Unit 14: The Question of Causation

SUMMARY OF VIDEO

Causation in statistics can be a tricky thing because appearances can often be deceiving. Observing an association between two variables does not automatically mean that there is a cause and effect relationship. One of the biggest challenges in attempting to prove causation comes from hidden factors. They might not be immediately apparent; they just lurk in the background. And that is exactly what we call them, lurking variables. For example, one study found that people who owned two or more cars tended to live longer than people who owned only one car. In this case, the lurking variable is the car buyer's affluence. Richer individuals own more cars and tend to live longer, probably because they have better access to medical care and healthier food. The cars have nothing to do with it.

There are times, however, when causation seems to be the only reasonable explanation for the relationship between an explanatory variable and a response variable. A good example of this is the case of smoking and lung cancer. There was a time when smokers did not give a second thought to the health risks they might be taking. This is a far cry from today when anyone can tell you smoking causes lung cancer; it is even printed on cigarette packs. But how can we say for sure that smoking causes lung cancer? The fact that there is a strong association between smoking and lung cancer isn't enough to show that smoking actually causes lung cancer. How do we know that the actual cause isn't due to a lurking variable instead?

The best way to make a case for causation is to do an experiment. We could go to a local hospital and randomly assign newborn babies to one of two groups: those we force to smoke, and those we prevent from smoking. We keep the newborns in isolation to keep out lurking variables. As the newborns get older, we compare the cancer rates in each group. The only difference between the two groups would be their smoking habits. However, we can't actually conduct such an experiment. So how can we get evidence for causation? The answer to this question was long in coming, but offers a fascinating look at biostatistical research.

Cigarette smoking became increasingly popular in America after World War I, when cigarettes were handed out to soldiers to boost morale. As smoking's prevalence increased, so did lung cancer rates. A handful of doctors began to raise early warnings about the dangers

of smoking. However, many doctors were smokers themselves and they didn't believe that smoking was the culprit. But in the early 1940s, new studies sounded a louder alarm on the dangers of smoking. One of the earliest and most compelling was a retrospective study conducted by Ernst Wynder and Evarts Graham. This study compared people with and without lung cancer, looking for big differences in background or habits. Smoking stood out. They discovered that patients that had cancer of the lung were 17 times to 1 as apt to be two-pack-a-day smokers than non-cancer patients. Despite the remarkable discrepancy in smoking habits between the two groups of patients, this retrospective study was not good enough. Because the study looked at past behavior, behavior it could not control, it is possible that lung cancer was due to any number of lurking variables – such as DNA (a common cause), or polluted environments (a confounding factor), or even just coincidence.

The next step in solving this epidemiological mystery was setting up prospective studies. Doctors Hammond and Horn of the American Cancer Society gave about 200,000 people a smoking questionnaire and followed them for four years. Unlike a retrospective study, which begins with sick people – cancer patients – and works backwards to examine their habits, a prospective study looks ahead, following healthy people – both smokers and nonsmokers – forward through time to see which ones develop lung cancer. The results of this study caused quite a sensation. It showed that people who smoked cigarettes had a lung cancer rate 10 times higher than people who never smoked. However, there was still concern that lurking variables could be present, making the association between smoking and lung cancer only appear strong.

The association between smoking and lung cancer stood up in many different studies in different places and with different kinds of people. However, these were still not experiments. Researchers turned next to animal experiments, and they showed that cigarette smoke does contain substances that cause cancer in animals. These experiments also confirmed a dose/response relationship: more smoke causes more cancer.

Between 1940 and 1960, while this research was going on, per person cigarette consumption doubled. In 1962, the Surgeon General assembled a group of experts to review the entire issue. They concluded that there was excellent evidence that cigarette smoking did in fact cause lung cancer. Since the Surgeon General's report, smoking has been under attack and has declined considerably.

The causal link between smoking and lung cancer was difficult to prove because direct experiments aren't possible. In this case, the non-experimental evidence is about as strong as it gets – the link was established in many studies with different groups of people, the association was very strong, smoke did contain cancer-causing substances, and finally, no other explanation other than causation was plausible.

STUDENT LEARNING OBJECTIVES

A. Understand that an observed association between two variables need not be due to a cause-and-effect relationship between the two variables.

B. In simple situations, identify lurking variables that can affect the interpretation of an observed association between two other variables.

