1 Cognitive Psychologists' Approach to Research

Introduction

When you are driving and your mind wanders from the song on the radio, to the next left turn you have to make, to what's for dinner, do you pause in the middle to wonder what makes your mind wander? Probably not. Most of the people we know do contemplate how the mind works, but only when their mind lets them down. They contemplate memory ("Why can't I remember the answer to this test question?"), attention ("I want to understand this material, so why can't I keep my focus on my book and not on my phone?"), and vision ("How could someone think those two colors go well together?"). Questions such as "How does vision work?" seem somewhat interesting, but no more interesting than thousands of other questions about how the world works (how do viruses work? How do cell phones work? How do your lungs work?). These questions become interesting to most people when they consider how the answers might help their own lives. For example, if we understood how vision worked, maybe we could build cars that can see (see Figure 1.1).

Figure 1.1. As it turns out, engineers designing self-driving cars gave up on making cars see as well as people (solving "human vision") and added a bunch of useful sensors such as GPS, lidar (which sends out pulses of light and measures how they bounce back), as well as radar, and infrared and ultrasonic sensors, all unavailable to human vision. (Credit: JasonDoiy/iStock Unreleased/Getty Images.)

To scientists, these questions are the fascinating entry into a world of other questions. Once we start looking a little closer and more systematically (by using the methods of science) we can uncover answers to these vital questions, but we also discover new layers of questions. Viruses have parts, but how are these parts related and what are their functions? How do viruses reproduce? What are the steps in the process and what happens if we interfere?

Cognitive psychology is a science of mental processes. This book is therefore an introduction to the scientific study of your own mind. We will provide some answers you didn't know you wanted and a world of fascinating questions you didn't know you had about something we all too often take for granted: our own mind.

The first thing we have to decide, then, is which questions to ask – how to get more specific than "How do we see?" You'll find that the questions we ask are deeply influenced by assumptions we make about the mind and, indeed, assumptions about what it is to be human.

It seems obvious that it would be better not to make assumptions when we are just starting to study the mind. After all, shouldn't we have an open mind about what we might find before we begin our investigation? The first question to take up is **Why make assumptions?** As we'll see, the answer is that it is often impossible to avoid making assumptions. If that's true, we should at least be clear about the assumptions cognitive psychologists make. If you know the assumptions, it will be clearer why cognitive psychologists ask the questions they do, and if you understand why they ask a particular question, it will be much easier to understand the answer.

But the approach cognitive psychologists take to scientific questions developed as a response to other approaches that people had tried in the past. Thus, our second question is

How did philosophers and early psychologists study the mind? As we'll see, a number of different approaches have been tried in the last 2,000 years, but it was only about 150 years ago that scientists began a serious, systematic effort to apply the scientific method to human thought. That date is some 200 years or more after the scientific method had been used in other domains of knowledge. Furthermore, cognitive psychology was not the first scientific approach to studying the mind; it arose in response to the flaws in other methods.

Finally, our third question is **How do cognitive psychologists study the mind?** As we'll see, the cognitive approach is informed largely by an analogy of the mind to a computer; like a computer, the brain takes in information, manipulates it, and then produces responses. The truth is more complicated than that, of course, and we elaborate on this metaphor later.

Why Make Assumptions?

Preview

People make two types of assumptions when they study the mind. The first assumption concerns the questions we ask. Our mental processes are not obviously composed of parts, or based on foundations, so decomposing the big questions into parts or foundations involves assumptions about what those big questions are and how they can be divided. We can't study everything at once, so we must pick some aspect of the mind as a starting point for study. What we perceive to be the starting point is biased by our assumptions about the mind. The second type of assumption is a set of general, vague beliefs about the mind that affects how we think about vision, attention, or memory before really knowing anything about them. In this section, we look at examples of these assumptions in the study of vision.

Psychologists typically make two types of assumptions in studying the mind. First, we make assumptions about what aspects of the mind are important enough to explain. We can't say, for example, "This study will explain everything about vision." Of course, we want to do that eventually, but we have to start somewhere. So what question about vision will we pose first? Maybe "how do we perceive colors?" Or "how do we perceive space? Or objects? Or motion?" All of these are possible starting points, but they also represent an assumption, namely that they are separate questions. Are perceiving an object and perceiving that object's motion actually separate psychological processes? Does recognizing an object require a different mental process than knowing its location so you can grab it?

