ACTIVITY 7

Addressing Cognitive Bias in Science

READING

Cognitive biases can impact a scientific investigation.

7: ADDRESSING COGNITIVE BIAS IN SCIENCE

GUIDING QUESTION

How does slow thinking improve scientific conclusions?

INTRODUCTION

Like any human, scientific researchers can be unconsciously influenced by cognitive shortcuts or pre-existing ideas. For instance, they might unknowingly pay more attention to data that supports their first guess and ignore data that goes against it. To reduce the chance of errors from cognitive shortcuts and cognitive bias, the scientific process includes steps to support slow thinking and an actively open mindset. In this activity, you will learn about scientific practices that limit a researcher's personal bias when designing studies, analyzing data, and forming conclusions. By looking at examples from historical and modern disease outbreaks, you'll explore how these practices help make scientific information more reliable.

CONCEPTUAL TOOLS

MATERIALS LIST

FOR EACH STUDENT

— 3–5 STICKY NOTES

PROCEDURE

1 Read about the scientific investigations of a disease called pellagra and the more recent outbreak of COVID–19. Use the Read, Think, and Take Note Guidelines as you read.

READ, THINK, AND TAKE NOTE GUIDELINES

Stop at least three times during each section of the reading to mark on a sticky note your thoughts or questions about the reading.

As you read, use a sticky note from time to time to:

- explain a thought or reaction to something you read.
- note something in the reading that is confusing or unfamiliar.
- list a word from the reading that you do not know.
- describe a connection to something you've learned or read previously.
- make a statement about the reading.
- pose a question about the reading.
- draw a diagram or picture of an idea or connection.

After writing a thought or question on a sticky note, place it next to the word, phrase, sentence, diagram, drawing, or paragraph in the reading that prompted your note.

After reading, discuss with your partner the thoughts and questions you had while reading.

READING

CASE STUDY 1 THE PELLAGRA EPIDEMIC

Pellagra is a disease that causes a red scaly rash, dementia, diarrhea, and sores in the mouth. Ultimately, pellagra can lead to death. Pellagra has been found in the United States, Indonesia, Europe, China, and throughout Africa. From 1900 through 1940, over 3 million people suffered from it in the United States, and more than 100,000 died from it. The epidemic struck the southern part of the United States hardest, mostly affecting those who were living in poverty, such as farmers and mill workers.

A man (left) and 4-year-old child (right), both showing severe pellagra rashes.

In the early 1900s, new diseases were often thought to be caused by infectious microbes (sometimes called germs). The cause of pellagra was unknown, but most scientists thought that pellagra was caused by a microbe that made people sick. This idea was influenced by pellagra's similarities to well-known contagious illnesses such as typhus and cholera, which spread through contact with infected human feces. This idea was strengthened by the Thompson-McFadden report in 1912. It included evidence that pellagra occurred more often in neighborhoods without sewers or proper sanitation. Another researcher proposed that pellagra was spread by black flies, which were often found where the disease was severe. Because the flies were so annoying, the fly explanation came easily to mind for researchers.

Goldberger's Actively Open Mindset

Although the pellagra-germ hypothesis was accepted among researchers, not much progress was made in proving a microbe was the cause. For example, it was true that the fly lived in the same poor areas as people with the disease, but pellagra was also found where the fly was absent. Researchers were also unable to transmit the disease to animals by using samples from patients with the disease. New ideas needed to be considered.

In 1914, the United States government hired Joseph Goldberger to investigate. As Goldberger began his research, he relied on scientific practices that used slow thinking and an actively open mindset. He began to explore alternative explanations for what was causing pellagra. One was a toxin hypothesis that claimed that the disease came from eating spoiled corn. Pellagra appeared in areas where corn was regularly eaten, and some of pellagra's symptoms resembled those from food toxins. However, the corn did not make everyone sick, and no specific toxin was found.

Another explanation Goldberger considered was a missing-nutrient hypothesis. This hypothesis suggested that pellagra had a nutritional cause. Many people who developed pellagra ate a very limited diet of cornmeal, fatty pork, and molasses syrup, with few fruits or vegetables.

