Designing Studies

CO-3: Describe the strengths and limitations of designed experiments and observational studies.

Video

Video: Designing Studies (1:34)

Now that we have learned about the first stage of data production — sampling — we can move on to the next stage — designing studies.

Introduction

Obviously, sampling is not done for its own sake. After this first stage in the data production process is completed, we come to the second stage, that of gaining information about the variables of interest from the sampled individuals. Now we'll discuss three study designs; each design enables you to determine the values of the variables in a different way.

You can:

- Carry out an **observational study**, in which values of the variable or variables of interest are recorded as they naturally occur. There is no interference by the researchers who conduct the study.
- Take a **sample survey**, which is a particular type of observational study in which individuals report variables' values themselves, frequently by giving their opinions.
- Perform an **experiment**. Instead of assessing the values of the variables as they naturally occur, the researchers interfere, and they are the ones who assign the values of the explanatory variable to the individuals. The researchers "take control" of the values of the explanatory variable because they want to see how changes in the value of the explanatory variable affect the response variable. (Note: By nature, any experiment involves at least two variables.)

The type of design used, and the details of the design, are crucial, since they will determine what kind of conclusions we may draw from the results. In particular, when studying relationships in the Exploratory Data Analysis unit, we stressed that an association between two variables does not guarantee that a causal relationship exists. Here we will explore how the details of a study design play a crucial role in determining our ability to establish evidence of causation.

Here is how this topic is organized:

We'll start by learning how to identify study types. In particular, we will highlight the distinction between observational studies and experiments.

We will then discuss each of the three study designs mentioned above.

- We'll discuss observational studies, focusing on why it is difficult to establish causation in these type of studies, as well as other possible flaws.
- We'll then focus on experiments, learning, among other things, that when appropriately designed, experiments **can** provide evidence of causation.
- We'll end by discussing surveys and sample size

Identifying Study Design

Learning Objectives

LO 3.1: Identify the design of a study (controlled experiment vs. observational study)

Because each type of study design has its own advantages and trouble spots, it is important to begin by determining what type of study we are dealing with. The following example helps to illustrate how we can distinguish among the three basic types of design

mentioned in the introduction — observational studies, sample surveys, and experiments.

EXAMPLE:

Suppose researchers want to determine whether people tend to snack more while they watch television. In other words, the researchers would like to explore the relationship between the explanatory variable "TV" (a categorical variable that takes the values "on'" and "not on") and the response variable "snack consumption."

Identify each of the following designs as being an observational study, a sample survey, or an experiment.

1. Recruit participants for a study. While they are presumably waiting to be interviewed, half of the individuals sit in a waiting room with snacks available and a TV on. The other half sit in a waiting room with snacks available and no TV, just magazines. Researchers determine whether people consume more snacks in the TV setting.

   This is an **experiment**, because the researchers take control of the explanatory variable of interest (TV on or not) by **assigning** each individual to either watch TV or not, and determine the effect that has on the response variable of interest (snack consumption).

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2. Recruit participants for a study. Give them journals to record hour by hour their activities the following day, including when they watch TV and when they consume snacks. Determine if snack consumption is higher during TV times.

   This is an **observational study**, because the participants themselves determine whether or not to watch TV. There is no attempt on the researchers' part to interfere.

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3. Recruit participants for a study. Ask them to recall, for each hour of the previous day, whether they were watching TV, and what snacks they consumed each hour. Determine whether snack consumption was higher during the TV times.

   This is also an **observational study**; again, it was the participants themselves who decided whether or not to watch TV. Do you see the difference between 2 and 3? See the comment below.

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4. Poll a sample of individuals with the following question: While watching TV, do you tend to snack: (a) less than usual; (b) more than or usual; or (c) the same amount as usual?

   This is a **sample survey**, because the individuals self-assess the relationship between TV watching and snacking.

Comment:

- Notice that in Example 2, the values of the variables of interest (TV watching and snack consumption) are recorded forward in time. Such observational studies are called **prospective**. In contrast, in Example 3, the values of the variables of interest are recorded backward in time. This is called a **retrospective** observational study.

Did I Get This?: Study Design

While some studies are designed to gather information about a single variable, many studies attempt to draw conclusions about the relationship between two variables. In particular, researchers often would like to produce evidence that one variable actually causes changes in the other.

For example, the research question addressed in the previous example sought to establish evidence that watching TV could cause an increase in snacking. Such studies may be especially useful and interesting, but they are also especially vulnerable to flaws that could invalidate the conclusion of causation.

In several of the examples we will see that although evidence of an association between two variables may be quite clear, the question of whether one variable is actually causing changes in the other may be too murky to be entirely resolved. In general, with a well-designed experiment we have a better chance of establishing causation than with an observational study.