The second type of assumption is that beliefs about characteristics of a mental process are often based on our own experience of them. For example, we assume that our eyes are active agents in perception, that they *do* something to help us see; indeed, as we move our heads, point our eyes in different directions and focus on objects, so we perceive different parts of the world. But a faulty assumption also stems this experience. Some people today (and many people years go) thought that we perceive the world by emitting something from our eyes. In antiquity, many believed that the mechanism for vision was some sort of invisible ray shooting out of our eyes, rebounding off the world and returning to tell us its characteristics (see Figure 1.2). Such an assumption might lead us to investigate the nature of those rays. Interestingly, many young children (Winer & Cottrell, 1996) and some adults (Winer et al., 2002) still believe something like this.

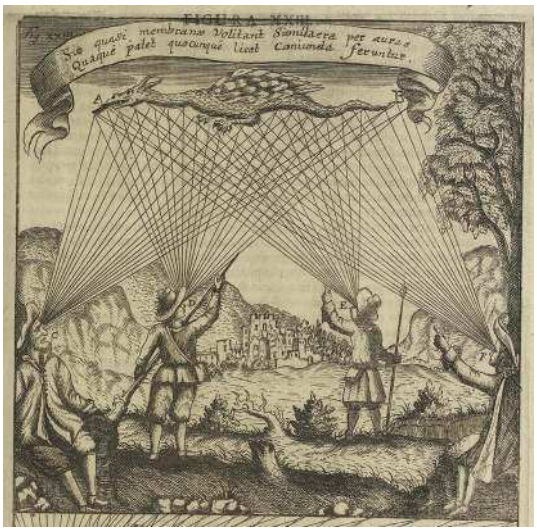

Figure 1.2. Many ancient philosophers thought that vision was dependent on rays emitted from the eyes. The Muslim polymath Alhazen was one of the first to propose a purely intromission theory (only rays coming in) in the tenth century, but such beliefs persisted. Even Leonardo da Vinci remained convinced that our eyes emitted rays. (Johann Zahn's *Oculus Artificialis* (1685), image from The Public Domain Review, https://publicdomainreview.org/collections/images-from-johann-zahns-oculus-artificialis-1685/.)

Here's another example of each type of assumption (the first: what's to be explained, and the second: how to characterize what we're explaining). For most of the last 2,000 years, people interested in vision have wanted to explain the conscious experience of visual perception, asking, "How do we consciously perceive the qualities of an object – its shape, size, and distance?" In assuming that the conscious experience of perception was what needed explaining, unconscious processes involved in vision were not considered. For the second type of assumption, in seeking to explain conscious perception, most investigators have assumed that what seem like distinct and separable qualities in our conscious visual experience are processed separately and therefore can be investigated separately. For example, color, shape, and motion feel like different conscious visual properties, and are therefore (we assume) supported by different mental processes. This is a pretty useful assumption, but it is not always true, as the illusion in Figure 1.3 shows.

Cognitive psychologists also seek to explain conscious visual perception, but they are more interested in the unconscious processes that eventually lead to conscious perception. In some ways, visual information in consciousness is the endpoint of vision; we need to explain the many steps that lead to this endpoint. Indeed, it has recently become obvious that some types of vision never become conscious. For example, some parts of the visual system help you maintain your balance, but you are never aware of any aspect of this type of vision.

The second type of assumption, about the characteristics of mental processes, includes beliefs that influence the questions we pose when we study something. For example, one dilemma about vision was this: The lens of the eye inverts the image of the world so that the image is projected onto the back of the eye upside down. We obviously don't see the world upside down, so how does the image get turned right side up? (See Figure 1.4.)

This question was posed in 1604 after Johannes Kepler speculated that the crystalline body of the eye functions as a lens and therefore inverts the image. (René Descartes put the idea to the test some 20 years thereafter, conducting an experiment with the eye of a bull.) This question bothered philosophers until the early nineteenth century, even though William Molyneux, writing in 1692, gave the correct answer to this problem: It's not really a problem. It doesn't matter that the top of the world is represented on the bottom of the retina (the layer that contains the light-sensitive cells at the back of the eye).