C. Recognize the distinction between an experiment, a prospective study, and a retrospective study.

D. Understand that good experiments give the best evidence for causation, and that in the absence of experiments, we must rely on a combination of other evidence.

CONTENT OVERVIEW

In Unit 10, Scatterplots, a scatterplot of manatee deaths and the number of powerboat registrations shows a positive association between the two variables. However, the fact that there is a relationship between two variables is not sufficient evidence to prove cause-and-effect linkage. A well-designed experiment in which the researcher imposes some treatment on its subjects to see how they respond can give good evidence for cause and effect as you will learn in Unit 15, Designing Experiments. The main thrust of this unit, however, is to look at the problem of assembling evidence for causation when experiments cannot be done.

Many investigations of major public issues seek to find cause-and-effect relationships without conducting experiments. Does living near high-tension lines, or having low concentrations of natural radon in your basement, or eating foods with preservatives, increase cancer risk? Does the prevalence of violent video games increase violence in society? Do lower speed limits reduce traffic deaths? Smoking and health is one example in which the question has been settled, but only after decades of study.

A strong observed association can be due to direct cause-and-effect. But it can also be due to the effects of another variable, which we call a **lurking variable** because it lurks in the background. For example, an article in a women's magazine reported that women who nurse their babies feel more receptive toward their infants than mothers who bottle-feed. The author concluded that breast-feeding leads to a more positive attitude toward the child. But women choose whether to nurse or bottle feed, and this choice may reflect already existing attitudes toward their infants. Mothers who already feel more positive about the child may choose to nurse, for example, while those to whom the baby is a nuisance may be more likely to choose the bottle. The mothers' already established attitude is a lurking variable that prevents conclusions about whether breast-feeding itself changes mothers' attitudes.

To establish causation when an experiment cannot be done, we must amass a variety of less direct evidence. **Retrospective** and **prospective** studies can be part of that evidence. A retrospective study starts with an outcome (for example, a group of cancer patients and non-cancer patients) and then looks back to examine exposures to suspected risk factors or protective factors that might be linked to that outcome. A prospective study starts with a group (for example, a group containing smokers and nonsmokers) and watches for outcomes (cancer/no cancer) during the study period and relates this to suspected risk factors or protective factors that might be linked to the outcomes. Problems associated with lurking variables and bias are more common in retrospective studies than in prospective studies, so

prospective studies would be preferred over retrospective studies. However, retrospective studies are faster to complete since researchers look back at data that have already been collected. Prospective studies require researchers to collect the data as the study progresses. In addition, retrospective studies are generally preferred if the outcome of interest is uncommon. In that case, the size of the group under study in a prospective study may need to be so large that it would be too costly to conduct the study.

Now, we return to the study on the question of smoking causing lung cancer that was featured in the video. For that study, the "good evidence" includes:

- The observed association is very strong (heavy smokers are about 20 times more likely to get lung cancer than nonsmokers).
- The association appears in many studies, both retrospective and prospective, of different groups in different places. Prospective studies are more convincing than retrospective studies.
- The effect regularly follows the alleged cause in time.
- There is a plausible causal mechanism (cigarette smoke contains substances that can be shown by experiments to cause cancer in animals).
- There is no similarly plausible explanation based on lurking variables (for example, heredity can't account for the effect).

So, without an experiment where the levels of the explanatory variable are controlled and outcomes observed, it takes a great amount of evidence to establish a cause-and-effect relationship.

KEY TERMS

A **lurking variable** is an extraneous variable that is related to other variables in a study. A lurking variable that is linked to both an explanatory variable and a response variable can be the underlying cause for an observed relationship between the explanatory and response variable.

A **retrospective study** starts with an outcome and then looks back to examine exposures to suspected risk or protective factors that might be linked to that outcome.

A **prospective study** starts with a group and watches for outcomes (for example, the development of cancer or remaining cancer-free) during the study period and relates this to suspected risk or protective factors that might be linked to the outcomes.

THE VIDEO

Take out a piece of paper and be ready to write down answers to these questions as you watch the video.

1. People who own more cars tend to live longer than people who own fewer cars. Why is this relationship not evidence that buying more cars increases life expectancy?

2. Heavy smokers are about 20 times more likely to get lung cancer than nonsmokers. Why isn't this link by itself good evidence that smoking causes lung cancer?

