Section 1D – Experimental Design

Vocabulary

Explanatory Variable: The independent or treatment variable. In an experiment, this is the variable causes the effect.

Response Variable: The dependent variable. In an experiment this the variable that measures the effect.

Confounding Variables (or lurking variables): Other variables that might influence the response variable other than the explanatory variable being studied.

Experimental Design: A scientific method for controlling confounding variables and proving cause and effect.

Random assignment: A process for creating similar groups where you take a group of people or objects and randomly split them into two or more groups.

Placebo Effect: The capacity of the human brain to manifest physical responses based on the person believing something is true.

Placebo: A fake medicine or fake treatment used to control the placebo effect.

In statistics, we often want to determine if there is a relationship or association between two variables. We also may want to measure the strength of the relationship. For example, we may want to know if there is a relationship between blood pressure and heart rate. We may want to see if living in tropical climates is associated with having nut allergies.

In order to show that two variables are related or associated we use an observational study. We would collect data and use statistical methods to analyze and measure the strength of the relationship. However, showing that two variables are related does not prove that one causes the other.

Association ≠ Causation!!!!

Why?

Let us suppose that we have shown that there is a strong relationship between drinking alcohol and getting into a car accident. This tells us that alcohol consumption is an important factor to be considered when studying car accidents. However, this does not prove that drinking alcohol causes car accidents. Many factors go into having a car accident besides how much alcohol they consume. Can you name a few?

Other factors that may influence having a car accident besides alcohol: age of driver, experience of the driver, condition of the car, traffic, road conditions, weather, other drivers, distractions (like texting, eating or changing a radio station), using drugs, …

These are called "confounding variables". Confounding variables are factors that might influence your response variable other than the explanatory variable you are studying. In this case, factors that might influence having a car accident other than how much alcohol the driver consumed. Some statistics books call these "confounding variables" or "lurking variables".

Note: The explanatory variable (alcohol consumption) is not a confounding variable. Alcohol is the explanatory variable we were studying. Confounding variables are factors other than alcohol that might influence the response (car accident).

Here is the point. If many variables were involved in having a car accident, it would be wrong to say that the alcohol was solely responsible for the car accident. Alcohol is just one of many factors involved. We have shown that drinking alcohol is related but we have not proven cause and effect. To prove cause and effect we need to deal with the confounding variables.

Experimental Design

So how do we prove cause and effect? It is difficult. You would need to prove that each confounding variables is not involved and so it is only the explanatory variable that is causing the response. The key is controlling the confounding variables. Thankfully, scientists have put a great deal of thought into this process of controlling confounding variables and proving cause and effect. We call this process "experimental design".

Experimental design is a scientific method for controlling confounding variables and proving cause and effect. A key component to experimental design is the creation of similar groups through random assignment.

To control confounding variables, we will need to create two or more groups of people or objects that are very alike. One way to do this is by "random assignment". Random assignment is a process where you take a group of people or objects and randomly split them into two or more groups. The randomly assigned groups tend to be very similar. If we do not think the groups are similar enough, we can use techniques like blocking or direct control to make the groups even more alike.

Another way to make alike groups is to use the same group of people twice. Think about it. The two groups would be perfectly alike. They would have the same ages, same amount of stress, same genetics, same blood pressures and the same jobs.

Example

Let us look at the previous example. How do we prove that drinking alcohol does cause car accidents?

Explanatory (treatment) Variable: Drinking alcohol or not

Response Variable (what we will measure): Did the person get into a car accident or not?

So how do we set up an experiment to prove that drinking alcohol causes car accidents? The first thing is to list out your possible confounding variables.

Possible Confounding Variables: age of driver, experience of the driver, condition of the car, traffic, road conditions, weather, other drivers, distractions (like passengers, texting, eating or changing a radio station), other drugs, gender, race, genetics

To control the confounding variables, we need to create two groups of people. The two groups should be the same (or at least as similar as possible) in all areas that the confounding variables address. Therefore, the groups should have similar ages, similar driving experience, similar cars and car condition, similar road conditions and similar distractions, similar genders, similar race and ethnicity, similar genetics and reflexes.

There are two ways to go about this. Let us suppose we have a group of 80 adult paid volunteers to conduct this experiment. One option would be to randomly put the volunteers into two groups and try to make the groups as similar as possible. A better option in this case would be to use the same people twice.

We had the people in the experiment drive an obstacle course sober. They must have no alcohol or other drugs in their system. They all used the same car on the same track with the same weather. The course was designed with cones and we will monitor how many cones the people hit. They all were not allowed to have any other person in the car. There was no other distractions as radios and phones were not allowed. We will monitor how many car accidents they had by checking how many cones they hit.

Now we will have all the people drink a certain amount of alcohol and then drive the course again. It is important to see that the alcohol (treatment) group was made up of exactly the same people as the sober (control) group. The response variable we measured was the number of cones they hit.

Conclusion

The results found that the alcohol group hit significantly more cones (significantly more car accidents) than the sober group. We have now proven that drinking alcohol causes car accidents.

Think about it. It cannot be the ages of the drivers or driving experience. The two groups had the exact same ages and the exact same driving experience. It cannot be gender, race, genetics, or reflexes. The two groups had the exact same genders, race, genetics, and reflexes. It cannot be drugs or other distractions like phones or radios. Neither group had drugs or any other distractions. If you notice, every one of the confounding variables is the same in the two groups. The only difference was that one group had alcohol and the other did not. Therefore, the only reason why the alcohol group had significantly more accidents is the alcohol. The experiment has proven that drinking alcohol causes car accidents.