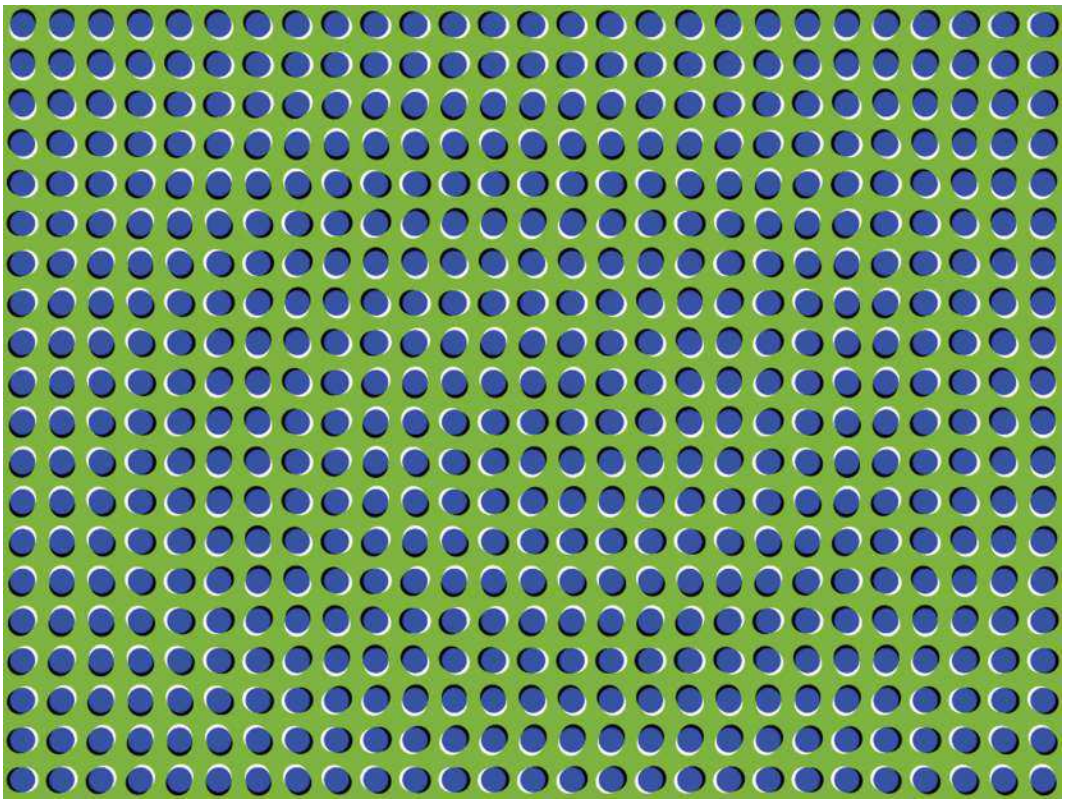

Figure 1.3. Color, shape, and motion seem like they should be independent and separate mental processes, but it turns out that certain colors and shapes can cause us to see motion. (Credit: Akiyoshi Kitaoka.)

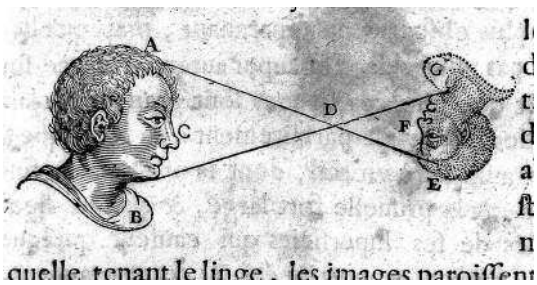

Figure 1.4. Light falling on the eye is inverted by the lens. Descartes depicted this in a drawing for his *Discourse on the Methods*. Therefore, the image on the retina is upside down compared with objects in the real world. (Wellcome Collection. Reproduced under Creative Commons License Attribution 4.0 International (CC BY 4.0).)