However, experiments are also subject to certain pitfalls, and there are many situations in which an experiment is not an option. A well-designed observational study may still provide fairly convincing evidence of causation under the right circumstances.

Experiments vs. Observational Studies

Before assessing the effectiveness of observational studies and experiments for producing evidence of a causal relationship between two variables, we will illustrate the essential differences between these two designs.

EXAMPLE:

Every day, a huge number of people are engaged in a struggle whose outcome could literally affect the length and quality of their life: they are trying to quit smoking. Just the array of techniques, products, and promises available shows that quitting is not easy, nor is its success guaranteed. Researchers would like to determine which of the following is the best method:

1. Drugs that alleviate nicotine addiction.
2. Therapy that trains smokers to quit.
3. A combination of drugs and therapy.
4. Neither form of intervention (quitting "cold turkey").

The explanatory variable is the method (1, 2, 3 or 4), while the response variable is eventual success or failure in quitting. In an observational study, values of the explanatory variable occur naturally. In this case, this means that the participants themselves choose a method of trying to quit smoking. In an experiment, researchers assign the values of the explanatory variable. In other words, they tell people what method to use. Let us consider how we might compare the four techniques, via either an observational study or an experiment.

1. An **observational study** of the relationship between these two variables requires us to collect a representative sample from the population of smokers who are beginning to try to quit. We can imagine that a substantial proportion of that population is trying one of the four above methods. In order to obtain a representative sample, we might use a nationwide telephone survey to identify 1,000 smokers who are just beginning to quit smoking. We record which of the four methods the smokers use. One year later, we contact the same 1,000 individuals and determine whether they succeeded.

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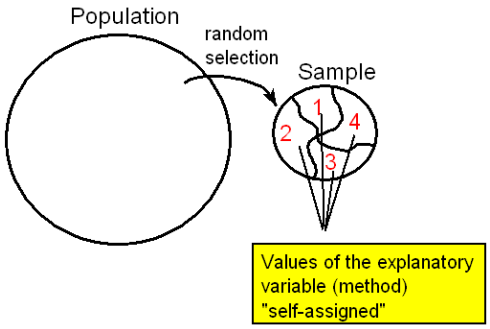
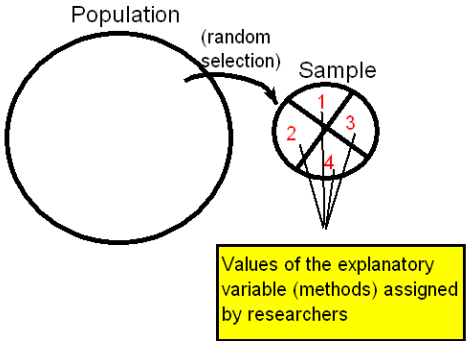
2. In an **experiment**, we again collect a representative sample from the population of smokers who are just now trying to quit, using a nationwide telephone survey of 1,000 individuals. This time, however, we divide the sample into 4 groups of 250 and **assign** each group to use one of the four methods to quit. One year later, we contact the same 1,000 individuals and determine whose attempts succeeded while using our designated method.

The following figures illustrate the two study designs:

Observational study:



Experiment:



Both the observational study and the experiment begin with a random sample from the population of smokers just now beginning to quit. In both cases, the individuals in the sample can be divided into categories based on the values of the explanatory variable: method used to quit. The response variable is success or failure after one year. Finally, in both cases, we would assess the relationship between the variables by comparing the proportions of success of the individuals using each method, using a two-way table and conditional percentages.

The only difference between the two methods is the way the sample is divided into categories for the explanatory variable (method). In the observational study, individuals are divided based upon the method by which they **choose** to quit smoking. The researcher does not assign the values of the explanatory variable, but rather records them as they naturally occur. In the experiment, the researcher **deliberately assigns** one of the four methods to each individual in the sample. The researcher intervenes by controlling the explanatory variable, and then assesses its relationship with the response variable.

Now that we have outlined two possible study designs, let's return to the original question: which of the four methods for quitting smoking is most successful? Suppose the study's results indicate that individuals who try to quit with the combination drug/therapy method have the highest rate of success, and those who try to quit with neither form of intervention have the lowest rate of success, as illustrated in the hypothetical two-way table below:

	Quit	Didn't Quit	Total	% Who Quit
Cold Turkey	12	238	250	5%
Drugs only	60	190	250	24%
Therapy only	59	191	250	24%
Drugs & Therapy	83	167	250	33%

Can we conclude that using the combination drugs and therapy method caused the smokers to quit most successfully? Which type of design was implemented will play an important role in the answer to this question.

> **Did I Get This?:** Study Design #2