The Spartanburg General Hospital in South Carolina, 1914. It was created to study and treat pellagra patients.

Goldberger decided to seek out new information to help narrow down the possibilities. He observed that in orphanages and mental institutions, the children and residents frequently got pellagra, but the staff (doctors, nurses), who were in constant contact with the sick, never did. This seemed unlikely if the disease was infectious. He also noted that the staff had access to better food, while residents ate the limited cornmeal diet. Goldberger could not find any contamination in the corn and food supplies. He wondered if the difference was in the quality of food eaten. He thought this could explain why children and residents at institutions developed pellagra while the nurses and doctors did not.

Goldberger's observations were not enough to prove that the poor diet caused the disease. To address this, he designed an experiment. In 1914, Goldberger tested the missing-nutrient hypothesis at an orphanage in Mississippi by adding fresh meat, milk, and vegetables to the children's diet. He left other factors, such as sanitation, the same. The disease cleared up, and no new cases developed in the children who received the better diet. However, when funding ran out in 1916, the old diet resumed, and pellagra returned. Similar results developed in other experiments. Goldberger concluded that it was not bad sanitation but a poor diet that caused people to develop pellagra.

Facing Skepticism

Despite Goldberger's evidence that pellagra was caused by a poor diet, most scientists were convinced of the pellagra-germ hypothesis. Wealthy business owners also rejected the link to a poor diet because this meant admitting that they did not pay their employees enough to afford better food.

To prove the disease wasn't infectious, Goldberger hosted a series of "filth parties." He had volunteers intentionally consume capsules made from the skin, feces, mucous, and urine of pellagra patients. None of the volunteers developed pellagra. This further supported the idea that pellagra was not caused by a germ. The outrageousness of the parties brought needed attention to Goldberger's ideas. This led to his ideas being eventually accepted by the scientific community.

Goldberger continued his research and eventually discovered an inexpensive cure for the disease. A daily dose of brewer's yeast, which is used to make bread and beer, could get rid of pellagra symptoms. This provided even more evidence that the disease was caused by a missing nutrient. Goldberger suspected that lack of a specific vitamin was the cause. In 1937, years after Goldberger's death, researchers discovered that a lack of Vitamin B_3 (niacin) was the specific cause of pellagra.

Goldberger was successful, in part, because he did his best to avoid cognitive biases and use slow-thinking techniques. His actively open mindset also motivated him to explore different hypotheses about the cause of pellagra. Goldberger experienced more resistance than he should have to his ideas, but challenging ideas is a normal part of the scientific process. Instead of settling on the easiest answer, researchers regularly question one another's reasoning. This practice keeps the scientific community open to alternative explanations. Eventually, enough evidence is collected over time to reach a reliable conclusion.

CASE STUDY 2 THE mRNA VACCINE

Since the time of Goldberger's investigations, the process of science has evolved. While the practices of slow thinking and an actively open mindset remain central, there have been formalized scientific practices to support it. These practices help ensure accuracy, reduce bias, and improve conclusions in scientific research.

A great example of this progress is the development of the vaccines for SARS-CoV-2, the virus that causes COVID-19. In 2020, the dangerous COVID-19 pandemic swept the world and has since claimed over 7 million lives worldwide. The start of the pandemic led to an urgent search for solutions, such as treatments and vaccines. Vaccines help prevent an infectious disease or drastically reduce the severity of the illness. However, scientists quickly realized that traditional vaccine development—which can take up to 15 years—was too slow for this global emergency. The clock was ticking. Scientists looked for alternatives. The solution was found in a decades-long idea that led to the development of the COVID-19 vaccines in less than 1 year. It was one of the fastest, yet effective, medical advancements in history.

A Decades-Long Idea

It began in 1997, with a chance meeting of biochemist Katalin Karikó and immunologist Drew Weissman. Karikó, an immigrant from Hungary to the United States, had struggled to fund her research but had a new idea for using messenger RNA (mRNA) as a way to transport a new type of medicine in the body. When Karikó met Weissman, he was working on vaccine research for Human Immunodeficiency Virus (HIV) and other diseases. He was open to her ideas. For many years, they worked together to develop an mRNA technology for delivering medication to the body. Progress was slow and their ideas were not well accepted at the start, but their persistence helped their work gain acceptance.

