Contents

Beginnings

Humans have probably studied minds informally for as long as minds have been around. Psychological laboratories, in contrast, only began popping up at universities in the nineteenth century. One of the first psychology labs was established by a professor at Harvard named William James (1842–1910). James used his lab mainly for teaching demonstrations as part of the first known psychology course ever offered.

William James started off his career as a painter but quickly switched over to chemistry, then physiology, and finally ended up in medical school. Dissatisfied with medicine, he briefly followed in the footsteps of Darwin by joining an expedition to the Amazon as a naturalist, where he quickly discovered a deep dislike of jungles. After a period in Europe, supposedly spent studying the physiology of nervous systems, James ultimately got a position at Harvard as an instructor teaching comparative physiology. Soon afterward, the first course in psychology and its associated laboratory were born.

From Physiologist to Cognitive Psychologist

James started studying medicine mainly because his father told him to, and he chose physiology as a focus to avoid having to deal with doctors and patients. He became intrigued, however, by the emerging research experiments relating sensations to neural circuits being developed in Germany. James's first course on psychology was called "The Relations between Physiology and Psychology," reflecting his early interest in linking brain mechanisms to mental processes. In fact, the main focus of this course was on the new experimental methods that German researchers developed to study "physiological psychology" and "psychophysics."

The starting point for psychology in the United States was thus based on experimental studies of sensation, perception, and the relationship between mental experiences and biological mechanisms. James's interests in psychology quickly shifted from understanding the mechanisms of mentality to identifying fundamental principles that described how all minds function. James attempted to explain these principles in what is widely regarded as the first textbook on psychology, a lengthy text entitled *The Principles of Psychology*. The first principle James identified was, "the phenomena of habit in living beings are due to the plasticity of the organic materials of which their bodies are composed" (James, 1890, v.1, p. 105). In other words, James claimed that the things people and other animals do and think on a regular basis are the result of physical changes in their nervous system that have accumulated throughout their lives. Those changes not only affect how you might walk and talk but also how you see the world and understand it.

In the first volume of *Principles*, James lays out how neural plasticity and habits affect consciousness of the self, attention, conceptual thought, the perception of time, learning, and memory. His second volume extends these ideas to explain imagination, spatial perception, production of voluntary actions, emotions, and reasoning. In attempting to understand and explain how minds work, James quickly identified many of the core processes that are now the focus of cognitive research around the world.

Cognition and Consciousness

Ironically, paternal attempts to lead James toward a practical life in the field of medicine ultimately led him to pursue a career that by the standards of that time was probably even less respectable than a career as a painter. James's interest in mental states quickly expanded into personal explorations of spiritualism and transcendent psychedelic states (often pharmaceutically induced). James famously rejected the idea that cognition could be understood mechanistically and instead argued that psychology should be the science of mental states, especially consciously experienced "streams of thought." That is not to say that James disregarded the role of the brain. The second chapter of *Principles* is an extended discussion of brain function. And, as noted earlier, James considered human "habits" to be the direct result of changes to peoples' brains. Nevertheless, from the Jamesian perspective, neural circuits serve mainly as channels that guide the ways in which your conscious states tend to flow, they do not determine what you think or the kinds of cognitions that might arise from those states.

As you'll see in the next several chapters, cognition continues to be central to our understanding of minds and behavior, forming the core of what distinguishes psychology as a scientific field. Modern cognitive research, however, tends to focus less on the experiential elements of thought that James thought were critical and more on the collection, organization, and manipulation of information. It has only been in the last decade that cognitive scientists have begun to give James's "first principle" the consideration it deserves. If your everyday activities and thought patterns are the cumulative outcomes of physical changes in your neural pathways that have been building up since the time you were born, then what does it mean to say that your brain (or mind) is like a biological computer or information processor? Because computers do NOT change their hardware based on how they are used. And so far, computers appear to experience nothing. What really makes something cognitive? Are behavioral, neural, or experiential properties critical? Or is storage and manipulation of information key? Following the path blazed by James, the next three chapters argue that behavior, brains, and consciousness are all fundamental components of cognition and to truly understand minds one needs to experimentally explore how all three change over time.

1 The Science of Minds

Max4e Photo via Shutterstock

The final tally: Watson with $77,147 and everyone else in the competition, combined, with $45,600. So ended humankind's reign as master of the television quiz show *Jeopardy!* (**Figure 1.1**)

Contestants on *Jeopardy!* must supply answers, in question form, that match specific clues from a wide range of categories, including pop culture, history, and science. To qualify for the show, people have to pass a screening quiz and do well in practice games. Successful contestants have a phenomenal ability to rapidly retrieve answers that match the clues.

IBM's Watson, a system that originally included a room-sized supercomputer, was developed to compete on *Jeopardy!* and win. The more impressive part of Watson's performance on *Jeopardy!*, however, was its ability to use spoken sentences to construct appropriate questions to the clues. Some of the clues involved puns, allusions, or obscure references, making them challenging for many people, never mind a machine, to answer.

Watson differs from most apps in that it improves over time through a kind of trial-and-error learning; it's not simply following predefined programs. According to its makers and marketers, Watson is the first cognitive computer.

But what does it mean to say that a computer is cognitive? What would a computer have to do to qualify as cognitive? In general, the kinds of things a computer needs to do to be called cognitive are the same things a person might do that other people would consider cognitive—things like responding appropriately to spoken sentences, recognizing familiar individuals, making reasonable decisions, solving problems in clever ways, remembering things that they've been told, and so on. In short, a cognitive computer should behave somewhat like a human.

This seems like a straightforward criterion until you try to decide which specific computer behaviors should be compared to human behaviors. Animatronic robots at Disneyland *act* a lot like humans, but you probably wouldn't say that they *think* like humans. Digital personal assistants like

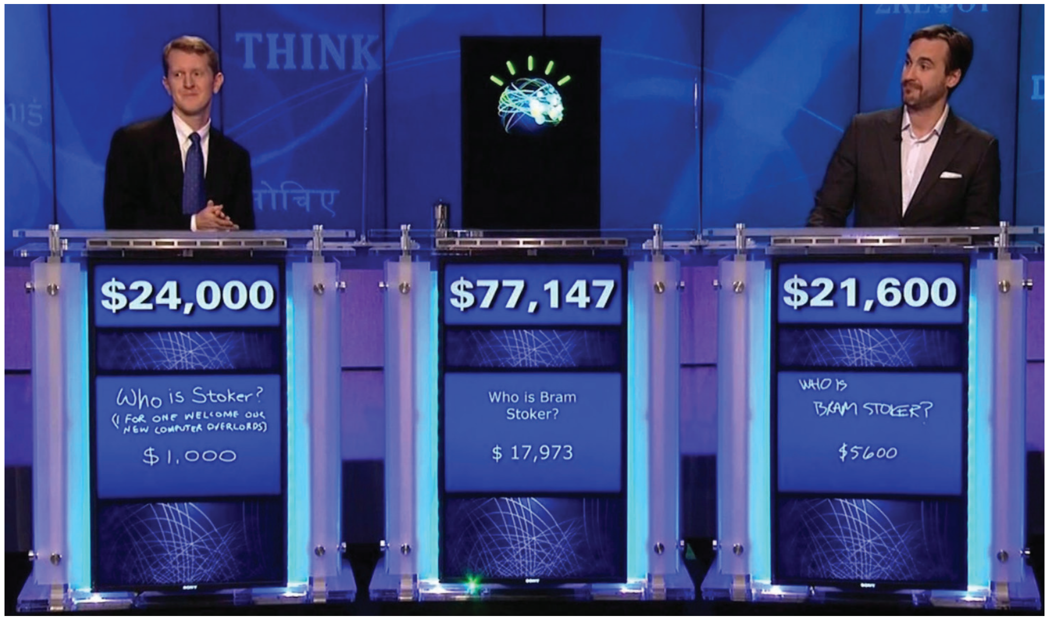


FIGURE 1.1. Watson. IBM's Watson computer system dominated human champions on the game show *Jeopardy!* What do the superior abilities of machines, at least when playing mind games, tell us about cognition?

Siri can answer your questions and follow your instructions. Does that mean Siri knows, perceives, or understands anything about you or what you are trying to achieve? Probably not. Did IBM's Watson need to know anything about people or the world to beat its human competitors? Or was it simply Siri with a bigger library of facts?

Watson shares many of the qualities that are associated with cognition, but not all of them. First, the system responded to natural sentences and produced answers comparable to those produced by the other contestants. Watson's behavior, therefore, mimicked the behavior of the contestants, whom everyone would agree are thinkers. Second, the sentences Watson produced were mostly correct responses. This is what raises Watson above the level of a talking doll. Watson's sentences are intelligent, in that they demonstrate Watson's ability to solve problems by flexibly accessing and conveying facts. If you heard Watson competing and weren't aware of its digital nature, you'd probably be convinced that "he" was just as cognitive as any other contestant.

One quality that distinguishes Watson from other *Jeopardy!* contestants is that Watson doesn't want to win. Fundamentally, Watson does not understand what winning is all about. Watson cannot appreciate the pressure of competition, the uncertainty of other contestants, or the implications of the outcome of the contest.

Most people don't have access to the piles of facts that Watson does, but they do know what it's like to watch people compete and can even imagine what it's like to be a contestant. This kind of awareness is what makes watching game shows entertaining. It's also what makes knowing that Lincoln was president of the United States (a fact) different from knowing that you have never been the president (a personal memory).

There are some exceptional individuals who are able to recall massive amounts of details about past events (LePort et al., 2017), somewhat like Watson. When people with this ability attend a sporting event, they can answer questions about details of the game years after the event, including the date it happened, what the weather was like, and who made critical plays. This impressive recall ability is called **highly superior autobiographical memory (HSAM)**, and it is not limited to sports—detailed memories of many meals, lines from movies, clothes worn, and emotions felt are also available. People with highly superior autobiographical memory describe memory retrieval as reliving a previous moment in time. You might experience something similar if you think back to some of the most notable events of your life.

Your ability to remember notable events and the feelings of familiarity that they spark are essential components of cognition. Watson lacks any ability to do this. Calling Watson cognitive is like saying a puppet is funny. Puppets are funny only to the extent that their puppeteers make them look and act funny. Puppies, on the other hand, are often funny without the help of handlers.

What makes puppies funny, at least partly, is the way they actively explore the world. But what exactly are playful puppies doing? Are they forming personal memories of playing with your shoe that they will recall the next time they see you? If they were, how would you be able to tell? If a puppy learns to recognize you and seems to have fun playing with you, does this mean that the puppy thinks about you? Which is more cognitive: a computerized *Jeopardy!* champion or a playful puppy? Or maybe both are cognition-less?

Cognition, which enables people to contemplate, converse, question, realize, reflect, remember, solve problems, think, and understand, seems self-evident yet it's enigmatic. Lacking cognition, people become little more than bodies. At its peak, cognition enables geniuses to reshape planets.

This book is about the scientific study of cognition, including how studies are carried out and what such studies have revealed. People have been interested in the nature and capacities of minds long before scientists came on the scene, but it has only been in the last century that researchers have begun to pinpoint the mechanisms that make minds tick. As you read this chapter, you will gain a better sense of the types of questions that cognitive psychologists have answered and the types that they have yet to answer—questions like, "What would it take to give Watson a mind or to show that it has one?"

COGNITION: IT'S WHAT YOU THINK

SNEAK PEEK: Psychologists develop models to better understand how cognition works. By looking at how well different models predict and explain what individuals notice, remember, and think, researchers can change the ways that future generations think about thinking.

Psychology is often described as the study of mind and behavior—two topics that are different yet undoubtedly linked. The connection between mind and behavior is apparent from the way people talk about them. For instance, people whose behavior is abnormal are described as having mental disorders, which implies that their minds aren't working right. Similarly, actions that seem foolish or pointless often are described as "mindless." While behavior mainly refers to those things you do with your body—or physical activities that you could record yourself doing—the concept of mind is trickier to define.

Right now, you're reading, and you could record yourself doing it, so it's a behavior. But while you're reading, you might also be thinking about other things, such as what you're planning on doing later. That's not going to show up in the video. Also, while you are reading, you might come across an unfamiliar acronym like HSAM. Feelings of uncertainty are not going to show up in the video either.

These kinds of hidden mental actions and events probably seem just as real to you as reading, even if no one else can verify that they're happening. It seems reasonable to say that if physical activities are what your body does then mental activities must be what some hidden part of your body does.

Mind is what many people in Western societies call that hidden part, and cognition refers to a particular kind of mental activity, sort of like how "sports" refers to certain kinds of physical activities. Just as the prowess of an athlete depends on that athlete's body, the genius of a thinker depends on that thinker's mind. But since no one has ever seen a mind, it's difficult to know what properties of it would even contribute to genius.