Note: It is easy to confuse the two variables in an experiment with the two groups. They are not the same thing.

In this case, the explanatory variable is having alcohol or not. The response variable is the number of cones (accidents) the drivers had. The two groups are decided by those that have explanatory variable (alcohol) and those that do not. In this case, the two groups are the exact same people measured twice.

We usually call the group that has the explanatory variable the "treatment group" and the group that does not have the explanatory variable the "control group".

Example 2

When a pharmaceutical company needs to prove that a medicine works, they must use experimental design. In the United States, pharmaceutical companies have to prove to the Food and Drug Administration (FDA) that their medicine has the effect it is supposed to and is relatively safe with few side effects.

Suppose a company has a new blood pressure medicine on the market and needs to prove to the FDA that taking it does decrease a person's blood pressure. The company needs to prove cause and effect.

If we have to prove cause and effect, we need an experiment. The first step is to think about the possible confounding variables. What are some reasons why a person's blood pressure might decrease other than taking this new medicine?

Possible Confounding Variables? Stress, Diet, Exercise, Genetics, Age, Gender, Race, Genetics, taking other medicines …

To set up the experiment we need to create two groups of people that are similar in these areas. We start with a group of volunteers with high blood pressure that want to try out this new medicine. We randomly assign the people into two groups. Amazingly when scientists randomly assign people into two groups, the groups tend to be a lot alike. The two groups would have similar numbers of people in each race, similar number of males and females, similar numbers of stressed out people, similar numbers of people that exercise a lot or do not exercise. The people running the experiment can also exercise direct control and intentionally assign people to certain groups to make the groups even more alike.

Human Brain (placebo effect)

There is a problem with our experiment. If a person believes something is true, their brain can tell the body to manifest physical responses. We call this the "placebo effect". Think of it this way. The group that thinks they are getting blood pressure medicine will not be as stressed out about it and their blood pressure may decrease slightly because of that belief. Similarly, the group that thinks they are not getting blood pressure medicine will be more stressed and worried and their blood pressure may increase because of that belief. In a sense, the human brain is a confounding variable that we need to control.

Placebo (fake medicine)

To control the placebo effect as a confounding variable, we need the groups to believe the same thing. One group cannot think they are getting medicine, and the other group cannot believe they are not getting medicine. So we introduce a placebo or fake medicine. The treatment group gets the real blood pressure medicine and the control group gets a fake medicine (placebo). No one in the experiment knows if he or she will be receiving real medicine or a placebo. Some may ask, "Won't that make them more stressed and increase their blood pressure?" Yes. The key is that the two groups will be equally stressed and believe the same thing. That way we control the placebo effect.

For this to work, the people in the experiment cannot know if they are getting the medicine or a placebo. This is called "single blind". When scientists first started using placebos, they were shocked to find that the people in the experiments somehow knew if it was a placebo. This defeated the whole purpose. It turned out they could tell by the body language of the person giving the medicine. The person giving the medicine tended to act differently if they were giving the real medicine verses a placebo. So the standard for an experiment about medicines is to use a "double blind" approach. A double blind experiment means that neither the people in the experiment, nor the people giving the medicine, know if it is a placebo or not. Someone knows though. The scientists keep very careful track of who receives a placebo and who receives the medicine. The person directly giving the medicine or placebo cannot know if it is a placebo or not.

Double blind works well. The people in the experiment no longer know if they are receiving a placebo or the real medicine. The experimental design has controlled the placebo effect.

Conclusion

Since we have controlled all of the confounding variables, the experiment has the possibility of proving cause and effect. We still need to see the blood pressures of both groups and make a conclusion. If the treatment group had a significantly lower average blood pressure than the control group, this would prove that taking the medicine does cause a person to have lower blood pressure. If the treatment group and control group have relatively the same average blood pressure, then we may conclude that the medicine is not effective in lowering blood pressure. This would be bad news for the pharmaceutical company. Deciding if one group is significantly higher than another can be very difficult. We will study confidence intervals, test statistics and P-value in later chapters to address this.

Summary

Use an experiment to control confounding variables and prove cause and effect. The groups in the experiment should be the same people either measured multiple times or separated by random assignment. The main idea is that the groups should be very similar in all areas that involve confounding variables. Experiments with medicines should be double blind with a placebo to control the placebo effect.

Use an observational study to see if there is a relationship (association) between two things. Remember observational studies do not control confounding variables, so cannot prove cause and effect.

How can I tell if a study is an experiment or not? Generally, look for random assignment. An experiment usually does not have a random sample of people from the population. The people in the experiment are usually volunteer. The volunteers are then randomly assigned into two or more groups. Random assignment means that they are not trying to apply something to the population, but instead are trying to use experimental design in order to prove cause and effect. If a study takes a random sample from the population, but does not randomly assign, it is probably just an observational study and cannot prove cause and effect.

Note: It should be noted that there are more complex forms of experiments than the types listed in this section. It may not be possible to randomly assign people into two groups. In that case, the scientist need to prove that each confounding variable is not involved. That is a more complex case that you may see in more advanced statistics classes.