Why was the inversion of the retinal image so perplexing? Because of a background assumption about vision everyone was making. It seemed reasonable to assume that the conscious perception of the visual world was not in the retina but in some part of the brain. The assumption was that the retina presents an image to the part of the brain that handles conscious perception. You might think of the back of the eye as a screen on which another part of the brain watches the world go by – upside down. So the natural question to ask is "How does the mind perceive the world right side up?" But this assumption is wrongheaded because the conscious visual part of the brain is not a little

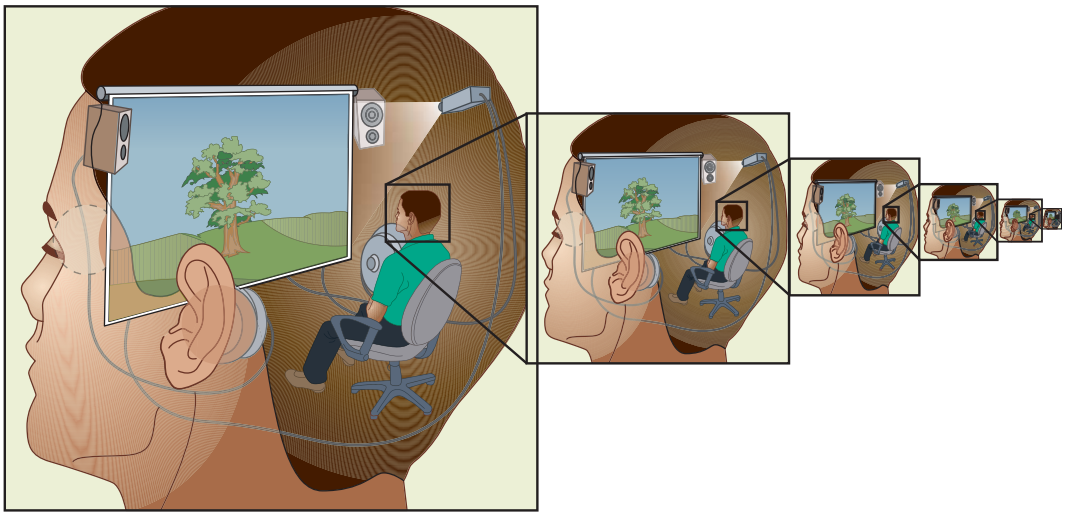

Figure 1.5. If there is a little person in our head, watching the image on the back of our eye, like a movie screen, what is inside the head of that little person that enables them to perceive the world? (Illustration by Jennifer Garcia.)

person watching the retina. Who would watch that little person? And what happens to their eyes? (See Figure 1.5.)

Johannes Mueller, a German physiologist, proposed instead that everything the mind perceives is a function of the state of the nerves coming into the brain. He called it the "theory of specific nerve energies" (Müller, 1840). The pattern of neural activity is perception; perception is not the product of a little person in your brain watching an image that your eye makes. Therefore, it doesn't matter whether the top of the world is represented in the top or the bottom of the retina as long as there is a consistent relationship between what is in the world and the pattern of neural activity to which it leads. If the top of the world could be represented anywhere in the retina, that would be a problem, but with the top of the world consistently in the bottom of the retina, we understand what we are seeing.

Here's another way to think about it. As you might know, a computer graphic file is stored as a series of 1s and 0s. You might have discovered this fact if you tried to open an image file with a word processor. When they are interpreted by the (correct) software in your computer, the 1s and 0s form an image of . . . let's say a lovely view of a college graduation. You would not expect that if you printed out the 1s and 0s on a piece of paper, they would form the image of the fountain; the 1s and 0s are a different representation of the image of the view (see Figure 1.6). If you were transmitting that information, information from the top of the image wouldn't have to be transmitted first. In the same way, the pattern of neural activity on the retina doesn't have to look like the thing it's representing. Once you drop the belief that the pattern of neural activity on the retina must look like what is out in the world, you realize the inverted image is not a problem. The way that information about the light gets from the retina to the brain is not as an image, but as a code. And codes aren't upside down or right side up.

If making assumptions prompts you to ask pointless questions, it seems obvious enough that we should avoid making assumptions. But it's much harder than you might think not to assume anything. Many of our assumptions are hard to spot because we take them for granted. Had the authors of this book lived in the seventeenth century, we don't think we would have been smarter than everyone else about the lens-inverting-the-image problem. We would have been scratching our heads with the rest of them.