When athletes perform, they exercise a range of skills—running, hitting, catching, aiming—that when combined together might be called competing. When thinkers perform, they similarly engage in various mental skills—perceiving, knowing, understanding, recognizing. This kind of mental performance is referred to as cognizing.

When you **cognize**, you are consciously aware of ongoing events, both internal and external. A process is considered to be cognitive when it involves an act of cognizing, just like a sporting event is competitive when it involves athletes competing.

Cognizing may seem a lot like thinking. But thinking usually involves some effort to achieve a goal (see Chapter 10), while cognizing does not necessarily require any effort. You pretty much just have to be awake and taking in your experiences.

Because mental activities are unobservable to everyone other than the person performing them (and sometimes to the person who is cognizing, too), it's often difficult to know when or how minds actually matter. Is mindless behavior ever really mind-free? How much control do minds have over behavior, and what is it about minds that enable them to cognize? In attempting to answer such questions, cognitive psychologists rely heavily on models of minds.

Models of Minds

Imagine a kindergartner asks you what a mind is. Assuming you don't go with the classic "I don't know," you might attempt to explain to the child what a mind is by using various examples. Of course, your explanation might lead to a never-ending stream of follow-up questions, but in the best-case scenario, you will manage to come up with answers that satisfy the child's curiosity.

In answering the question, you're providing the child with a conceptual model, or simplified description, of how to think about a mind. People have come up with all kinds of conceptual models of minds. One of the most influential of these is the model popularized by the French philosopher René Descartes (1596–1650) (**Figure 1.2**).

In Descartes's model, your mind (or, as Descartes called it, your soul) is not part of the physical world, and so it does not follow the same rules as objects in the world, including your body (Descartes, 1644/1984; 1662/1972). This division between body and mind maps smoothly onto the difference between physical (public) and mental (private) activities. Moreover, it offers the possibility of mental immortality, making the model intuitively appealing. From a scientific per-

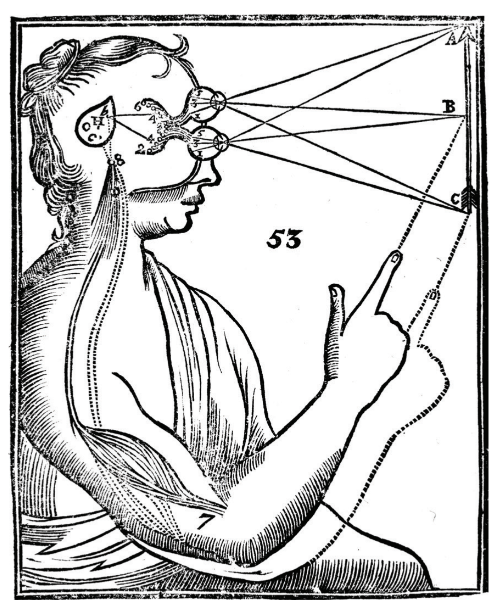


FIGURE 1.2. Descartes' model of how minds work. Descartes viewed minds as spiritually based controllers of bodies. He modeled bodily actions as a kind of hydraulics in which external events release fluids in the brain that trigger the release of other fluids that control muscles. The mind influenced these processes remotely from a spiritual world—the eyes react, but the mind sees. (Photo 12/Alamy Stock Photo)

spective, however, Descartes' model doesn't explain much about why minds work the way they do nor does it provide many insights into how one might heal a mind that has become "disordered" (Urban, 2018).

Associationist Models

While Descartes focused on the unique capacities of minds, such as their ability to think, other philosophers pointed out that the kinds of thinking performed by minds seemed to depend a lot on experience (Locke, 1693). They noted that scholars who grew up in different countries often used different languages, writing systems, and explanations for how minds work. Most thoughts, ideas, and concepts that you have are a consequence of memories you've formed from past experiences, and many of your mental activities depend on your ability to make connections between current events and past experiences.

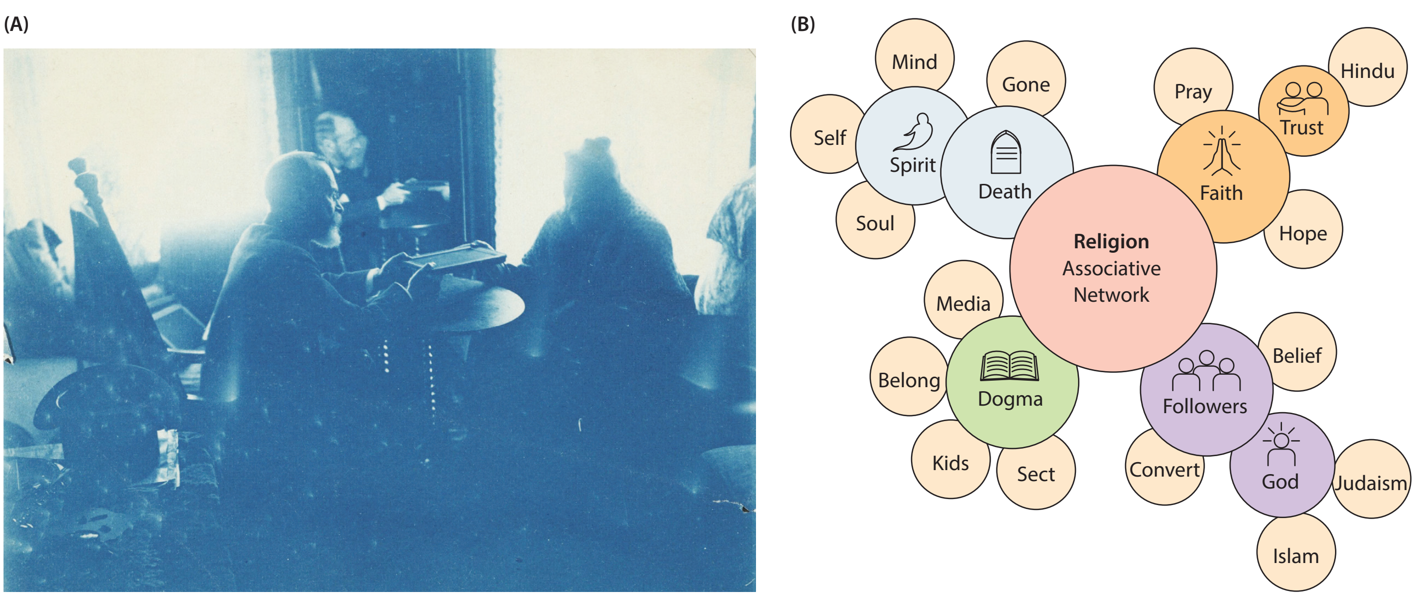
For example, if most apples you've seen are red, you'll tend to link the color red to apples. If you draw an apple, describe one, or imagine eating one, it will likely be a red one. Everything you know and understand about apples comes from past encounters you've had with them, including what you've read about them. Since apples are not the only things that are red, this color will also be linked to other objects you've experienced. In **associationist models** of mind, cumulative experiences shape how you think.

One of the more influential associationist models was proposed in the late 1800s by the American psychophilosopher William James (1842–1910) (**Figure 1.3**). James proposed that the links between memories and ideas are literally physical connections in your brain and that these associative connections form gradually, becoming stronger over time. In other words, James thought that the organization of your thoughts directly corresponds to the structural organization of observable, physical connections inside your head (James, 1890; 1962). This associationist model implies that most thoughts, ideas, and concepts that you have are a consequence of memories you've formed from past experiences

James's approach carried models of mind from the domain of religion and philosophy into the world of science. In principle, since physical connections in the brain are observable, those connections can be compared with how people think about things. Many modern models of minds argue that "minds are brains" or that "minds are what brains do," which seems similar to what James claimed. However, James actually ridiculed the idea that minds are brains; instead, he felt that mental states

FIGURE 1.3. William James. (A) American mind modeler and explorer of conscious cognition. James was the first psychologist to champion the idea that mental contents are a function of physical links between brain cells that make it possible for experiences to guide thought processes. (B) In James' associationist model, your mental activities are like a set of falling dominos; ongoing events knock over the first "mental domino," which then triggers the retrieval of associated memories (shown here as connected circles). Modern associationist models are descendants of James's ideas. (A MS Am 1092 (1185), Houghton Library, Harvard University; B after Hurwitz 2016.)

(A) (B)



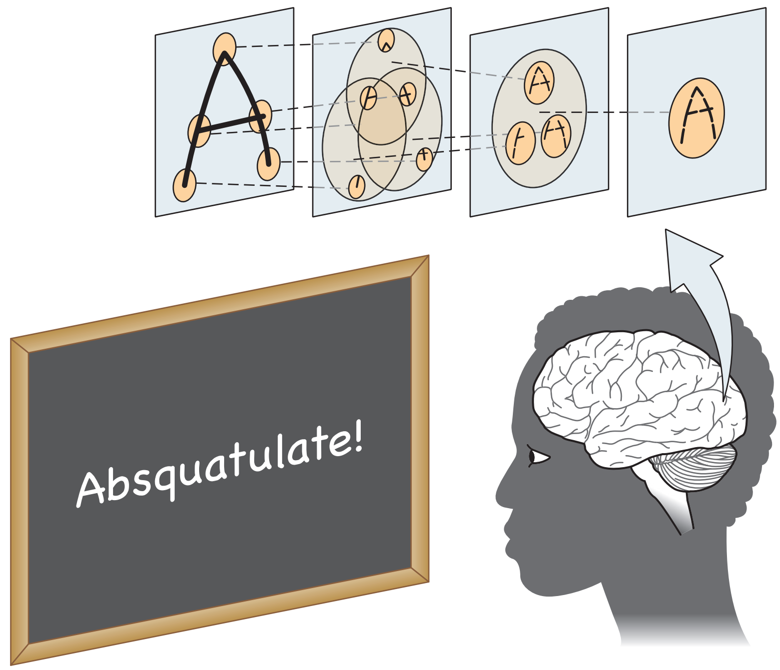


FIGURE 1.4. A computational model of letter recognition. Early computer models portrayed perception and identification of letters as a process of recognizing simple features followed by recognition of combinations of those simple features.

followed different laws from those that determine physical reactions within brains. He particularly emphasized purposeful action, willpower, and consciousness as key features of minds (Marchetti, 2021).

Modern examples of associationist models appear several times throughout this book—anytime you see the word "network," "connections," or "learning," you should immediately think, "Here comes another associationist model."

Minds as Machines

When Descartes split minds from bodies, he described bodies as biological machines. He argued that humans were the only creatures with bodies that also housed a mind; all other animals were deemed mindless machines.

James took the opposite position, claiming that every organism that could move probably had a mind, even going so far as to suggest that the minds of the most capable nonhuman animals were cognitively superior to those of the least capable humans.

It was only a matter of time before someone suggested a third possibility: that minds *are* machines (Putnam, 1960). If you think that this third option seems counterintuitive, you may be surprised to learn that this is the most popular model among all modern scientists.

The mind-as-machine model is commonly called the **computational theory of mind**. It proposes that brains are biological computers and that minds are information processing systems (like IBM's Watson) (**Figure 1.4**). From this perspective, cognition is computation (Minsky, 1986). In the terminology of computers, brains are the hardware, cognitive processes and consciousness are the software, and together they make up a mind.

The computational theory of mind began gaining steam in the 1960s, about the same time that computers started becoming useful tools and neuroscience began to take off as a scientific field (Fodor & Pylyshyn, 1988). Part of the appeal of this model was that one could use computers to simulate mental activities, creating the first physical (electronic) models of minds (Oliveira, 2022). These simulations included computer programs specifically designed to behave like humans—**artificial intelligence (AI)**—the forerunners to today's chatbots and automated customer services.

