Module 6 - Experiments (1 of 2)

We now focus on experiments.

The primary goal of an *experiment* is to provide evidence for a cause-and-effect relationship between two variables. An experiment intentionally manipulates the explanatory variable in an attempt to cause an effect on the response variable. To establish a cause-and-effect relationship, we want to make sure that the explanatory variable is the only factor that impacts the response variable. We therefore attempt to get rid of all other factors that might affect the response. These other factors are called *confounding variables*.

To confound means to mix up or to confuse. Confounding variables mix up our ability to determine if the explanatory variable causes a change in the response variable. If we do not control the effects of confounding variables, the experiment does not provide evidence of a cause-and-effect relationship between the explanatory and response variables.

Researchers use two common strategies to control the effects of confounding variables:

- Direct control
- Random assignment

EXAMPLE

Direct Control

Researchers compare bacteria reduction for three different hand-drying methods. In this experiment, participants handled uncooked chicken for 45 seconds, then washed their hands with one squirt of soap for 60 seconds, and then used one of three hand-drying methods. After participants completely dried their hands, researchers measured the bacteria count on their hands. The *Infectious Disease News* published the results in 2010.

In this experiment, the explanatory variable is *hand-drying method*.The response variable is *bacteria count*. Notice that the explanatory variable determines the three treatments in the experiment. Each treatment is a different hand-drying method. For this reason, the explanatory variable is also called the *treatment variable*.

In this experiment, researchers attempt to directly control the influence of three variables that could affect the bacteria count:

(1) Length of time participants handle the raw chicken.

- Direct control: All participants handle the raw chicken for 45 seconds.

(2) Amount of soap participants use.

- Direct control: All participants use one squirt of soap.

(3) Amount of time participants wash hands.

- Direct control: All participants wash their hands for 60 seconds.

Notice that the control works by stabilizing the impact of the confounding variable across the treatments. For example, the amount of soap will still influence the bacteria count. We cannot avoid this. But if all participants use the same amount of soap, then *differences* in bacteria count among the three treatments cannot be due to the amount of soap used.

Similarly, the amount of time that participants wash their hands will influence the bacteria count. But if all participants wash their hands for the same amount of time, then *differences* in bacteria count among the three treatments cannot be due to the amount of time participants washed their hands. This is what we mean when we say that the control works by stabilizing the impact of the confounding variable across the treatments.

Now we examine random assignment. Random assignment controls the effects of confounding variables that a researcher cannot control directly or that are difficult to identify in advance.

EXAMPLE

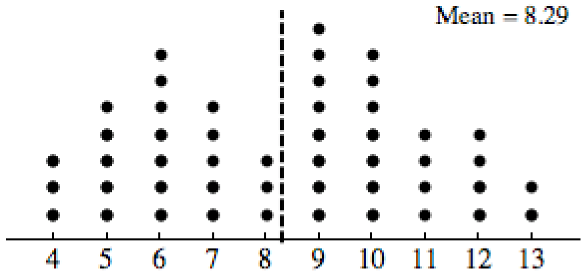
Random Assignment

Medical researchers conducted an experiment to compare two different types of surgery for children with hernias. They compared the recovery times for each type of surgery. The two surgery types are laparoscopic repair (a surgery that involves three small incisions) and open repair (a surgery that involves one large incision). Researchers identified a variety of variables that might influence recovery time, such as child's age, weight, and physical fitness level.

Let's consider one of these variables: age. How could the researchers control the impact of age on recovery time?

Direct control involves use of children of the same age. For example, researchers might use only 10-year-old children in the experiment. But it may be difficult to find enough 10-year-old children with hernias. So how do researchers create treatment groups that are similar with respect to age? One way is to assign children at random to treatment groups.

The goal of random assignment is to create similar groups with respect to age, weight, and other characteristics that might influence recovery time. To illustrate how random assignment creates similar groups, we focus on age. Here is a dotplot of the ages of the 48 children with hernias who participated in this experiment. Each dot represents a child. The average age of the 48 children is 8.29 years.



If random assignment is working, the average age for each treatment group should be about equal. We see how random assignment works in the next activity.

