Lesson 1.3.1
Collecting Data by Conducting an Experiment

INTRODUCTION

In Lesson 1.1.2 you learned the following:

- An experiment is one type of statistical study.
- In an experiment, we observe a response variable under different experimental conditions.
- We almost always observe differences in the response variable. We want to figure out whether the observed difference is a result of the experimental conditions.
- To determine if the observed difference is a result of experimental conditions, first we must rule out chance variation.
- Even after chance variation is ruled out, we must think about other possible explanations for differences in the response variable. To accomplish this, the experiment must be planned carefully.

TRY THESE

Conducting an Experiment

Today we are going to conduct an experiment. Recall that in past lessons, we reviewed the four step process in a statistical study. The first step in this process was to ask a question that can be answered by collecting data. In today’s experiment we ask the following question, “Does listening to music make a difference in how much students remember while studying?”

In order to prepare for our experiment we must first write a hypothesis. A hypothesis is an educated guess or a possible explanation for what you think the results will be in this study. You can then test your hypothesis by collecting and analyzing data.

Your answers to the following three questions will help you as you write your own hypothesis.
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1. Think about your own study habits. Do you prefer to study in silence or do you prefer to study while listening to music? Write your answer and write one reason why you prefer to study this way.

2. Imagine that you were told to memorize Abraham Lincoln's famous speech, The Gettysburg Address. You study the speech for 5 minutes and try to memorize as much of the speech as possible. Do you think that listening to music while you are studying will make a difference in how many words you can memorize? If you think there will be a difference, what is the effect that you think listening to music will have on the amount of the speech you can memorize?

3. Now think about students in general. Do you think that students who study the Gettysburg Address while listening to music memorize more than, less than, or about the same as students who study in silence? Write one reason for your answer.

Your answer to question 3 is your hypothesis. This is your best guess of the answer to your question. You can test your hypothesis by gathering data.

4. You are assigned to design an experiment to test your hypothesis. You must collect data and make a decision about your hypothesis. Write down what you will do to test your hypothesis.
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We are now going to conduct an experiment in which you will try to memorize as much of the Gettysburg Address as you can in 5 minutes.

Now that you have done the experiment, answer the following questions with your group members.

5 Did the person in your group who memorized the most words study in silence or while listening to music?

6 Did the person in your group who memorized the fewest words study in silence or while listening to music?

7 Think about the study method of the person in your group who memorized the most words. Are you convinced that the method they used is the best one? Why or why not?

You have gathered the results for one person. One result is not sufficient or enough evidence. This is an example of anecdotal evidence. Even though it may be persuasive, it is not statistically useful. That is, it is not sufficient evidence.

Another example of anecdotal evidence would be observing a person who smokes a pack of cigarettes every day and does not get cancer. This is just one person so it is not sufficient evidence. It would not be a valid conclusion if we were to say that people who smoke a pack of cigarettes every day do not get cancer.

8 What could we do with the results from all the students in class to see if there is a difference between the students who studied while listening to music and the students who studied in silence?
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9 Is there a difference between the students who studied while listening to music and those who studied in silence? In your answer, write about the averages and the dotplots.

10 Think about what you know about a well-designed study. What are the two possible reasons that you might observe a difference between the students who studied while listening to music and the students who studied in silence? Write the two reasons.

NEXT STEPS

In Statistics, if we believe the difference is large enough that it is unlikely to have been caused just by chance variation, we say the difference is significant. Unfortunately, at this stage in the lessons, we do not have the statistical tools to figure out if the difference is due to music or due to chance variation. We will study how to figure out if the difference is significant later in the course.

For now, we have to be careful when we design the study to rule out other possible causes of any observed difference. This means that we to need think about other causes that could explain the difference we observed among the students in the class. For example, if several students were taking American History and recently studied the Civil war, these students might be more familiar with the Gettysburg Address. The fact that they might be more familiar with the Gettysburg Address could explain the difference and not if they listened to music or studied in silence.

A Bit of Terminology

Before we move on, let’s take a look at some terminology used when describing experiments.

When planning an experiment, it is helpful to think of the research question in the following form:

\[
\text{What is the effect of } 1 \text{ on } 2 ?
\]
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For example, for the music listening experiment, you could say:

What is the effect of listening to music on memory retention?

The numbered parts of the question correspond to an important aspect of the plan for the experiment.

1—“the effect of ___”

This part of the question identifies the treatment variable for the experiment. The treatment variable will be manipulated, that is, it will be changed intentionally. The observed values of this variable that will be used in the experiment determine the experimental conditions that will be compared in the experiment. For the music listening experiment, the treatment variable is music and the experimental conditions to be compared are studying while listening to music and studying in silence.

2—“on ___”

This part of the question identifies the response variable in the experiment. This is the variable that you will be observing to determine if there are differences.