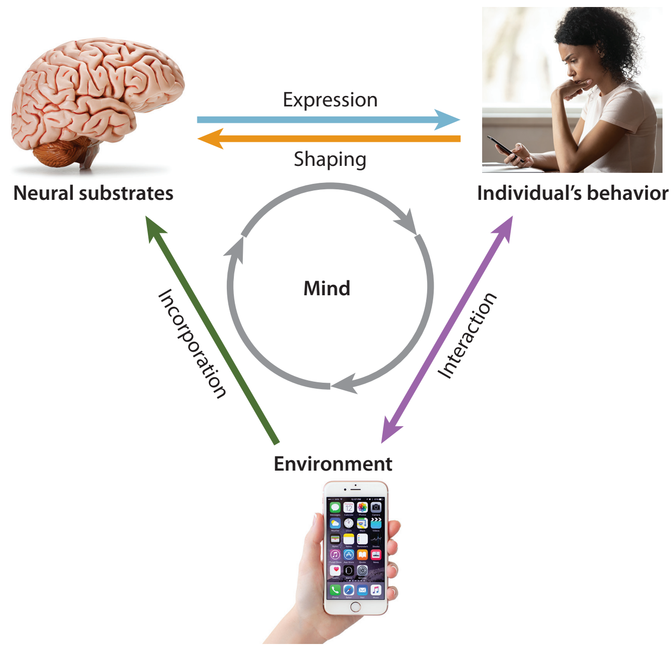


FIGURE 1.5. Expanding the concept of mind. While most mind models lodge your mind inside your brain, the extended mind thesis claims that your mind includes elements of the world outside your head, including objects you interact with to augment your cognitive activities and your own actions. (After Lux et al., 2021, brain: DNY59, student: Fizkes, phone: Prykhodov)

External Elements of Minds

In the last few decades, there has been a mini-rebellion against the computational theory of mind, based on the idea that how minds operate is tightly linked to the bodies and environments within which they function—unlike most computers (Clark & Chalmers, 1998; Menary, 2010).

This newest model of mind, sometimes called the **extended mind thesis**, proposes that minds are not something trapped inside your head; instead, minds encompass any tools that you use to support your thought processes, including written notes, computers, smartphones, and even your own body (**Figure 1.5**). Have you ever talked to yourself when no one else was around, sung in the shower, or pulled your hair in frustration? The extended mind thesis suggests that such behavior is not a sign of mild derangement but may actually support or enhance certain mental processes (Ongaro et al., 2022).

Minds are many-splendored entities: souls, brains, associations, machines, and more. Like ancient astronomers, cognitive psychologists are able to explore and describe patterns in the movements of minds without necessarily having a complete grasp of what the patterns mean or even what it is that they're seeing move.

Cognitive processes are the constellations in these patterns—scientific mind maps of associated phenomena given weighty labels like "attention," "language," and "memory." As you read through this text, you may discover new ways of thinking about minds and cognition, expanding not only your understanding of what cognition is but also your ability to judge the pros and cons of different claims about how your mind works. An important step toward both goals is to get a better handle on why cognitive psychologists are obsessed with models.

Why Models Matter

Models of cognitive processes—all the operations of your mind that enable you to cognize—come in two basic flavors: quantitative and qualitative. Quantitative models are based on quantities, represented as numbers, and on techniques for combining or comparing those quantities, like equations. The most common quantitative models used by cognitive psychologists are computational models—basically, computer simulations of cognitive processes (Farrell & Lewandowsky, 2018). Most other models are qualitative, meaning that they focus on describing the qualities of a cognitive process, usually through diagrams and/or stories. Both quantitative and qualitative models are abstractions that try to capture some essential elements of what cognizing involves and how cognitive processes work (**Figure 1.6**).

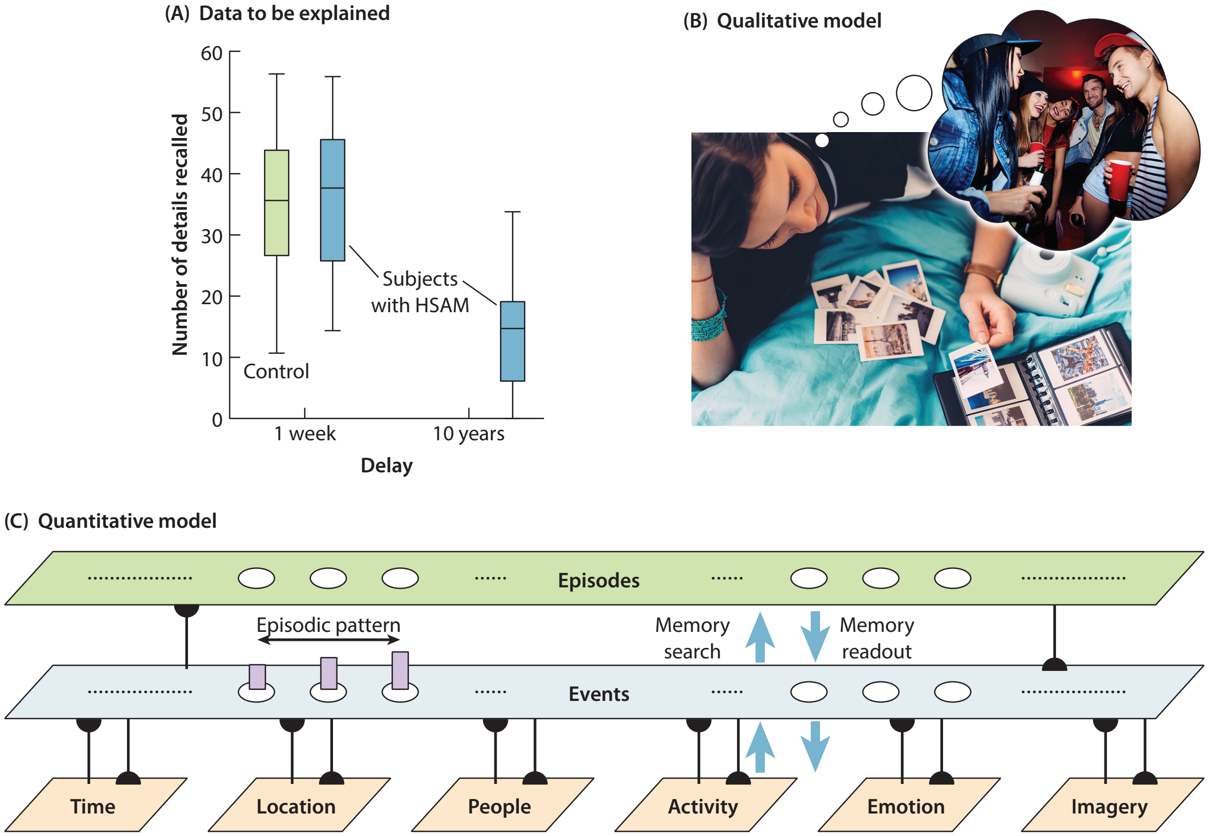


FIGURE 1.6. Modeling variations in autobiographical memory. (A) Behavioral studies show that a subset of adults (subjects with highly superior autobiographical memory) can recall details of personal episodes after a decade. (B) Qualitative models often explain this unique ability as an almost limitless capacity for mentally replaying past episodes. (C) A quantitative model of variations in autobiographical memory must specify numerically what information people store from their experiences, how each event is represented (in this example as an episodic pattern), and how specific episodes from the past are found and reactivated. In this model, verbal questions about a past date would trigger an episodic pattern, after which a memory search would be initiated to locate a past episode that best matches that pattern, making recall of additional details possible. (A after Wang et al., 2016; B bubble: shironosov; square: martin-dm; C after LePort et al., 2016.)

Here's a qualitative model of highly superior autobiographical memory: "People with highly superior autobiographical memory are more likely to recall details of personal episodes many years after they happened. Most people store memories of notable events and can recall those events years later. People with highly superior autobiographical memory process memories the same way as everyone else but perceive every day of their life as highly notable. Why? Because the part of their brain that detects cross-day similarities is dysfunctional, such that every day seems special."

This qualitative model explains a unique cognitive ability—highly superior autobiographical memory—as an extension of the usual memory mechanisms that most people possess caused by a brain disorder. You could potentially create a quantitative model of highly superior autobiographical memory that is similar to this qualitative model. The quantitative version might be a computational model that includes a special computer subroutine devoted to storing highly notable inputs, which has lost the ability to discriminate notable events from everyday events.

Putting Models to the Test

Is the qualitative model of highly superior autobiographical memory described in the previous section correct? Probably not, but that's okay because a model doesn't need to be correct to be useful (Marr, 1982; Warren, 2012).

A better question might be, does this model allow scientists to accurately predict phenomena that they would be unable to predict otherwise? For instance, the model predicts that if you could watch the brain of a person with highly superior autobiographical memory recalling a random day in their life, you might see the same sort of activity that happens when they are recalling a historically relevant day. And if you compared brain activity in people with highly superior autobiographical memory to activity in people with more mundane memory capacities recalling a historical event, then the model predicts that their brains should be doing basically the same thing.

These predictions are testable. If it turns out that the predictions are accurate, then you understand more about how memory works than you did before. If they are inaccurate, you may still have learned something from the experiment that you didn't know, which could help you to develop a more useful model.

Refining models is a never-ending process in cognitive psychology (and in most other sciences). Even the best models can't predict and explain everything. In some cases, the models that perform best are so complicated that they are not much easier to understand than the cognitive process they were built to explain. In other cases, there may be two or more models using different explanations of what's happening that seem to work equally well. The models of cognition presented in this textbook include some of the latest and greatest, as well as some older models that have proven to be particularly useful. You should think of these models as formalized hypotheses—testable explanations for a phenomenon—rather than as facts to memorize. The models provide ways of thinking about cognition that have proven useful to those scientists that have thought the most about cognitive processes, and they can give you a head start in your quest to know more about how minds work (O'Reilly, 2006; O'Reilly et al., 2010).

Confusingly, models of cognition are often called theories, and different researchers have used the two terms in ambiguous ways. For the purposes of this book, you can think of theories of cognition as impressive models or sets of models that are meant to explain how cognition works.

Human Mind, Animal Mind: Comparisons across Species

When psychologists talk about "the mind," they usually have one particular class of minds in mind: those of adult humans. While Descartes argued that these were the only kinds of minds there are, other scientists, including Charles Darwin (1809–1882), begged to differ (Darwin, 1871). It would be ridiculous to argue that only adult humans have physical bodies (including brains), so the fact that people find it reasonable to argue that humans are the only organisms with minds reveals a conceptual divide between how people think about physical acts of the body versus mental acts of the mind. This divide also relates to the persistent feeling people have that humans aren't really animals. Even scientists who confidently claim that human brains generate minds often hesitate to claim that other animals' brains can do the same.

Margaret Washburn (1871–1939) was a pioneering psychologist who argued that lots of animals other than humans have minds (**Figure 1.7**); she was also the first woman to get a Ph.D. in psychology and the first woman psychologist to be elected into the National Academy of Sciences, one of the highest honors any scientist can receive. In the early 1900s, she published a classic textbook called *The Animal Mind*, which catalogued experimental and physiological evidence that she felt supported her (and Darwin's) claims that minds were less rare in nature than people assumed (Washburn, 1926).

You may be wondering what sort of evidence Washburn used to try and convince other scientists that nonhuman animals have minds. Some evidence was based on physiological comparisons showing few major structural differences across vertebrate brains. Most of the evidence, however, revealed how similarly nonhuman animals and humans behaved when faced with various cognitive tasks (Andrews, 2020).

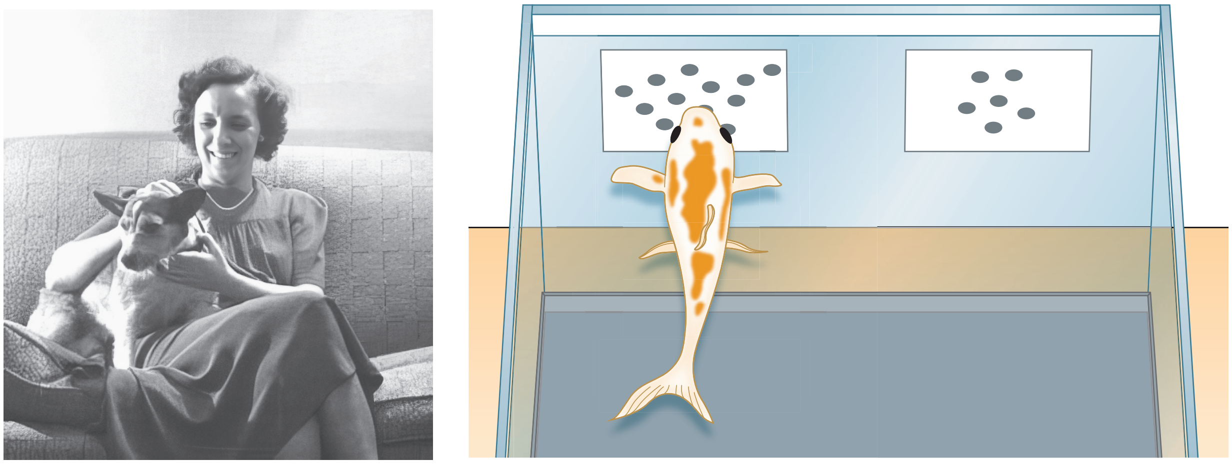


FIGURE 1.7. Margaret Washburn. (A) Champion of experimental studies of animal minds and mega-pioneer. (B) She explored many cognitive processes in various species, including visual perception in fish. (A The Drs. Nicholas and Dorothy Cummings Center for the History of Psychology, The University of Akron)

Self-Reflection versus Experimental Observation

Interestingly, Washburn's doctoral training focused on introspective approaches (described later in this Chapter) that require reporting on one's own mental activity. This was once the dominant approach to studying cognition, which makes some sense given that the only thinking you can directly observe is your own. Even then, there is no guarantee that your impressions are accurate (Boring, 1953; Danziger, 1980).

