment or observational study.

   Jody wants to know whether water that has high levels of dissolved calcium will inhibit or promote orchid growth.

5. **SHORT RESPONSE** The amount of juice dispensed from a machine is normally distributed with a mean of 10.5 ounces and a standard deviation of 0.75 ounce. Within what range do about 68% of the amounts dispensed fall? *Explain* your reasoning.

6. **SHORT RESPONSE** A survey shows that the time spent by shoppers in a supermarket is normally distributed with a mean of 45 minutes and a standard deviation of 12 minutes. What is the probability that a randomly chosen shopper will spend between 45 and 69 minutes in the supermarket? *Explain* your reasoning.

7. **MULTI-STEP PROBLEM** A survey of students shows that 15% of respondents, or 315 students, prefer having gym class during the last period of the day.

   a. How many students were surveyed?

   b. What is the margin of error for the survey?

   c. Give an interval that is likely to contain the exact percent of all students who would prefer to have gym class during the last period of the day.

8. **SHORT RESPONSE** A local sports TV station wants to find the number of hours per week people in the viewing area watch sporting events on television. The station surveys people at a nearby sports stadium. What type of sample is described? Is this sample biased? *Explain* your reasoning.