(a)

(b)

Figure 1.6. A computer can represent the image of a happy college graduation (a) in a format that looks nothing like the image (b). The representation is interpreted by software in the computer and displayed as an image on the screen. The cells in our eye and brain could do the same thing, representing the light, dark, and color of a scene without being "image-like" at each step. This is why the "upside-down problem" is not really a problem. (Credit: (b) Photo by Cedar Riener.)

So we need to ask what assumptions cognitive psychologists make. How do they view the mind? What questions seem natural to ask if you're a cognitive psychologist? We get to that later in the chapter. In fact, we're not going to continue our discussion of studying the mind with cognitive psychology. The field of cognitive psychology is only about 60 years old, yet people have been thinking about how the mind works for more than 2,400 years. It is misleading to wrench cognitive psychology out of that historical context. Many of the ideas in cognitive psychology grew out of older ideas, or in some cases, in direct opposition to older ideas. So we start with the older ideas, which set the stage for cognitive psychology. We will follow a similar pattern in many future chapters, understanding how older ideas (which are often the first that come to mind) have changed our assumptions about the mind.

Stand-on-One-Foot Question

1.1 What two types of assumptions are usually made when we study the mind?

Question That Requires Two Feet

1.2 When we study the mind, we can't observe it directly. We can observe what people do and we can observe the environment around them, but we can't observe thought directly. What do you think this fact will mean for theories of the mind?

How Did Philosophers and Early Psychologists Study the Mind?

Preview

We can identify three waves in the history of the study of the mind before the advent of cognitive psychology. In the first wave, philosophers considered the workings of the mind. They were interested primarily in the acquisition of knowledge in all its forms. The second wave occurred in the late nineteenth century, when researchers applied the scientific method (which stresses observation, not reason alone) to the study of the mind. Although the scientific method had been developed during the Renaissance and applied to other domains, it had not been applied to the mind, mostly because of assumptions people held about how the mind was likely to work. Initially, psychology was largely the study of conscious experience, but it took a radical turn between 1910 and the 1920s, when consciousness was expunged and psychology became the science of overt behavior. This movement, called behaviorism, was the third wave. Behaviorism was ascendant until the late 1950s, when mental life reasserted itself as an important part of any explanation of human behavior.

In this section, we cover three broad trends in the history of the study of the mind before the development of cognitive psychology. The first trend concerns the philosophical background of the study of the mind. We discuss only Western philosophy because that is the philosophical tradition that influenced early psychologists and, eventually, cognitive psychologists. Other philosophers and thinkers certainly thought about the mind, but many of their ideas did not have as direct an influence on modern thought, even if they were closer to the truth than many of their Western counterparts.

The second trend concerns the application of the scientific method to the study of the mind. Even if the scientific method was applied to much of the physical world in the eighteenth century, it wasn't until much later that it was used to study the human mind. The third concerns the abandonment of the study of the mind in favor of the study of behavior. Studying mental processes proved quite difficult for early scientific psychologists, and focusing on behavior, instead of mental processes, dominated psychology in the early twentieth century.

Philosophical Underpinnings

ANCIENT GREECE Approximately 2,400 years ago, the philosophers of ancient Greece left the first written record displaying consistent curiosity about the mind and speculation about how it works (although there are bits and pieces scattered through earlier documents).

Philosophy is the pursuit of knowledge in all its forms, although over time many philosophical questions have been co-opted by the sciences. Because knowledge is central to philosophy, philosophers have been especially interested in how knowledge is acquired. There are three ways of asking how knowledge is acquired, and these three questions were later asked by cognitive psychologists:

- **Perception.** How do we gain access to knowledge about the world immediately around us?
- **Memory.** How do we retain knowledge about the world for later use?

- **Nature and nurture.** What is the origin of knowledge? Is knowledge gained through experience, or is it largely innate, with experience serving to release or activate knowledge we are born with?

The Greek philosophers posed questions about the mind that were relevant to their broader interests about knowledge. How accurate were their answers? They weren't even close. In fact, the Greeks were usually incorrect both in outlook and in detail. For example, Plato proposed that visual perception occurs when the eye emits some sort of beam, which combines with an essence of the object and then projects back to the eye, an idea we've already mentioned held sway for a long time.