If animals other than humans think about their experiences, we don't yet have a way to detect it. However, by using the same tests that researchers use to examine peoples' perceptions, it's possible to show that many other animals respond to sensory differences in ways that are comparable to humans (Stebbins, 1970) (Chapter 4 describes several such perceptual studies).

Given these similarities, you would have about as much evidence for claiming that nonhuman animals can perceive sensory differences as for claiming that humans do. You might think that the fact that people can tell you, "I'm perceiving a difference," provides stronger evidence that they're consciously aware of a difference, but you ultimately have no way of verifying this. You could probably train a parrot to say something similar while performing the same kind of task.

Reasoning versus Instinct

Of course, being able to tell things apart is not a particularly impressive cognitive act compared to something like figuring out that the earth is orbiting the sun. For many, acts of reasoning are what make cognition in humans radically different from mental activity in other animals (Penn & Povinelli, 2007).

The kind of rational thought that people engage in when solving problems or making decisions (see Chapter 10) definitely goes beyond merely perceiving what the world is like. But whether rational thinking involves cognitive processes that are unique to humans is still up for debate (Beran et al., 2016; Laland & Seed, 2021).

For a long time, researchers thought that humans were the only animals that could solve problems by constructing and using tools, but now there is evidence that many other animals do this (Goodall, 1964; Shaw, 2021). Scientists also assumed that nonhuman animals were driven by instincts while human behavior was more rational (as suggested by Descartes). However, observations of dolphin, bonobo (a type of ape), and even ant behavior (**Figure 1.8**) have revealed creativity and insight in performing actions and solving problems (Olmstead & Kuhlmeier, 2015) (see Chapter 9).

Realistically, how frequently do you reason in any given week? When you decide what to have for lunch, do you do it by considering all the potential consequences? Or do you think, "What do I want for lunch?" Or maybe you just look at a list of options and choose one that looks good. Just because it's possible for humans to logically consider the outcomes of multiple actions before choosing one, doesn't mean they normally do it.

Memory-based action selection can account for many of your daily "choices," like what you do first when you wake up, when you go to a store, or what time you go to bed. These "normal things that people do," are learned actions that depend on memory abilities rather than on instincts or reasoning. Chapters 5, 7, and 8 will reveal the many ways that memories affect behavior and cognition in all animals, including humans.

FIGURE 1.8. Ant de soleil. Ants show sophisticated abilities to socially coordinate their actions, creating complex structures customized to solve specific foraging and navigation problems that they encounter. Is their ability to do this innate? And if so, then why does it take people years of specialized training to perform similar feats? (frank60 via Shutterstock)

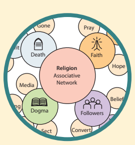
Language and Thought

The one feature of human cognition that is most often noted as being the difference that makes humans different from other animals is language (Adler, 1967; Chomsky, 1959). As far as anyone can tell, no animals other than humans naturally use language.

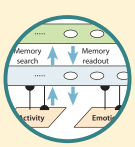
Many nonhuman animals communicate using sounds and other signals (see Chapter 12), but none seem to communicate using symbols in the way that humans do (Fitch, 2020). The use of symbols is heavily emphasized in educational contexts, so it's not surprising that thinking and cognition would be closely linked to language. This does not imply, however, that one needs language to cognize. It simply means that at least part of human cognizing typically involves associating arbitrary symbols with perceived events, especially if one wants to demonstrate a certain level of intelligence to others.

That being said, there are many cognitive skills that do seem to benefit from the capacity to produce and comprehend language, and much of the evidence that people perceive, know, and understand what is happening comes from their use of language (Gentner & Goldin-Meadow, 2003). So, it's not too surprising that ideas about language and thinking are tightly linked. This is perhaps most clear in standardized tests of individual differences in cognition, which depend heavily on a person's ability to answer questions. The following section considers what such tests have revealed about the relationship between intelligence and cognitive abilities.

SIGHT BITES



Conceptual models of minds describe cognitive processes in terms of associations, computations, and more, providing a way for cognitive psychologists to test the usefulness of different proposals.



Researchers are always refining existing models of cognitive processes based on experimental tests of model predictions.

Comprehensive approaches to studying cognition depend on developing methods that can be applied to both humans and other animals.

INTELLIGENCE: KNOWING HOW TO THINK

SNEAK PEEK: Individual differences in cognitive abilities separate the duds from the brainiacs. More than just brains and cognitive capacities determine how people perform on intelligence tests, however. What are the factors that make some minds excel and others fail?

The idea that humans possess cognitive abilities that are superior to those of all other animals has a long history rooted in religious beliefs. However, even humans vary greatly in their abilities to solve problems, gain new knowledge, and critically evaluate information (Worrell et al., 2019).

Cognitive psychologists historically have given less attention to individual differences in cognitive ability than to identifying general principles that apply to cognitive processes in most people. Sometimes, though, it is the exceptional mind that provides the clue that sheds light on typical cognitive processes.

For instance, studies of mnemonists (people with exceptional memorization abilities) have clarified the important roles skill learning and imagery can play in memory retrieval (Luria, 1968), and research with chess champions has revealed just how closely their exceptional problem-solving abilities apply to chess (Charness et al., 2005). Interviews with famous scientists and artists can potentially reveal aspects of their thought processes that differ from the norm, and studies of individuals with exceptional abilities (like people with highly superior autobiographical memory or amnesia) can lead to new ways of thinking about cognitive processing (Lubinksi & Benbow, 2021; Simonton, 2009).

Geniuses, whose ideas and accomplishments seem to exceed those of all their peers, are particularly intriguing because they highlight how little is known about the factors that contribute to lower or higher levels of intellectual ability, not to mention what levels of cognition are even possible.

Geniuses: Domestic and Wild

The defining quality of a genius is that other people judge that individual to be exceptional to an extreme degree (**Figure 1.9**). This quality can vary depending on who the judges are and when they make their decision.

Genius is often viewed as the high end of a continuum of smartness that begins with idiocy. People who aren't geniuses often assume that geniuses are born with hyper-capable brains that give them special abilities, like a seven-foot basketball player who benefits from their height advantage.

People who have been called geniuses, however, often attribute their successes to qualities that tend to be associated with mental disorders, such as extreme perseverance and disinterest in typical social activities and norms. Yet, people who persevere and don't attract public attention are unlikely to be classified as geniuses, regardless of their cognitive capacities. Since not all people with unique brain power are recognized by the public at large, the qualities that are often possessed by geniuses may actually be more widespread than they seem.

FIGURE 1.9. Origins of intelligence. Exceptional minds are often assumed to come from exceptional brains. Why might measures of brain structure be less reliable indicators of above-average cognitive abilities than behavioral tests?

Nature versus Nurture versus Computational Power

The origins of individual differences in cognitive capacities have been hotly debated for centuries—this is a key element of the nature versus nurture debate regarding whether genetics or experience more strongly determines how individuals act and what they can achieve (Plomin & von Stumm, 2018; Sternberg, 2020).

In the field of cognitive psychology, the question of whether DNA or practice makes perfect has been studied most extensively using strategic games like chess in which there are quantifiable differences in performance that can be compared to the amount and quality of a player's training (Howard,

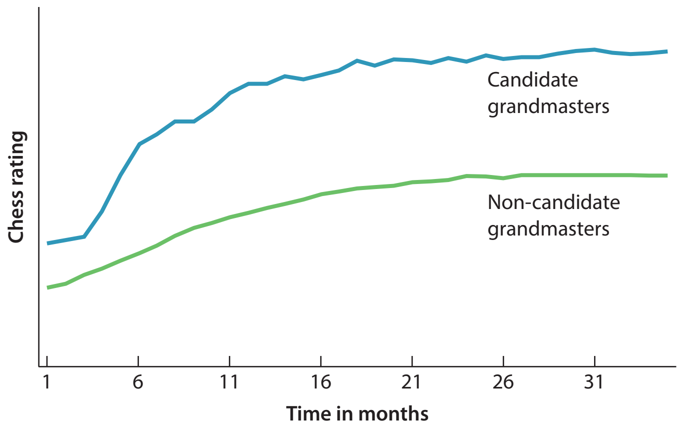


FIGURE 1.10. Practice in chess doesn't always make perfect. Chess competitors who started out performing better in tournaments and who ultimately became grandmasters benefitted more from practice than other chess experts, suggesting that their initial talents strongly determined their ultimate chess rating, a numerical indicator of their performance in tournaments. (After Howard, 2009.)

2009). One thing that studies of chess players make clear is that the best players in the world usually aren't also Nobel laureates, math wizards, musical savants, or world-class poker players—their brilliance is often limited to selecting winning chess strategies. If good genes are what enable grandmasters to excel at chess, then the relevant genes are not genes for "smartness."

As in sports, exceptional cognizing requires exceptional specialization. Training experiences play a key role in how highly a chess player is likely to be ranked (Ericsson et al., 2009); starting intensive training at a young age can make a big difference. But chess experts with thousands of hours more practice are still often defeated by younger, less experienced players—an outcome which seems to point toward talent (nature) winning the day (Blanch, 2020) (**Figure 1.10**).

And then there are current artificially intelligent chess engines (chess-playing software), the best of which are so proficient that they have never lost a match to any human. Their only competition now is other computer programs. Like Watson, artificially intelligent chess programs mimic the behavior of human chess experts and are essentially computational models of chess-related problem-solving. Several factors determine how good a chess program is, including its processing power, its database of chess positions, and the rules it uses to sort through possible moves. Could similar factors determine your cognitive capacities?

Potential Differences

A notable feature of top-ten chess experts is that they are almost always males of European or Asian descent. Only one woman has ever competed in a world chess championship, and it is rare that more than one woman is in the top 100 players.

The skewed distribution of chess champions cuts to the heart of whether nature versus nurture is determining cognitive abilities. Are there no women at the top because of genetic differences (nature)? Or is this a cultural artifact related to social norms in the countries where chess is most popular (nurture)?

Women are about five inches shorter than men, based on worldwide averages, a difference that is mostly coming from the nature side of the equation. Could chess-playing ability be like height? Or, maybe, it's like strength, which also differs between men and women, but depends much more on experience? So far, no male-specific chess genes have been identified and debate rages on about what specific cognitive abilities grandmasters have that give them an edge.

The problem is that, unlike height and strength, the cognitive processes that contribute to chess-playing finesse are invisible, making any side-by-side comparisons dicey. This is true not just for chess players but for all behaving organisms. The hidden nature of mental actions makes it tricky to know what is varying cognitively between individuals, much less how capacities and potential are varying.

It may be hard to say for sure what it is about an individual that makes them cognitively exceptional, but it is undeniable that some thinkers stand out (Sternberg, 2018). In the earliest studies of problem-solving by chimpanzees, it was one chimpanzee in particular, named Sultan, that consistently led the pack in discovering the steps required to reach high-hanging fruit (Köhler, 1925). It was one parrot, named Alex, that convinced researchers that they had been underestimating the cognitive capacities of birds (Pepperberg, 2013). And it was one dog, named Chaser, that showed that dogs can learn thousands of spoken words (Pilley & Reid, 2011).

Like human geniuses, it is difficult to know how exceptional such animal stars truly are. One thing these unique cases do tell us is that even the most sophisticated cognitive abilities can vary considerably across individuals, and even within an individual, as they develop. Identifying ways to measure variations in mental processes has been a key challenge throughout the history of cognitive research.

Measuring Intelligence

At the core of all measures of cognitive competence, or intelligence, are tests. The tests vary in terms of whether they probe what an individual knows versus what that individual can figure out, but they all serve the same goal of ranking an individual's performance relative to that of other test takers (Spearman, 1904; Horn, 1968).

The basic idea is that tests convert unobservable mental abilities into observable behavior. Most current tests of intelligence assess a broad range of verbal, perceptual, reasoning, and memory abilities (**Figure 1.11**). The results of multiple tests aren't always consistent, however, making it hard to know which mental abilities determine a person's score on different tests. Much of the debate about intelligence tests revolves around their validity—are the highest scorers really the most cognitively competent (Haier, 2016)?