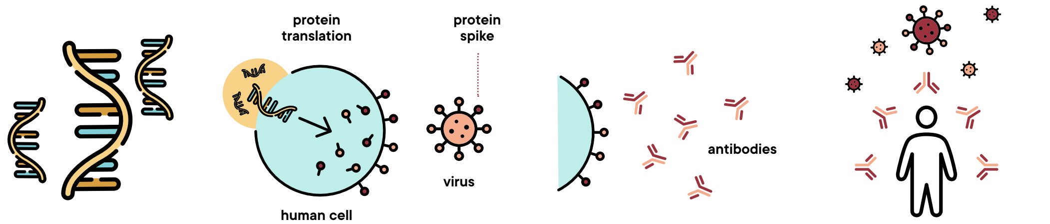


FIGURE 7.1 Information about mRNA vaccines

WHAT IS mRNA?

In our bodies, mRNA lives in our cells and carries information on how to build specific proteins.

HOW IS IT USED?

In vaccines, mRNA is used to deliver the instructions for building a protein identical to part of a virus or bacterium.

HOW DOES IT HELP?

Once the protein is assembled, our immune system recognizes it as a foreign body and produces antibodies that will attack the protein when it encounters it again.

WHAT HAPPENS NEXT?

The body's own immune cells take over, remembering which protein to target, and the mRNA vaccine breaks down and is cleared from the body.

Before the COVID-19 pandemic, the mRNA delivery technology that Karikó and Weissman created was used for years to safely deliver cancer treatments. Other researchers recognized the potential of mRNA vaccines as a solution to preventing infectious disease. This is because mRNA is a key component of a cell's protein-making machinery. An mRNA vaccine works by using a specially engineered piece of mRNA that signals your body's own cells to produce pieces of protein that look like the virus. Then, like other vaccines, your immune system recognizes and attacks the virus-looking proteins. This leaves the immune system primed and ready to fight off the real virus if it encounters it later.

Karikó and Weissman were not the only ones working on vaccine solutions during the pandemic. A team led by Chinese virologist Zhang Yongzhen identified the virus that causes COVID-19 and mapped out its genetic code by early 2020. A United States' research team led by Barney Graham and Kizzmekia Corbett had spent years working on an mRNA vaccine for a different virus. They quickly switched their focus to the COVID-19 virus. Using the genetic code, they engineered a modified version of the virus' mRNA with the natural spike protein that could be used for the vaccine. The spike protein is a marker found on the surface of the virus that the immune system can recognize and attack. The researchers combined the spike protein mRNA sequence with Karikó and Weissman's proven mRNA delivery technology. These breakthroughs led to the two similar vaccines that were available about the same time. They were the first vaccines approved for emergency use to fight the pandemic.

Throughout the decades of work on the mRNA technology and viral vaccines that led up to the COVID-19 vaccines, scientists used a well thought out and complete scientific process. Unlike treatments developed in the era of the first pellagra outbreaks, these new vaccines had to pass rigorous testing to prove that they worked and wouldn't cause harm. The COVID-19 vaccine research relied on strict scientific practices.

Experimental Design

To test the COVID-19 vaccines, researchers held large-scale clinical trials. A clinical trial is a carefully controlled experiment to test a medicine's safety and effectiveness. For example, in the clinical trial for the Pfizer-BioNTech COVID-19 vaccine, over 40,000 participants from 6 different countries participated. They were randomly split into 2 groups. One group received the actual mRNA vaccine, while the other received a placebo. A placebo is a treatment that looks exactly like the real medicine but contains no active ingredients. This approach improves scientific conclusions by reducing cognitive bias while gathering data, such as confirmation bias from patients knowing if they got the vaccine or not.