Maybe the answers that Greek philosophers produced were not accurate, but were they at least asking good questions? Many books will tell you that the Greeks' lasting contribution lies in the questions they raised, which set the agenda for future philosophers and eventually for cognitive psychology. We don't think that's quite accurate, though. Their real contribution lay not in their specific questions but in three assumptions they made that allowed them to pose those questions:

- **The world is predictable**: The world can be understood and predicted because it works in systematic ways. If events occurred randomly or at the whim of capricious gods, trying to predict events would be hopeless.
- **Humans are physical objects**: Humans are part of the physical world, and as is true for other entities in the world, we can potentially understand and predict how they will operate. If humans were completely different from physical objects and animals, we could never hope to predict what people might do or think.
- **Explanations of phenomena should consist of other physical events**: Explanations of events in this world should rely on other events within this world instead of invoking magical or mystical happenings. For example, Hippocrates proposed that epilepsy was a disease of the body (as other diseases were understood to be), thereby rejecting earlier views that it resulted from direct intervention of a god.

These beliefs seem so natural to us today that it is hard to remember that they are assumptions. Indeed, these three assumptions are critical to all the sciences. Experience tells us that these assumptions are helpful in trying to explain things around us; at the time the Greeks first made them, however, they were quite bold. Once you assume that the world is predictable, that you can understand it, and that humans have no special place in this world (meaning that human behavior can be explained just like anything else), it is natural to take the next step and ask a few questions about how the human mind works, such as how it perceives and remembers things. Again, it's the assumptions of the ancient Greeks that are most impressive rather than the questions or the answers they posed.

THE DARK AGES AND THE MIDDLE AGES Few contributions were added to the philosophy of mind between the time of Aristotle, who died in 322 BCE and the birth of Descartes at the end of the sixteenth century. How is this possible?

Several factors contributed to the lack of progress. By 146 BCE Greece was dominated by the Romans, who had a more practical mind-set than the Greeks. Pursuit of knowledge for its own sake was not especially esteemed, so no one was asking where knowledge comes from, as the Greeks had (see Figure 1.7). After the fall of the Roman Empire in AD 476 Western Europe was dominated by various Germanic peoples, usually called barbarians. Although *barbarian* has unpleasant connotations that perhaps aren't fairly applied to these folks, it's doubtful that they were sitting around contemplating the workings of the mind. In addition, feudalism and the decline of

Figure 1.7. The Romans who built amazing ways to move water through their cities were not as concerned with figuring out how thoughts moved throughout their minds. (Credit: Photo by David Soanes Photography/Moment/Getty Images.)

urbanism did little to help intellectual life. Nor did the ascendance of the Christian church around the year 400 make for a favorable climate for philosophy of mind. The church was interested in the soul, not in scholarly pursuits unrelated to theology.

You shouldn't have the impression that intellectualism was dead during this age, but it was definitely channeled in certain directions, and those directions were not toward the study of the human mind.

THE RENAISSANCE THROUGH THE NINETEENTH CENTURY

The Advent of the Scientific Method The Renaissance refers to a time in Europe (the thirteenth through seventeenth centuries, very broadly) marked by the rise of humanism, a subsequent flowering of literature and the arts, and the beginnings of modern science. Humanism emphasizes secular concerns and the individual (as opposed to religious concerns and the religious community). From the viewpoint of a cognitive psychologist, a critical feature of the Renaissance was the return of one of the assumptions characteristic of ancient Greece: that the world can be understood and predicted, and even more, that trying to understand the world is a worthwhile pursuit. Thus, the literal meaning of *Renaissance* ("rebirth") is appropriate. The Renaissance also saw a birth: the birth of modern science.

What makes something scientific? We often think of science as being associated with white coats and antiseptic laboratory equipment. In fact, science is not characterized by the people who do it or by subject matter. Science is simply a *method* of finding out new things. The scientific method is well suited to some questions ("What does the heart do?") and poorly suited to other questions ("What makes a song great?").

What made the scientific method new in the Renaissance was its emphasis on observation as a route to knowledge. How do you know something is true? There are two possible roads to the truth: You can sit in your armchair and reason about what you think must be true, or you can go out and observe what happens in the world. For example, you might reason that planetary orbits must be circles because a circle is a perfect shape, and it would make sense for the Universe to be organized in terms of perfect shapes. Or you might get a telescope and make observations of the planets and try to determine what orbital shape is consistent with your observations. Before the Renaissance, people