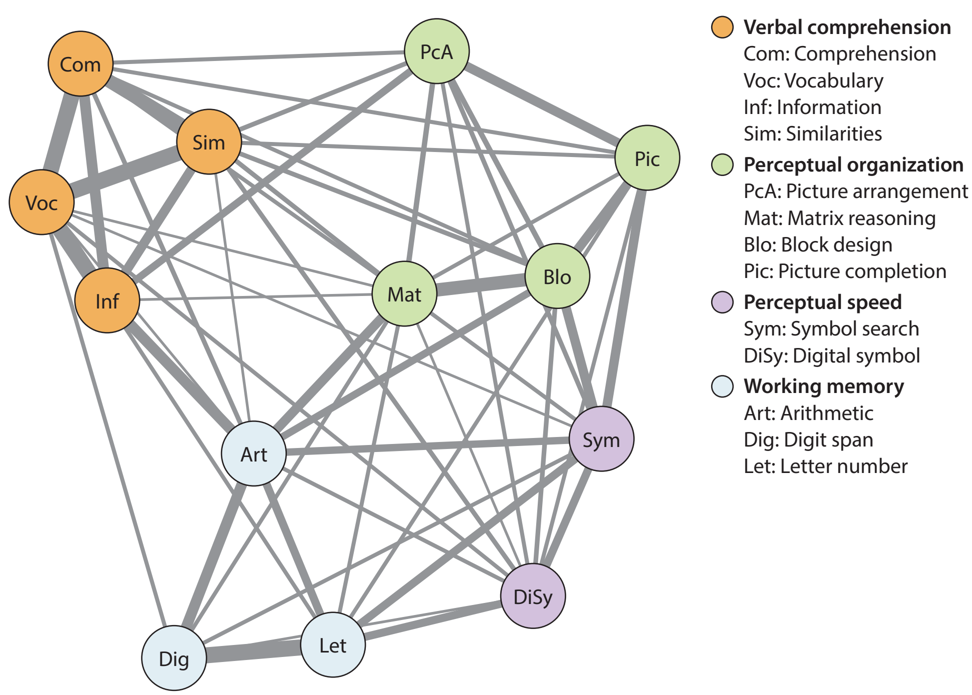


FIGURE 1.11. A quantitative model of intelligence. Intelligence tests use the accuracy of answers to various questions to compare individuals' performance. This makes it possible to assess not only how well a person performs in different areas but also how overall performance relates to specific strengths and weaknesses. Analyses of people's performance on intelligence tests have revealed that a person's ability to succeed on certain tasks is most predictive of their performance on related tasks. For example, your vocabulary size does a good job of predicting your ability to comprehend language (indicated here by a thick gray line). In contrast, vocabulary size is not a great predictor of your ability to arrange pictures (PcA) into a meaningful story (indicated by a thin gray line). (After Van Der Maas et al., 2017.)

Potential Biases

One of the main complaints about intelligence tests is that they can be culturally biased. A culturally biased test assumes that all test-takers have similar background knowledge and experiences so that test-takers are unlikely to be confused by the questions. This would not be the case, however, if the test includes questions that cover unfamiliar topics, or questions that are written in an unfamiliar language.

The concern is that intelligence tests may unfairly rank individuals based on factors other than their actual intellectual abilities, especially in cases where entire racial, ethnic, socioeconomic, or gender groups show lower-than-average scores (Reynolds et al., 2021). Systematic differences in test scores also are seen across generations, with average scores continuously increasing over time (called the Flynn effect; Flynn, 2000).

Such changes are consistent with the idea that systematic differences in experience or environmental conditions may affect people's scores on intelligence tests. For example, increases in health or educational support may improve cognitive performance, and cultural emphasis on particular cognitive skills like reading and mathematical skills can also affect performance.

Another common critique is that intelligence tests don't really reveal what an individual's future potential is. For instance, one long-term study of children classified as geniuses found that although many of them achieved success later in life, most lived relatively unexceptional lives (Terman, 1940). Also, some children who did not make the cut to be included in the study ended up becoming Nobel laureates, suggesting that performance on intelligence tests was not a great predictor of who would accomplish the most intellectually.

On the other hand, measures of intelligence are currently some of the best predictors of later success in college and in job performance (Deary et al., 2010), suggesting that intelligence tests do capture some differences in cognitive ability that can affect future performance.

Correlates of Intelligence

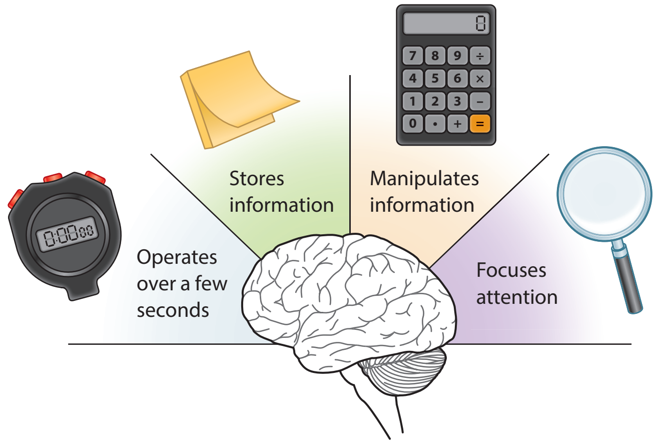
Interest in measuring intelligence was originally driven by practical problems related to sorting students and soldiers (Wasserman, 2018). Specifically, the goal was to weed out the people who were unlikely to get much out of school or training in complex military skills before effort was put into trying to teach them.

From this perspective, intelligence tests provide clues about the kinds of cognitive skills a person is likely to be able to learn. If intelligence were like height, then it would be relatively simple to predict what levels a person might reach in their lifetime. But unlike height, most cognitive abilities of adults depend on learned skills: language use, writing, reading, decision-making, and problem-solving.

The ease with which a person learns such sophisticated skills depends on even more basic perceptual and memory abilities, most notably **working memory** (Baddeley, 2012), which relates to the capacity to store, temporarily maintain, and manipulate recent thoughts in mind (see Chapter 8) (**Figure 1.12**), like when a server remembers what each customer ordered once the food is ready. Measures of working memory are highly correlated with measures of intelligence—people with exceptional working memory capacity are often highly intelligent (Conway et al., 2003).

Why working memory and intelligence are so closely linked remains mysterious. But the fact that one's capacity to remember the recent past is in some way connected to their overall cognitive competence suggests that understanding more about how working memory works could be important to understanding why differences in cognitive capacity arise. Recent studies suggest that the link may have less to do with retention and more to do with attention (Draheim et al., 2022). Specifically, your capacity to control where your attention is directed during performance of both working memory tasks and intelligence tests may affect how you perform on both.

FIGURE 1.12. A qualitative model of working memory. Working memory refers to the ways in which you can keep certain ideas or images in mind for a short period of time and manipulate them to perform cognitive tasks or control attention. A person's capacity to do this is predictive of how well they will perform on intelligence tests.



WEIRD, TRUE, FREAKY

Working Memory Wizard

Tests of intelligence typically consist of a series of specially designed problems of varying difficulty. In general, the more questions a person can answer correctly in such tests, the higher the person's intelligence score will be. Measures of working memory capacity, in contrast, focus on how long a person can keep information in mind before it fades away. As mentioned previously, working memory measures are surprisingly good at predicting the results of intelligence tests (Conway et al., 2003). Some researchers have pointed to the relationship between working memory and intelligence as evidence that working memory is important for performing many cognitive tasks and that lower working memory capacity makes such tasks more difficult.

At the same time that American psychologists were gathering evidence linking working memory to intelligence scores, a unique research study in Japan called the Ai Project was developing new computerized techniques for testing cognition in chimpanzees. One of the tasks chimpanzees were trained to perform involved remembering where the numbers one through nine appeared on a screen. They were tasked with touching the places on the screen where each number appeared in sequential order after the numbers were covered with squares (Inoue & Matsuzawa, 2007).

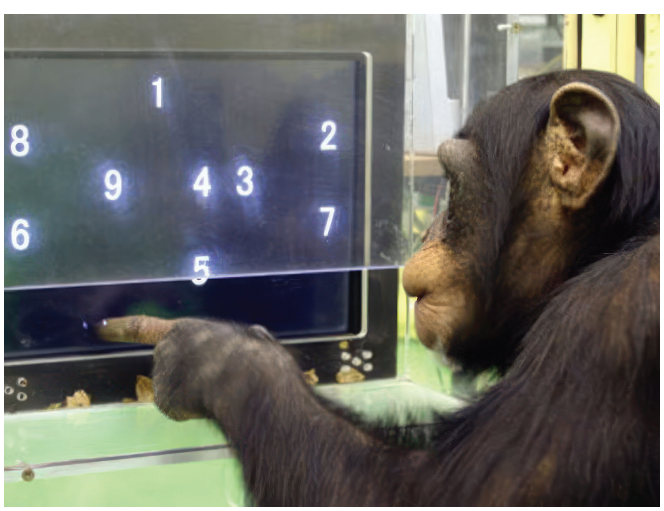
All chimpanzees were able to learn this task, but one chimpanzee in particular, named Ayumu, was way better than the other chimpanzees (see figure). Ayumu consistently remembered about 80% of number positions, even when the screen only displayed the numbers for 200 milliseconds. For comparison, college students identified about 20% of numbers when tested on the same working memory task.

Could it be that some chimpanzees have working memory capacities exceeding those of humans? Might working memory in chimpanzees also be correlated with intelligence, and if so, would that make Ayumu a chimp genius? The researchers studying Ayumu suggested another possibility: that Ayumu used eidetic imagery to perform the task.

Eidetic imagery, more commonly referred to as photographic memory, involves mentally retaining a detailed image of a perceived event for relatively long periods. It has been reported in some young children (Giray et al., 1976).

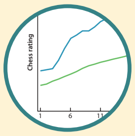
Another possibility, however, is that extensive training on a working memory task can dramatically increase an individual's working memory capacity. In fact, two undergraduate students at the University of California, Santa Cruz, who practiced the same number memory task, were able to remember more than 90% of the numbers after extensive training (Cook & Wilson, 2010).

The students did not report using eidetic imagery, so it seems that Ayumu didn't need a photographic memory to achieve his amazing memory abilities. Even so, his abilities highlight the fact that scientists are just beginning to discover the extent to which basic cognitive capacities can vary across genetically similar individuals.

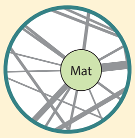


Ayumu uses a touch screen to select numbers in order and can do so even when the numbers are rapidly covered. (BBC)

SIGHT BITES



Individuals vary greatly in their cognitive abilities. The origins of individual differences in mental capacities continue to be debated.



Intelligence tests map mental performance onto observable behavior, but variations in scores can be driven by factors other than cognitive abilities.

Intelligence measures provide clues about the kinds of cognitive tasks a person is likely to be able to perform well.

BEHAVIOR: ACTIVITIES, ABILITIES, AND THEIR ORIGINS

SNEAK PEEK: The main evidence of cognitive processes comes from what individuals do, both in the lab and in the wild. Evolutionary forces provide the building blocks that experience shapes to construct knowledge and cognitive abilities.

When you think about why people you know or encounter behave the way they do, you might point to their character, personality, or general intelligence. You might also blame a person's bad behavior on clueless parenting or peer pressure. When it comes to explaining your own behavior, however, you're more likely to provide reasons why your actions made sense given the circumstances, even if those reasons suggest there was no reason, like "I panicked."

This kind of postgame analysis, both of other peoples' actions and your own, depends on your ability to put yourself in someone else's shoes—to evaluate what cognitive and noncognitive processes are controlling the actions. Thinking about why your friend refuses to pet dogs, or about why you might notice this, or even about how dogs view such non-petters, involves a peculiar kind of cognitive process called **metacognition** (Beran et al., 2012; Dunlosky & Metcalfe, 2009) (see Chapter 8).

When you are contemplating cognition (like now), you are thinking about the origins of actions and thoughts. This process is key to understanding cognition and how it relates to mental and physical activity. In particular, identifying which actions and thoughts are driven more by innate mechanisms (nature) versus specific experiences (nurture) is fundamental to developing an accurate picture of how different cognitive processes work.

Innate versus Learned Abilities

Debates about how much of human cognition is innate versus acquired through experience have been around for a long time. At one extreme, **nativists** claim that experiences are shaped by the innate properties of the human mind and brain, which effectively determine what percepts and thoughts are like. On the other side, **empiricists** have argued that pretty much everything that humans perceive and know comes from experience.