Click Random Assignment to randomly assign the 48 children to the two treatments. Repeat this process several times to investigate whether random assignment creates groups with similar ages. The average age is labeled as the mean and marked with a vertical line. Compare the average ages for the treatment groups.

What Is the Main Point?

The goal of random assignment is to create similar treatment groups. If the groups are similar, then any differences we see in the response variable are due to the differences in treatments. In this way, random assignment controls the impact of confounding variables. Random assignment in an experiment eliminates confounding, just as random selection in a survey eliminates bias.

Comment

How do we make random assignments? We use any method that allows random chance to choose the treatment for each participant. Random assignment means that each participant has an equal chance of receiving any one of the treatment options. For example, in the hernia experiment, you could put every child's name in a hat. The first 24 names drawn get the first treatment. The rest of the children get the second treatment. You could also flip a coin. Heads means the child is assigned to the first treatment. This method could create groups with slightly different sizes, which is fine.

Module 6 - Experiments (2 of 2)

Let's summarize what we know about experiments:

- The goal of the experiment is to provide evidence for a cause-and-effect relationship between two variables.
- A well-designed experiment controls the effects of confounding variables to isolate the effect of the explanatory variable on the response.
- Two commonly used methods for controlling the effects of confounding variables are *direct control* and *random assignment*.
- Random assignment uses random chance to assign participants to treatments. This creates similar treatment groups. With random assignment, we can be fairly confident that any differences we observe in the response of treatment groups is due to the explanatory variable. In this way, we have evidence for a cause-and-effect relationship.

Now we discuss a few more strategies that are commonly used to control the effects of confounding variables.

In an experiment, we manipulate the explanatory variable to determine if it has an effect on the response variable. Could the change we observe in the response variable happen without manipulating the explanatory variable? Maybe what we observe would have happened anyway.

For this reason, it is important to include a *control group*. A control group is a group that receives no treatment. The control group provides a baseline for comparison.

EXAMPLE

Control Groups

Music and rats: In David Merrell's experiment with rats, he wanted to examine the relationship between music and the ability of rats to run a maze. He had three treatment groups: exposure to music by the heavy metal band Anthrax, exposure to music by Mozart, and no exposure to music. The group of rats that did not listen to music is the control group. Merrell's experiment lasted 1 month. With a month of practice, the rats in all the groups would probably get faster at running the maze. The control group provides a baseline for comparison. At the end of 1 month, the rats in the Mozart group were much faster at running the maze than were the rats in the other two groups. Comparison to the control group shows that the improvement in the Mozart group is not due to the rats being more experienced with the maze.

Hernia treatments for children: In this experiment, researchers compared two different surgeries. The response variable was recovery time, so it would not have made sense to have a no-treatment group. However, one type of surgery was the standard treatment for hernias, and children who received this surgery represented the control group. This group provides a baseline for comparing recovery times.

In experiments that use human participants, use of a control group may not be enough to establish whether a treatment really has an effect. A substantial amount of research shows that people respond in positive ways to treatments that have no active ingredients, a response called the *placebo effect*. A placebo is a treatment with no active ingredients, sometimes called a "sugar pill."

EXAMPLE

The Placebo Effect

An article published in the *Washington Post* in 2002 illustrates the placebo effect in medical experiments.

- *After thousands of studies, hundreds of millions of prescriptions and tens of billions of dollars in sales, two things are certain about pills that treat depression: Antidepressants like Prozac, Paxil and Zoloft work. And so do sugar pills. 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....The new research may shed light on findings such as those from a trial last month that compared the herbal remedy St. John's wort against Zoloft. St. John's wort fully cured 24 percent of the depressed people who received it, and Zoloft cured 25 percent—but the placebo fully cured 32 percent.*

The placebo effect can confound the results of medical experiments. It is uncertain what is behind the placebo effect, but because people in medical experiments improve when taking a placebo, a placebo group provides a baseline for comparing treatments. We cannot eliminate the placebo effect on a treatment group. Both the placebo group and the drug group experience the placebo effect. If a treatment produces better results than a placebo, then we have evidence that the treatment (and not the placebo effect) is responsible for the improvement.

In experiments that use a placebo, participants do not know whether they are receiving the drug or a placebo. The participants are *blind* to the treatment to prevent their own beliefs about the drug (or placebo) from confounding the results.