For the music listening experiment, the response variable is number of words correctly memorized. You also need to identify who the participants in the experiment will be. Sometimes the participants are people and sometimes they are not.

For example, you could conduct an experiment to investigate the effect of a gasoline additive on fuel efficiency. In this experiment, the gasoline additive is the treatment variable. The response variable is fuel efficiency. An additive is added to the gasoline and you are testing whether this additive makes a difference on fuel efficiency.

You might choose to compare fuel efficiencies for two groups of cars, where one group of cars uses gas without the additive and the other group of cars uses gas with the additive. Here, the participants in the experiment are the cars.

In general, participants in an experiment are referred to as the subjects or experimental units. Participants in an experiment that are human beings or animals are subjects. Participants in an experiment that are not human beings, like the cars in this example, are experimental units.
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INTRODUCTION

Direct Control

The goal of an experiment is to determine the effects of different experimental conditions on some response variable. To do this, you want to rule out other possible explanations for differences in the responses to the different experimental conditions. Two common strategies to help with this are direct control and random assignment.

Direct control is simple. This means that if you notice there are other variables besides the treatment variable that might affect the response you try to control those variables.

For example, in the music listening experiment, whether the music was a type that the student enjoyed might affect the student’s ability to study. One way to control for this is to allow each participant to choose the type of music that he or she enjoys. But it might also be the case that allowing participants to choose the type of music will not help them study. One way to conduct the experiment to control for this is to have all participants listen to the same music. Another way is to have more groups of participants where some listen to music they enjoy and others listen to assigned music.

Designing experiments is very complicated. Today’s lesson is only an introduction to the design of experiments.

TRY THESE

Consider the following description of an experiment to investigate whether the way people dry their hands after washing them has an effect on how clean their hands are:

An experiment was conducted to compare bacteria reduction for three different hand drying methods: paper towels, hot air dryer, and evaporation. In this experiment subjects first handled uncooked chicken for 45 seconds. Next subjects washed their hands with a single squirt of soap for 60 seconds and finally used one of the three hand drying methods. After participants dried their hands completely, the bacteria count on their hands was measured.¹

¹ Infectious Disease News. (September 2010).
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1. What is the treatment variable in this experiment? How many experimental conditions were there in this experiment?

2. What is the response variable in this experiment?

3. One variable that might affect the response is the length of time that people handled the raw chicken. The researchers controlled this by having everyone handle the chicken for the same amount of time—45 seconds. Two other variables were controlled in this experiment. What are they?

Sometimes there are variables we can think of before starting a study that might affect the response, but they are variables that are not easily controlled. For example, in our class experiment on memorizing the Gettysburg Address, some students might be better at memorization. It is hard to know who those students are in advance of the experiment.

Random assignment can help us. When we randomly assign students to the different treatment groups, other variables that could affect the response should be fairly evenly distributed between the two groups. Unfortunately in our music listening experiment, we couldn’t use true random assignment because some students do not have a music player with them.

NEXT STEPS

When one goal of an experiment is to determine whether some experimental condition has an effect, it is important to make sure that the experiment includes a group that does not get a treatment. This group is called a control group. Including a control group in an experiment provides a baseline for comparison.

4. What was the control group in our music listening experiment?
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5 Why was it important to include a control group in this experiment?

Sometimes people have set ideas about the effectiveness of various experimental conditions in an experiment, and these prior beliefs might influence the response.

6 You are planning an experiment to compare the effect of two different doses of medication on the pain experienced by patients after knee surgery. Patients are randomly assigned to two groups. One group receives a low-dose of medication and the second group receives a high-dose of medication. Participants are given medication after surgery and are asked to rate their level of pain one hour later.

Imagine that participants know what group they are in. That is, they know that they are receiving either a low dose or high dose of medication for pain. Do you think this might influence or affect how they rate their pain level after one hour? Write the reasons why you think this.

7 Think about your answer to question 6 above. What is one strategy that you can use to make sure that participants’ prior beliefs do not influence their response?

When participants in an experiment do not know which experimental condition they are assigned to, they are said to be blinded. By making sure participants do not know what experimental condition they are assigned to, you can prevent prior beliefs about the experimental conditions from influencing the response.

8 Would it have been possible for the music listening experiment to be blind? Explain your answer.
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Another form of blinding in an experiment is to plan the experiment so that the person who measures the response does not know which experimental group a participant is assigned to. For example, a person who grades student essays on the Scholastic Aptitude Test (SAT) often needs to use his or her judgment to decide between two scores. In some cases, a paper might fall between a score of 4 and 5 on the grading scale. The grader must decide between these two scores.

Suppose you want to conduct an experiment to compare essay scores for two groups of students:

- Students who participated in an 8-hour SAT review course
- Students who participated in a 40-hour SAT review course.