Researchers studying the behavior of our furry and feathered friends have similarly argued either that most animals' actions are effectively pre-programmed reactions to environmental conditions (as

"No amount of culture would seem capable of modifying a man's GENERAL retentiveness . . . All improvement of memory consists then, in the improvement of one's habitual methods of recording facts."
—James, 1890, p 667

suggested by Descartes), or that they are more often habits shaped by an individual's specific experiences (Pavlov, 1927; Thorndike, 1932, 1949; Watson, 1924) (see Chapter 7 for a complete discussion). The modern take on this debate is that genes and the environment interact to determine cognitive mechanisms and behavioral tendencies (Carey & Gelman, 1991). But there is still no agreement on how specifically biological mechanisms relate to things like emotional responses, thoughts, consciousness, or intelligence (Berent, 2021; Carruthers, 2005), which is why it is not yet possible to tell a baby genius from a baby serial killer.

Talents versus Skills

Consider William James's paradoxical quotation above about memory abilities. James thought that a person's ability to store memories was determined by his or her ability to reorganize connections between neurons. He considered this ability to be a built-in feature of brains—so, innate. At the same time, he recognized that an individual's ability to remember things could definitely improve over time, which is why a server who has worked at a restaurant a long time is less likely to forget people's orders than a server who has been working for only a few weeks.

A person might be born with faster, better, stronger mechanisms for storing memories—they could be mnemonically talented. However, without sufficient training, they might still perform worse in memory tests than someone with less impressive memory-storing capacities.

So, which do you think is the case for people with highly superior autobiographical memory or for *Jeopardy!* champions? Do they possess unique brain qualities for storing memories? Or have they acquired exceptional skills for storing memories of personal episodes or facts? What about birds that retrieve thousands of seeds during the winter that they buried months earlier? In all of these cases, observations of behavior alone cannot definitively reveal whether innate or acquired cognitive mechanisms are the source of exceptional memory abilities.

One way to tease apart which aspects of cognition are "built-in" is by exploring which behavioral abilities can be shaped through selective breeding (Tryon, 1940). For instance, years of selective breeding has led to dog breeds that are better able to assist humans in the herding of sheep than others. Recent attempts to breed tame foxes revealed that tamer foxes showed greater capacity to interpret human gestures (Hare et al., 2005) (see Chapter 11). Brain imaging showed that selective breeding for tameness caused several brain regions that are known to contribute to cognitive capacity to enlarge (Hecht et al. 2021) (**Figure 1.13**).

When it comes to human cognition, however, assessing the innateness of cognitive abilities requires a bit more finesse than simply putting potential lovers together in cages.

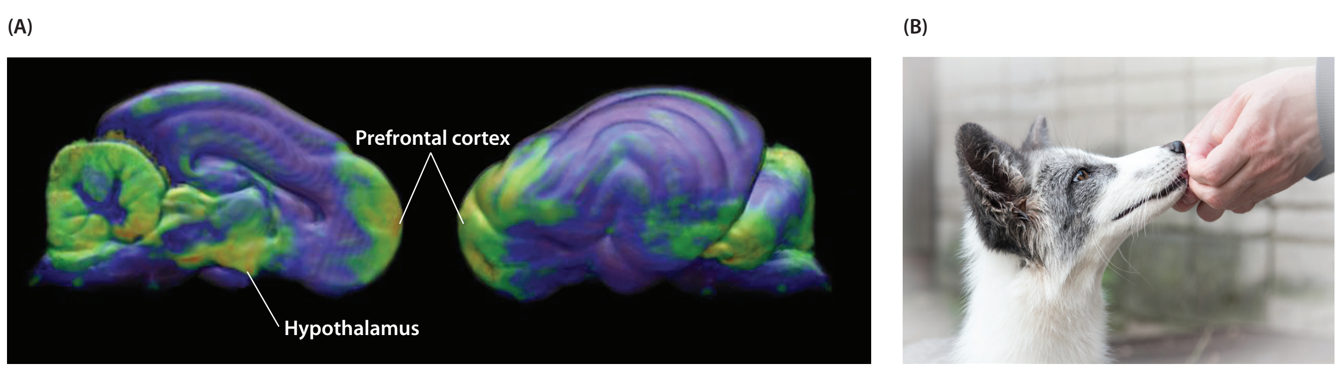


FIGURE 1.13. Shaping cognition across generations. Selective breeding of silver foxes based on their tameness quickly leads to a host of changes to their brains (A) and behavior (B). Not only do they become less aggressive, but they also show increased vocal communication and an enhanced ability to interpret human intentions. (A from Hecht et al., 2021, *J Neurosci* © 2021 by the Society for Neuroscience [CC-BY-4.0], B ressormat via Shutterstock)

Cognitive Scaffolding

Language abilities are the star of the nativist versus empiricist debate because they are clearly acquired through experience but are only naturally learned by humans (Chater & Christiansen, 2018). This has led some to argue that there must be some innate feature of human brains that makes language learning possible (Chomsky, 1975; Pinker, 1994) (see Chapters 2 and 12).

The social environments within which humans develop are unique among animals. It takes a comparatively long time for children to develop into self-sufficient adults, which provides extensive opportunities for children to learn from others (Bruner, 1965; Pozuelos et al., 2019). Psychologists like Lev Vygotsky (1896–1934) argued that human-specific cultural scaffolding, basically social support and traditions, guides language development. Guidance from peers and parents has shaped your self-directed speech, ultimately determining the kinds of thoughts that direct your actions and reasoning (Vygotsky & Cole, 1978). In this scenario, learned language abilities may fundamentally alter your mental activities.

The idea that your environment and learning experiences can profoundly shape how you think is a focal feature of the extended mind thesis described earlier. Recall that this model of mind claims that many of your daily cognitive processes depend on tools like smartphones, textbooks, or your own body to function.

Like James's views on memory capacity, advocates of the extended mind thesis would argue that your general mentality is innate, because your mind is an extension of the properties of your body, but that you can still progress up the cognitive ladder by acquiring new cognitive tools and learning how to use them—which is why you're reading this book!

Evolutionary Constraints on Activities

When empiricists claim that people's cognitive acts are a consequence of their experiences, they are adopting a version of the computational theory of mind discussed earlier. For an empiricist, learning new cognitive skills, like the ability to add or to speak in sentences, is like installing a new app, while performing these skills is like running the app.

From this perspective, just like not all apps run on all computers, not all cognitive processes will happen in all brains. The abilities of people with highly superior autobiographical memory imply that they are engaging memory "apps" that differ in some way from those available to most people. Similarly, the ability of humans to recall past episodes in their lives seems to differ from the kinds of memories sea turtles use to guide them to their birthplaces years later (Allen & Fortin, 2013; Tulving, 2002).

Experiences affect physical and mental actions by creating memories that determine what an individual can do or know. The sorts of memories resulting from specific experiences can vary considerably depending on the age and species of the individual. When it comes to cognition, it's important to remember that similar labels don't always imply similar cognitive processes. For example, there are many shades of memory, a topic covered more fully in Chapter 8.

Continuity in Cognition

Different species behave differently, but the systems that enable them to behave are generally quite similar. Many animals' activities cluster into categories that are recognizable across species, including actions related to foraging, mating, navigating, communicating, exploring, socializing, sleeping, etcetera (Shettleworth, 2010).

People have long debated about what cognitive processes different species share and about which kinds of behavior require the most or least cognition (de Waal, 2010; Premack, 2007). Charles Darwin was the first to argue on scientific grounds that there should be continuity between the mental abilities of humans and other animals (Darwin, 1871). Darwin's "mental continuity" hypothe-

FIGURE 1.14. Beluga bubblebatics. Beluga in aquaria sometimes learn to make and manipulate bubble rings, transforming them in creative ways. Once one beluga figures out how to do this, others soon pick up the trick. What might such creativity tell us about beluga minds? (Allen Creative I Steve Allen/Alamy Stock Photo)

sis suggests that any mental process that occurs in humans is likely to be present in some other animals either to a greater or lesser degree.

This does not mean that the mental actions of nonhumans are the same as those of humans. Just as there are many ways that animals use their bodies to move around in the world, there could be many ways that they mentally control and experience such movements.

Observing how birds, bees, and bats fly ultimately made it possible for humans to understand the mechanisms of flight. Darwin thought that by studying mental processes in other animals, we might similarly gain new ways of understanding how all minds work (Angell, 1909) (**Figure 1.14**).

Biological Predispositions

A major reason why animals have such varied ways of traveling is that they have become specialists at moving in their specific natural environments (Alexander, 2003). Evolutionary psychologists argue that the same forces have shaped cognitive processes (Bolhuis et al., 2011; Cosmides & Tooby, 1997; Workman & Reader, 2021). For example, animals that often navigate in the dark might depend on specialized perceptual processes that enable them to recognize objects from their echoes, and animals that rely heavily on social coordination might develop specialized systems for communicating (like language).

You'll hopefully recognize that this view is a kind of nativism. The basic idea is that if there is some cognitive process that naturally comes easily to you, then it's probably because evolutionary forces have adapted the way that human cognition works to make that process more effective and efficient. In other words, those processes are adaptations—evolved solutions to problems.

So, if humans find learning language easy, and other animals don't, then it must be, according to evolutionary psychologists, because humans evolved some specialized language processing abilities. If some kinds of birds are really good at remembering where they've hidden seeds months ago, then it must be because they evolved some specialized memory abilities (Branch et al., 2022), and so on. From this perspective, it is important to consider the conditions within which cognitive processes evolved when attempting to understand why they work the way they do.

Social Cognition

When considering the evolutionary origins of cognition, there are piles of problems that seem likely to be major drivers of cognitive adaptations (Fuchs, 2017). They're basically the same kinds of problems you've likely encountered in your daily life—deciding where to go and when, finding your way there and back, navigating social encounters with others, maintaining your health and appearance, and so on. These kinds of problems may not seem to require any kind of Watson-like intelligence to solve, but their prevalence means that the problems can strongly affect how organisms evolve.

Problems related to social interactions, in particular, have attracted lots of scientific attention, not only because of their importance in daily life but also because many of the most mysterious cognitive processes (language use, imitation, musicality) are closely tied to such interactions (De Jaeger et al., 2010; Micheal et al., 2016).

Social cognition research focuses on these kinds of cognitive processes, which are often viewed as the most sophisticated and specialized components of cognition (**Figure 1.15**). Chapters 11 and 12 delve into whether the kinds of cognitive processes that make social interactions possible are really so special, or whether they depend on the same basic mechanisms as other less social actions.

FIGURE 1.15. Social learning. Many complex skills that adults learn are taught or coached by experts who have previously learned them. Does this kind of learning through guidance require any specialized cognitive abilities, or would some kind of generic problem-solving process be good enough? (Tyler Olson via Shutterstock)

Motivation

Natural history may explain your innate tendencies to behave in certain ways, but if someone asked you to explain why you made a specific decision, like why you chose to take a certain class, you are probably more likely to mention factors such as your interest in the topic or your desire to sleep late rather than your parents' genes. The ongoing internal states that lead you to act in certain ways, either physically or mentally, are collectively referred to as **motivation**. These sorts of drives may seem separate from the kinds of processes you might typically think of as being cognitive, but they can strongly affect how you think, especially when you are trying to make decisions (Braem & Egner, 2018; Westbrook et al., 2020; Yee & Braver, 2018) (discussed further in Chapter 3).

For instance, many of the biases that can derail rational thought relate to motivational factors (Botvinick & Braver, 2015) (see Chapter 10). For example, people working together in committees notoriously make poor decisions, in part because individuals feel pressure to find solutions by a specific deadline and because of social drives to not be the odd person out. Motivational factors also can lead people to behave in ways that are irrational and even against their own beliefs, as in the infamous Milgram experiment in which participants showed a surprising willingness to electrocute random people for no reason other than that they were told to do so.

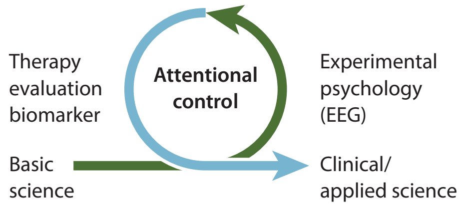
Cognitive Control

Closely related to the motivation to do things is **volition**, a cognitive process that enables you to consciously choose when and how to act (Haggard, 2019). Most cognitive acts, including recalling, deciding, problem-solving, and thinking, appear to be controlled in ways that imply the existence of a controller (Hammond, 1972; Miller, 2000). In cognitive psychology, processes that provide cognitive control are sometimes called **executive functions** (Posner et al., 2004).