EXAMPLE

Blinding

Recall our discussion of the experiment conducted by the Women's Health Initiative to study the health implications of hormone replacement therapy. In this experiment, researchers randomly assigned over 16,000 women to one of two treatments. One group took hormones. The other group took a placebo. The experiment was also double-blind, meaning that neither the women nor the researchers knew who had which treatment.

In a *single-blind*, experiment only one of the two (either the researcher or the participants) do not know which treatment the participants receive.

To end our discussion of experiments, we consider one last question: *If an experiment is well-designed, can we generalize the results?*

Recall the hormone replacement experiment. This experiment has all of the features of a well-designed experiment:

- A large number of participants (over 16,000 women)
- Use of a placebo group
- Random assignment of women to hormone treatment or placebo
- Double-blind design

After 5 years, the group taking hormones had a higher incidence of breast cancer and heart disease. Researchers were so alarmed by the results that the experiment was ended early to prevent further harm to the health of the women participating in the hormone group.

As a result of this experiment, the use of hormone replacement therapy fell by 66%.

Yet the British Menopause Society and the International Menopause Society questioned this reaction. The Women's Health Concern, a British nonprofit group that provides independent and unbiased information about women's health, wrote:

- *It must be remembered that the WHI data on which the concerns were raised related to overweight North American women in their mid-sixties and not to the women that are treated with HRT for their menopausal symptoms in the United Kingdom, who are usually around the age of menopause, namely 45–55 years.*

The concerns expressed here do not challenge the validity of the results of the WHI experiment. Instead, they question whether the results apply to a larger group of women: women who are younger and not overweight when they go through menopause.

This is an important consideration. If our goal is to generalize the results of an experiment to a more general population, we must consider issues of sampling design as well as random assignment.

An Important Point about the Role of Random Chance

We now know that in an experiment we intentionally manipulate the explanatory variable to observe changes in the response variable. We use the explanatory variable to create different treatments. If we see different responses in the different treatments, we want to be able to say that the differences are the result of the explanatory variable. We must rule out other possible explanations for the differences we observed, so we use direct control and random assignment, as well as a control group, a placebo group, or blinding as appropriate.

But none of these strategies will rule out the influence of *chance variation*. When we randomly assign participants to treatments, we produce similar groups most of the time. But there is a small chance that we will end up with treatment groups that are not similar.

For example, in the hernia experiment with children, we saw that random assignment creates two groups with average ages that are close. But there is a very small chance that we could get two groups that significantly differ in ages. This will not happen very often, but it could. And if it does happen, the results of our experiment are confounded by age.

Similarly, when we investigated how well a random sample estimates the proportion of students receiving financial aid in the population, we saw that the proportions from random samples gave good estimates—most of the time. Occasionally, a random sample did not give a good estimate. Larger random samples varied less, but they still varied.

What's the Main Point?

Good study design is important. Random selection in sampling can control bias. Random assignment in experiments can control the effects of confounding variables. But there is always a small chance, even when we randomly sample, that the results we observe in a poll do not represent the population well. Similarly, there is always a small chance, even when we use random assignment, that the differences we observe in an experiment are due to random variation and not the explanatory variable. For this reason, we have to understand how random chance behaves. This is the role of probability. We study probability later in the course, before we learn more formal statistical methods for determining if what we observe could be a result explained by chance.

Module 6 - Wrap Up "Collecting Data--Conducting an Experiment"

Let's Summarize

- The goal of an experiment is to provide evidence for a cause-and-effect relationship between two variables.
- A well-designed experiment controls the effects of confounding variables to isolate the effect of the explanatory variable on the response.
- Two commonly used methods for controlling the effects of confounding variables are *direct control* and *random assignment*.
- Random assignment uses random chance to assign participants to treatments, which creates similar treatment groups. With random assignment, we can be fairly confident that any differences we observe in the response of treatment groups is due to the explanatory variable. In this way, we have evidence for a cause-and-effect relationship.
- Other strategies for controlling confounding variables include use of a control group, use of a placebo group, and blinding.
- A well-designed experiment provides evidence for a cause-and-effect relationship. But even in a well-designed experiment, differences in the response might be due to chance. We learn to describe chance behavior when we study probability later in the course.