If the grader were deciding between two close scores (like a 4 or 5), she might unconsciously be influenced in one direction because she knows which review course the student took. This problem could be eliminated if the researchers blind the person grading or measuring the response.

When possible, it is usually a good idea to consider blinding both the participants and the person measuring the response. In this case we call the experiment double blind.

6 A group of students is preparing to take the Critical Reading portion of the SAT exam. Researchers are interested in investigating the effect of the length of a review course on exam scores. Researchers place participants in one of two groups. One group attends an 8-hour review course and the second group attends a 40-hour review course. Is it possible to blind the students participating in this experiment? Explain your answer.

7 A shoe company wants to compare two different products for making hiking boots waterproof. Researchers create an experiment to compare two different products. In the experiment, researchers give participants hiking boots that were waterproofed using one of the two methods. Participants then wear the boots on a hike along a mountain stream. They have to cross the stream and walk in the water in several places. After the hike, the boots are left to dry and then sent to a lab where a technician evaluates the boots for water damage.

Do you recommend blinding only the participants, only the lab technician, or both the participants and lab technician? Explain your answer.
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In experiments that use human subjects, use of a control group may not be enough to establish whether a treatment really has an effect. Studies have shown that people sometimes respond in a positive way to treatments that have no active ingredients. Treatments that have no active ingredients, such as colored water or sugar pills, are called placebos. For example, people often report that these non-treatments relieve pain or reduce other symptoms such as dizziness. This is called the placebo effect.

Because of the placebo effect, experiments often include a control group and a placebo group. Those in the placebo group get a placebo that is identical in appearance (and taste, etc.) to what the people in other experimental groups receive, but has no active ingredients. In this situation, you also want the participants blinded—you do not want to tell people they are receiving a placebo.

8 How does including a control group and a placebo group in an experiment allow you to decide whether a placebo effect existed?

9 How does including a placebo group in an experiment allow you to decide whether a particular experimental condition has a real effect on the response?
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TAKE IT HOME

A study done by researchers at Kings College London found that infomania has a temporary, but significant, negative effect on intelligence quotient (IQ). In the experiment, the researchers divided volunteers into two groups. Each subject took an IQ test. One group had to check e-mail and respond to instant messages while taking the test, and the other group took the IQ test without any distractions. Researchers found that the average score on the IQ test for the distracted group was 10 points lower than the average for the group that was not distracted.

A What is the response variable in this experiment?

B What is the treatment variable and what are the experimental conditions?

C Explain why the researchers should use random assignment to put each volunteer in one of the experimental groups rather than letting the volunteers decide which group they wanted to be in.

D Identify the control group in this experiment.

E Is it possible for the subjects to be blinded? Explain your answer.
2 Read the following passage from a 1999 *USA Today* article.\(^2\) Think about the following question: do ethnic group and gender influence the type of care that a heart patient receives?

Previous research suggested blacks and women were less likely than whites and men to get cardiac catheterization or coronary bypass surgery. These are two treatments for chest pain or heart attacks. Scientists thought this situation was due to differences in illness severity (how serious the illness was), insurance coverage, patient preference, and health care access.

Researchers eliminated those differences by videotaping different actors describe chest pain from identical scripts. These actors were: two black men, two black women, two white men, and two white women. They wore identical clothing, 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 was about how to make decisions while taking care of patients.

Researchers gave each doctor a different video. The video each doctor watched was determined by the roll of a four-sided die. For example, if a doctor rolled a “4” on the die, they had to watch video 4 featuring a white woman.

A In the experiment described, the researchers chose to control a number of variables other than ethnic group and gender that might have influenced the recommended treatment. How did they do this?

B Did the researchers use random assignment to create the experimental groups? If so, how did they do this?

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3 An experiment to investigate whether dogs can be trained to recognize cancer by smell was described in a newspaper article with the headline, “Doctor Dogs Diagnose Cancer by Sniffing It Out.” In the 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, the 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.”

A Explain what was meant by the last sentence.

B Explain why this blinding is important.

4 Swedish researchers concluded that viewing and discussing art can lead to improvement in medical conditions such as high blood pressure. This conclusion was based on an experiment in which 20 elderly women gathered once a week to discuss different works of art. The study also included a group of 20 elderly women who met once a week to discuss their hobbies and interests. At the end of four months, the art discussion group was found to have lower blood pressure than the hobbies discussion group.

A Why is it important to determine whether the researchers randomly assigned the women participating in the study to one of the two groups?

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B Why do you think the researchers included the hobbies discussion group in this study?

C Imagine that the experiment also included a third group of women who did not meet at all. The researchers randomly assigned participants to one of the three groups. Is including this group an improvement to the study? Write the reason(s) why you think so.

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