Some people (like Descartes) would argue that it's motivation and volition in particular that differentiate people from machines like Watson. Volition is a tricky topic, however. Plenty of man-made control systems can perform sophisticated actions, such as flying a plane. Those systems do not need volition to choose or decide actions in the way that people seem to; autopilots do not "go with their guts." Modern discussions of cognitive control have shifted from using terms like voluntary (dependent on volition) and involuntary (independent of volition) to describing processes as either explicit or implicit to avoid messy questions about the nature of volition and where it comes from (Braver, 2012; Munakata et al., 2012).

Many psychological disorders involve degraded cognitive control. For instance, people suffering from major depression often have problems with initiating goal-directed actions and with shifting

(A)



(B)

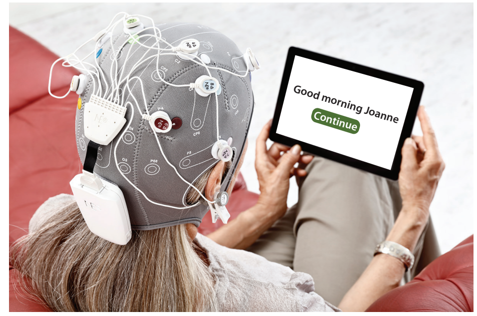


FIGURE 1.16. Cognitive pathways to recovery. (A) Qualitative models describing how mechanisms of cognitive control like attentional control are related to physiological measures like EEG (see Chapter 2) can be used to develop new techniques for diagnosing psychological disorders, as well as for evaluating novel therapeutic interventions such as neurofeedback (B) that is coordinated with cognitive training. Knowing what processes to redirect and when provides powerful tools for treating disorders that are more precise, dynamic, and customizable than current approaches. (B © 2023 Neuroelectrics. All rights reserved.)

attention away from negative thoughts (Dotson et al., 2020; Grahek et al., 2019). Findings from cognitive psychology not only can provide insights into why certain emotional states interfere with cognitive control but also can guide the development of interventions to overcome such limitations (**Figure 1.16**).

Information Seeking

The motivational force most closely tied to cognition and cognitive psychology research is curiosity. As soon as toddlers get a handle on communicating, the questions begin to fly.

Such acts of information seeking are another sign of metacognition in that they reveal that toddlers are, in some sense, aware of their ignorance. Exploratory actions provoked by novel objects, situations, or problems provide the clearest evidence of internal states that lead explorers to behave in the ways they do (Sobel & Kushnir, 2013).

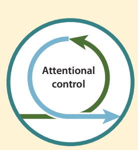
Much of the learning that drives cognitive development is thought to come from curiosity—ignorance may be bliss, but it's still rewarding to be in the know (Hacques et al., 2021; Köster et al., 2020). Curiosity also drives your attention, which determines what you perceive (see Chapter 4), and ultimately what you know. If you're curious about how cognition works, you will be more likely to buy and read a book about cognition, more likely to not zone out while reading it, and more likely to be able to recall specific theories and experiments described in the book.

Curiosity can also lead to creativity (see Chapter 9) as you attempt to invent or discover new solutions to problems or new ways of experiencing the world. Curiosity lies at the heart of all scientific efforts to understand behavior and mental processes (Chu & Schulz, 2019; Gruber & Fandakova, 2021). If you're curious about exactly how scientists have attempted to understand these processes, then read on!

SIGHT BITES

Cognition is shaped by evolutionary, environmental, and experiential forces—nature plus nurture—as are the behavioral markers of cognitive processes.

Experiences affect physical and mental actions by creating memories that determine what an individual can do or know.



Many cognitive acts, including recalling, deciding, problem-solving, and thinking imply voluntary control of cognition by a motivated controller.

SCIENTIFIC APPROACHES TO UNDERSTANDING COGNITION

SNEAK PEEK: Researchers seek to understand the nature of cognition by observing actions in various contexts and by conducting experiments to test the predictions of models.

People have studied minds and behavior for millennia. However, most early efforts relied on intuition, reflection, and reasoning rather than on the systematic collection of objective measurements, and so would not be considered scientific.

There are two main ways that scientists attempt to understand mechanisms of behavior and cognition: (1) through detailed observations and (2) through behavioral experiments. At first, psychological studies of minds emphasized observations over experiments, but in the last century, experimental approaches have taken over, especially in studies of cognition. The following sections cover a brief history of mind research, describing the basic methods that have led to modern ideas about what cognition is and how it works.

Ethology: Observing Natural Cognition

The starting point for what psychologists understand about cognition is folk psychology, also known as common sense or what your grandmother could have told you. It's a mix of authority, personal experiences, and secondhand reports that provides the foundation for scientific studies of cognition (Stich & Ravenscroft, 1994).

Darwin's early claims about the continuity of cognition across species relied heavily on folk psychology—his own observations of animal behavior as well as anecdotal stories that were passed on to him. Anecdotal evidence generally comes from unplanned observations of surprising or unique situations. For example, if you saw a squirrel in a park opening a soda can with its teeth, that would be anecdotal evidence that squirrels can solve the problem of how to open cans.

If you ever people-watch in an airport, you might also learn something about how cognition operates (or doesn't) in natural contexts (Kingstone, 2020). Such observations would only be considered scientifically relevant if you collected detailed measurements of actions that could potentially answer a specific question (Eibl-Eibesfeldt, 1979), such as, "Are people with less hair more likely to misplace their carry-on luggage?" Typically, that question would either confirm or refute a belief or suspicion you have about how and why people behave the way they do, such as "Older people have a shorter memory span."

Ethology is a scientific approach to studying behavior that involves systematically cataloguing the actions of individuals or groups in naturalistic contexts (Dhein, 2021; Tinbergen, 1972). You've probably heard about Konrad Lorenz (1903–1989), the European scientist who studied the natural tendency of certain birds to become attached to individuals they see soon after hatching (called imprinting) (**Figure 1.17**). Lorenz was an early ethologist who collected observations of animal behavior in many different contexts to try and better understand why they behave the way they do (Lorenz, 1978).

Ethologists tend to focus on studying natural actions performed by their subjects, such as those associated with mating, feeding, or social communication (Goodall, 1964). Observations of animals using tools (Seed & Byrne, 2010) and performing innovative actions (Arbilly & Laland, 2017) have increased researchers' interest in understanding how learning and experience contribute to an individual's ability to solve complex problems.

An advantage of the ethological approach is that, like evolutionary psychology, it considers how organisms behave in their natural environments, and attempts to relate behavior to the natural contexts within which the behavior evolved (Roth & Jornet, 2013; Sebanz et al., 2008).

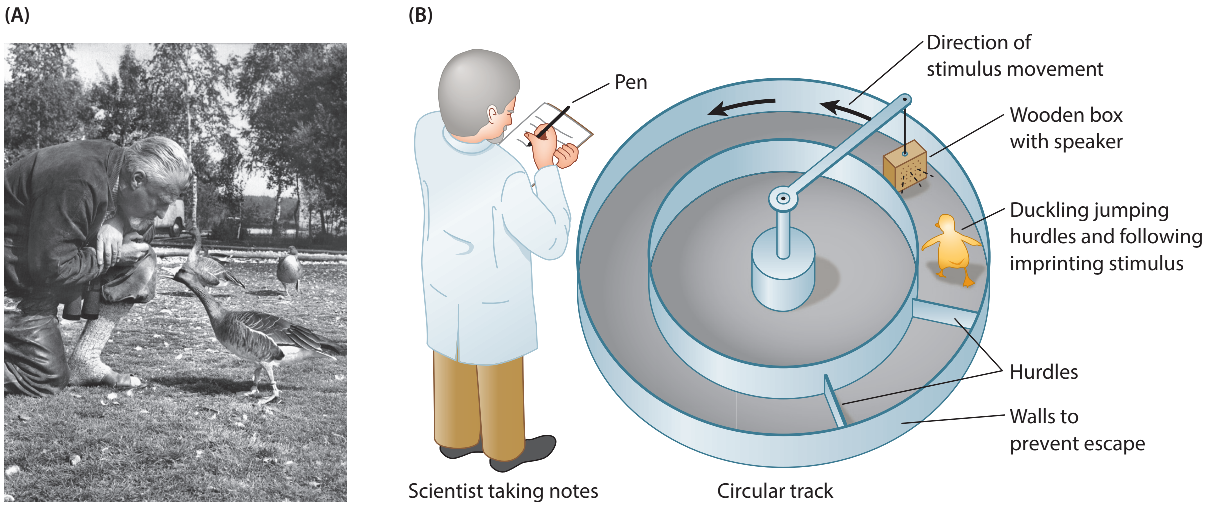


FIGURE 1.17. An ethological approach to understanding behavior. (A) Konrad Lorenz, shown here practicing his observational techniques, imprinted geese on himself to gain a better understanding of how the memories of young animals can shape their behavior toward specific individuals throughout their lives. (B) Later, more controlled experiments revealed the conditions necessary for imprinting to occur, like movement of a nearby object. (A dpa picture alliance/Alamy Stock Photo, B after Cardoso & Sabbatini, 2001.)

A limitation of this approach, however, is that ethologists are often at the mercy of their subjects with respect to what they can potentially study. For instance, if you attempt to conduct an ethological study of turtles in ponds, you might not observe much other than that they sometimes sit on logs and stick their heads above the surface when swimming. Such observations may reveal little about any cognitive processes that contribute to their actions.

People Watching

Ethology might seem less useful for understanding cognition in people, since if you want to know why a person is behaving in a specific way, you could just ask them. But there are many actions that people perform without noticing why or how they're acting. Plus, people's explanations for their actions may not be accurate.

Modern techniques for recording human behavior often use the same methods developed by ethologists. One method is studying how people's eyes move (called eye-tracking) as they read, look at a picture, or watch a movie (Hessels & Hooge, 2019; Lewis & Krupenye, 2022). This method can provide important insights into what features people focus on as they interpret visual scenes or recognize words (Just & Carpenter, 1976; Merkley & Ansari, 2010) (see Chapter 4).

Measuring movements, including those made while a person speaks or gestures, can reveal interactions between cognitive processes that contribute to the planning and execution of actions (Cienki, 2022; Özçalişkan & Goldin-Meadow, 2005). And technologies with the capacity to track changes within a person's body/brain as they perform different physical and mental actions (see Chapter 2) can identify hidden physical mechanisms of cognitive processing (Banich & Compton, 2018; Eagleman & Downar, 2015; Gazzaniga, 2009).

Careful scientific observation of the dynamics of natural behavior, including cognitive acts and the intricacies of functioning brains, provides an important supplement to the more casual observations that ground common sense interpretations of how minds work.

Behaviorism: Experimental Studies of Learning and Performance

Around the same time that Lorenz was swimming in European ponds with geese to try and understand what makes them tick, psychologists in the United States were stuffing other birds (pigeons) in boxes in an effort to reveal the secrets of how learning works (Skinner, 1938).

Unlike the ethologists, who emphasized the innate tendencies of different species that had evolved over millions of years, behaviorists were more interested in the effects of the recent past on changes in an individual's behavior—in other words, the role of nurture and specifically learning on behavior (Hull, 1943; Thorndike, 1932; Watson, 1924).

American behaviorists such as B. F. Skinner (1904–1990) emphasized the role of learning in behavioral change. Like ethologists, behaviorists were keenly interested in observing animal behavior. But unlike ethologists, behaviorists felt that more could be learned from looking at how animals behaved when placed in highly controlled scenarios than from simply watching how they behave in their daily lives (Skinner, 1953).

By controlling conditions in laboratory experiments, behaviorists gained insights into the factors that most strongly motivated animals to change their behavior and discovered new ways to reveal what animals other than humans perceive about the world. Behaviorists also discovered that many of the "rules of learning" operate in the same way for different species, presenting the possibility that one could reveal new facts about human learning by conducting experiments with nonhuman animals.

Looking at Learning

Behaviorist research is often associated with training rats to repeatedly press a lever for food. It may seem odd that psychologists would spend thousands of hours teaching rats to work vending machines in the hopes of understanding human behavior. However, behaviorists adopted a common scientific tactic of trying to understand a complex phenomenon by breaking it down into its most basic elements (an approach known as **reductionism**). By exploring which variables could lead to basic behavioral changes—increases or decreases in a simple action—behaviorists wanted to identify principles of behavior that would be likely to apply to most animals (including humans) and to many different kinds of actions.

Behaviorists considered the specific animals and tasks used in experiments to be less critical than how precisely experimental variables were controlled and measured. This way of thinking stemmed from an understanding that any set of principles should apply to all species and tasks. Psychologists conducted experiments mainly with small animals performing simple tasks because these methods were practical and worked well.

The rise of the modern field of cognitive psychology began, in part, as a response to limitations in the behaviorists' approach to studying complex human actions such as having a conversation (Chomsky, 1959), or thinking about possible solutions to problems (Miller, 2003). In shifting to experiments on humans, cognitive psychologists gradually turned from exploring how individuals learn toward measuring how they perform when faced with various tasks (Neisser, 1967).