3. What is the difference between a retrospective study and a prospective study?

4. Why is a prospective study that compares a group of smokers with a similar group of nonsmokers not an experiment?

5. Why do experiments with animals add to the evidence that smoking causes cancer in humans?

UNIT ACTIVITY:
RETROSPECTIVE AND PROSPECTIVE STUDIES

Conduct an Internet search to find examples of each of the following. In each case, does the study prove a cause and effect relationship?

1. Find a retrospective study that starts with some outcome group and looks to see if it is associated with increased or decreased physical activity. Be prepared to share a summary of the study that you found with the class.

2. Find a prospective study that investigates whether some disease or disorder (you pick the disease or disorder) is related to a suspected risk or protective factor.

3. Find an example of either a retrospective study a or prospective study different from your examples in questions 1 and 2.

EXERCISES

1. A study of elementary school children, ages 6 to 11, finds a strong association between shoe size and score on a reading comprehension test. Children with big feet tended to have higher reading scores. Is this evidence that big feet help people read better? What explains this correlation?

2. Members of a high school language club believe that study of a foreign language improves a student's command of English. From school records, they obtain the scores on an English achievement test given to all seniors. The average score of seniors who had studied a foreign language for at least two years is much higher than the average score of seniors who studied no foreign language. The club's advisor says that these data are not good evidence that language study strengthens English skills. Explain what lurking variables prevent the conclusion that language study improves students' English scores.

3. Recent studies have shown that earlier reports seriously underestimated the health risks (such as heart disease) associated with being overweight. The error was caused by overlooking important lurking variables. In particular, smoking tends both to reduce weight and to lead to health problems such as heart disease.

a. Describe how you would do a *retrospective study* of the link between being overweight and having heart problems.

b. Describe how you would do a *prospective study* of this same link.

4. Researchers posed the following question: Does physical therapy improve the return-to-work outcomes among workers with low-back pain due to injury? Consider the following two studies:

Study 1: Over the next five years, researchers, working with a large company, identify workers who file low-back injury claims. Then they follow up on those workers and record if they obtained physical therapy and if they returned to work.

Study 2: Researchers contacted the Workplace Safety and Insurance Board and retrieved the names of workers from a large company who filed lost-time claims due to low-back injury over the previous ten years. From the workers who filed lost-time claims, the researchers were able

to identify which of the workers requested reimbursement for physical therapy and which were able to return to work.

a. Which of the two studies is a retrospective study? Which is a prospective study? Justify your answer.

b. Which of the two studies is likely to be more costly? Explain.

c. Which of the two studies would be preferred in this situation? Why?

REVIEW QUESTIONS

1. A job-training program is being reviewed. Advocates claim that because the unemployment rate in the manufacturing region affected by the program was 9% when the program began and 5% four years later, the program was effective. Suggest lurking variables that might explain this outcome even if the program had no effect.

2. A study reported a positive association between using marijuana as a teen and having troubled relationships between ages 25 and 30. Based on this research should we conclude that teenagers' use of marijuana leads to relationship problems during the latter half of their 20s? Explain.

3. Does regular exercise reduce the risk of a heart attack? A researcher finds 2000 men over 40 who exercise regularly and have not had heart attacks. She matches each with a similar man who does not exercise regularly, and she follows both groups for 10 years. Is this an experiment? What kind of study is it? Explain your answers.

4. Consider the following two studies:

Study 1: A group of 568 married white men aged 30 – 70 who died from coronary heart diseases and a matched sample of living white men with similar characteristics (matched age, socioeconomic level, body mass index (BMI), etc.) were part of a study to see if there was an association between increased leisure time devoted to physical activity and decreased coronary disease.

Study 2: A group of 32,269 women were enrolled in the Breast Cancer Detection Follow-Up Study. The goal of the study was to see if increased physical activity was associated with reduced breast cancer rates. Usual physical activity (including household, occupational, and leisure activities) was assessed from a self-administered questionnaire. Subsequent breast cancer cases were identified through self-reports, death certificates, and linkage to state cancer registries.

a. Would you classify Study 1 as a retrospective or prospective study? Justify your answer.

b. Would you classify Study 2 as a retrospective or prospective study? Justify your answer.

c. Why did Study 2 need so many participants in the study compared to Study 1?