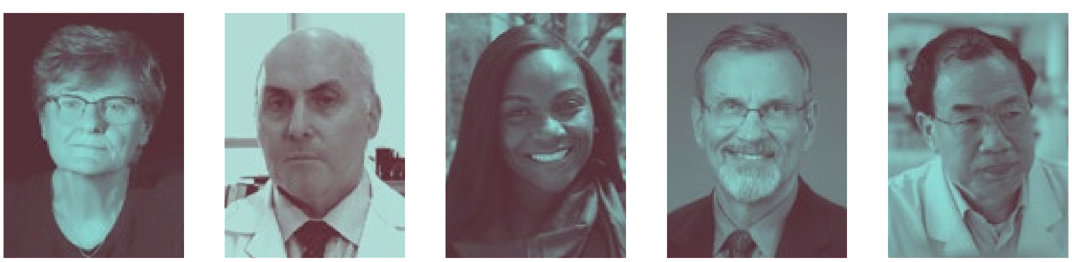
Another way to reduce the cognitive bias during data collection is to use a double-blinded experiment. In the COVID-19 clinical trials, neither the doctors giving the shots nor the participants knew who got the real vaccine and who got the placebo. This is an important procedure that keeps the data collection unbiased and without a conflict of interest. For example, if a doctor knew a participant got the real vaccine, they might ignore a mild cold symptom that could be a potential side effect. Similarly, if a participant knew whether or not they got the vaccine, they might ignore or exaggerate a symptom. By keeping everyone "blind" until the study was over, researchers ensured the evidence was genuine and reliable.

The clinical trials for the COVID-19 vaccine had exceptional results. The vaccine was 90% effective at preventing the infection. Nine out of 10 cases of severe COVID-19 occurred in the placebo group during the clinical trial. The careful and methodical way the data were collected helped make this evidence convincing. As a result of the clinical trial, the vaccine was approved and administered to millions of people over the next year, which altered the course of the pandemic by preventing millions of cases of severe illness and deaths worldwide.

Peer Review

Careful experimental design is only one aspect of scientific research that helps increase the accuracy of conclusions. Another critical piece of regular scientific practice is that of peer review. Peer review is a process in which a scientist's research is critically evaluated and judged by other independent experts. The experimental design, results, and conclusions are scrutinized. This practice pushes scientists to use slow thinking and an actively open mindset to consider evidence both for and against their ideas and to notice when they are interpreting their results in a biased way. While peer review is not fail-proof, it has an important role in increasing the accuracy of scientific conclusions over time.

Peer review of the science behind the COVID-19 vaccines was an important step in the vaccines' approval. This allowed other people to rigorously examine the experimental methods and data. The reviewers also reviewed the claims about vaccine safety and effectiveness. The success of the mRNA vaccines showed that even during a global crisis, science works best when researchers collect unbiased evidence, use carefully designed experiments, and work together to discover and critique new ideas.



Key contributors to the COVID-19 mRNA vaccine: Katalin Karikó, Drew Weissman, Kizzmekia Corbett, Barney Graham, and Zhang Yongzhen.

BUILD UNDERSTANDING

1. Give an example of a scientific practice from the reading that shows the following approaches, using an actively open mindset.
   - a Seek out evidence for and against a claim.
   - b Consider alternative explanations.
   - c Be open to others' ideas.
   - d Evaluate the need for more evidence.

2. Give an example from the case study about the pellagra epidemic that illustrates
   - a a cognitive shortcut.
   - b slow thinking.

3. Explain how the scientific practices described in the reading require scientists to apply slow thinking rather than relying on cognitive shortcuts.

CONNECTIONS TO EVERYDAY LIFE

4. Imagine that when you finish a big project for school, you ask a friend to read it over before you turn it in.
   - a How is this process similar to and different from what scientists do in a peer review?
   - b How might your friend's objective feedback help you avoid a cognitive bias in your own work?

5. You see an article that states: *A new study showed that a newly developed vaccine for tuberculosis (TB) prevents over 50% of TB infections.* You decide to look up the study to see if you trust the results. What would you look for in the study?

X-ray imaging of the lungs can help diagnosis tuberculosis, a very contagious respiratory disease.

KEY SCIENTIFIC TERMS

clinical trial
peer review