The distinction between learning versus performance is an important one for behaviorists, because how an individual behaves only reveals an incomplete picture of what they have learned. For instance, someone observing your behavior while you are reading this book would gain little insight into what you are learning from reading it because what you are learning is hidden from observers.

Behaviorists call this latent learning because the evidence that any learning occurred has yet to show up in your performance. An American behaviorist named Edward Tolman (1886–1959) championed the idea that latent learning was happening all the time and that hidden memories played a major role in guiding behavior (**Figure 1.18**). Tolman developed several ingenious tasks to show that rats running through mazes knew more about the spatial layout of the mazes than researchers could guess just from watching them run (Tolman, 1925, 1932).

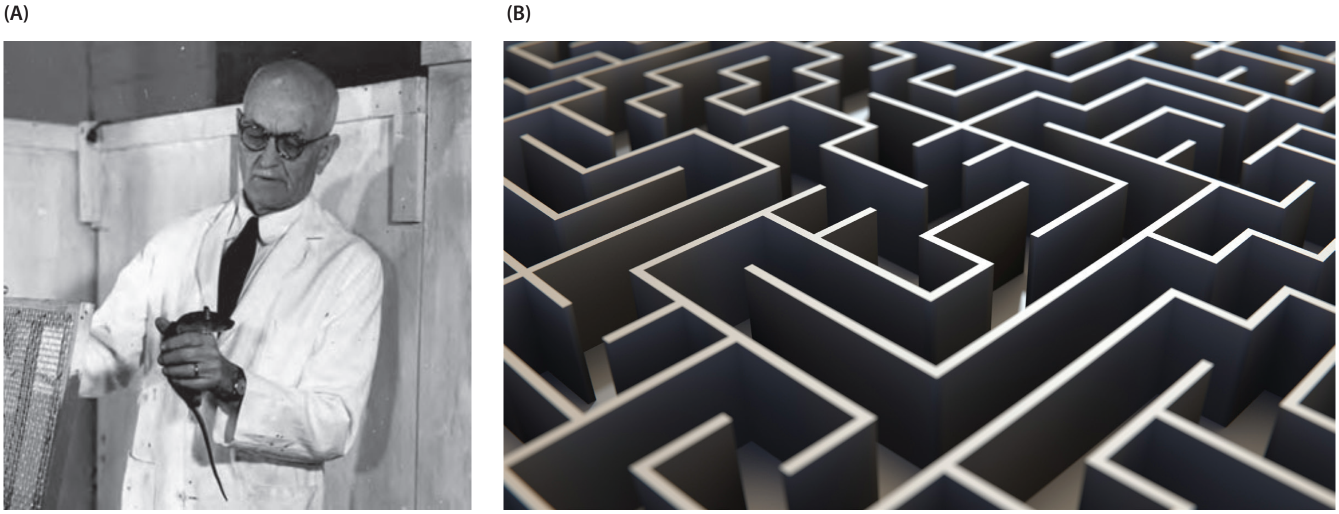


FIGURE 1.18. Amazing rats. Edward Tolman (A) explored what rats know about mazes (B) they are familiar with. He argued that rats gradually learn about the spatial layout of mazes in much the same way that humans do. (A from Berkely News. © 2023 UC Regents. All rights reserved; B James A Isbell via Shutterstock)

Cognitive Psychology: Drawing Inferences about Mental Processes

Like behaviorists, cognitive psychologists rely heavily on controlled behavioral experiments in their attempts to understand behavior (Gigirenzer, 1991; Glenberg, 2013). But rather than measuring how animals' behavior changes when they are rewarded or punished, cognitive psychologists focus more on measuring how people perform in tasks carefully designed to engage specific cognitive processes (Glaser, 1981; Roediger, 1980).

While ethologists and behaviorists differed in emphasizing either innate reactions (nature) or learned behavior (nurture), both groups agreed that the key to understanding the mechanisms of behavior was to carefully measure the actions of animals in different contexts. They also agreed that attempting to measure unobservable events that were happening inside an individual's head or mind was scientifically a waste of time. It's perhaps not surprising then that there has historically been some tension between ethologists, behaviorists, and cognitive psychologists (Lehrman, 1953; Mackenzie, 1977; Watrin & Darwich, 2012).

The earliest psychological laboratories often focused on experimental studies of cognitive processes like perception and memory. Many consider the German professor Wilhelm Wundt's (1832–1920) studies of attention and perception to represent the birth of experimental psychology as an academic field (Wundt sounds like "Voont"). Wundt trained researchers to make objective reports on their inner experiences while performing tightly controlled experimental tasks (Wundt, 1912), a kind of self-report he called **introspection** (the same approach Margaret Washburn used for her dissertation research).

People are sometimes described as introspective when they actively contemplate why things are the way they are or how they feel about ongoing events. Wundt's introspection differs, however, from just thinking about what it feels like to perform a cognitive task like reading or remembering. Wundt would probably argue that his trained observers were making judgments more like those that professional chefs make when judging entries at a cooking contest. In comparison, he might view your untrained observations of your own mental states as more comparable to those of a six-year-old describing a hamburger she ate at a fast-food restaurant.

Introspection hasn't been widely used in the last century as an experimental method for studying cognitive processes. This is partly because it's difficult to establish whether such observations are reliable or valid, and partly because it's hard to train observers to improve their reports when you don't know what they're observing (Gonzalez-Castillo et al., 2021).

Using introspection as a method for studying mental processes in nonhumans is even more problematic. This may explain why scientists who focused on studying animals historically considered attempts to understand animal behavior by studying mental processes to be a lost cause.

Self-reports remain part of some cognitive studies, however, such as when participants are instructed to "think aloud" as they solve a problem (Ericsson & Fox, 2011; van Someren et al., 1994), or to say whether they're certain they recently experienced an item in a memory test (Tulving, 1985).

Experimental Methods

Modern cognitive psychologists continue to use a subset of the experimental methods initially pioneered by Wundt, including measuring how long it takes people to respond to perceived and recognized events (Wenger & Townsend, 2000). Now, however, researchers focus more on analyzing patterns of performance that groups of participants consistently produce to try and figure out what's happening inside people's heads.

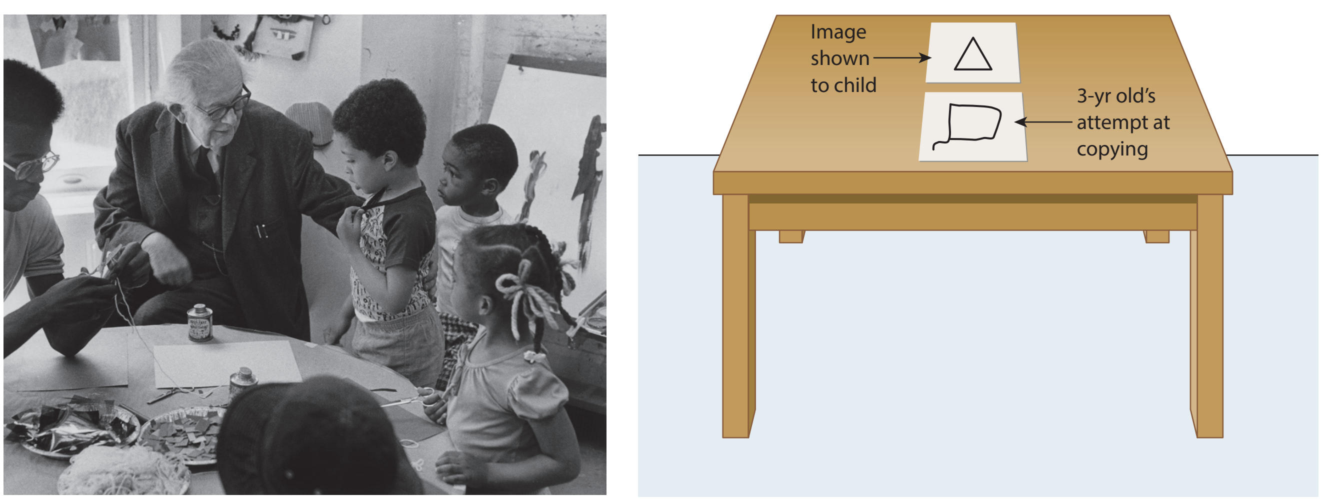
Developmental psychologist Jean Piaget (1896–1980), for example, constructed a variety of different tasks that could be presented to children to reveal how their responses to these tasks changed as they got older (**Figure 1.19**). Based on the specific kinds of errors that children made at certain ages, Piaget concluded that children pass through multiple developmental stages in which they cognize in specific ways (Piaget, 1952).

Piaget argued that just as infants first learn to crawl, then to walk, and finally to run, they also first learn to recognize objects and act on them, then to talk about those objects and actions, and finally to think about them. The key advantage of Piaget's approach over more introspective and observational methods is that researchers can quantitatively measure the reliability with which children make such errors (Baillargeon et al., 2011; Gelam & Gallistel, 1978).

You can still question, of course, whether the children made errors for the reasons that Piaget claimed they did (Spelke & Newport, 1998; Wynn, 1992). A behaviorist might argue that Piaget's explanations are no better than a fairy tale, since no one can ever really know what is going on inside a child's head. Perhaps Piaget would have countered that a potentially inaccurate hypothesis about how a child's understanding of the world guides his or her actions is preferable to the behaviorist assumption that it's impossible to know anything about what children understand.

FIGURE 1.19. Cognition revealed by children's errors. (A) Jean Piaget developed tasks to explore how children understand the world. (B) Young children often draw odd shapes when asked to copy a triangle. This suggests that they may think of triangles as something like squares with extra pointy parts. (A Bill Anderson/Science Photo Library)

(A) (B)



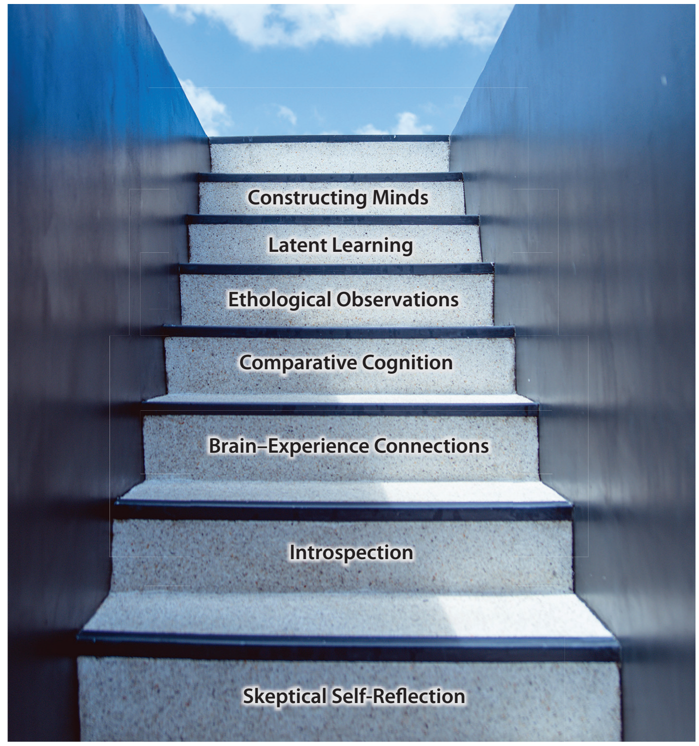


FIGURE 1.20. Where cognitive psychology came from. The history of cognitive research is a history of scientific methods and different ways of thinking about mental processes. Each new approach, from Descartes' skeptical self-reflection to Piaget's developmental construction of minds, yielded insights and raised intriguing questions. What are the biggest differences between these early approaches to understanding why people act and think the way they do? (Konrad B,ik/Alamy Stock Photo)

The goal of cognitive research is not just to understand how cognition works, but to get a better handle on the kinds of approaches that are most likely to lead to such an understanding. Making progress in cognitive psychology is not about collecting more observations, but about collecting the kinds of observations that reveal where our current thinking has gone wrong (Neisser, 1967; Shepard, 1968).

Some of the experimental methods used in cognitive research that you'll learn about in this book may seem a bit ridiculous given the complexity of the processes being investigated. Can cognitive psychologists really understand how language works by having undergraduates press a button as fast as they can whenever a word is presented?

Other brain-based methods like magnetoencephalography (see Chapter 2) may seem so science-fictional that it's hard to even grasp what it is that cognitive psychologists are observing. Regardless of which methods are used, their value comes not from how fancy they are, but from what questions they can help cognitive psychologists answer.

Every method has its strengths and weaknesses, as does every approach to scientifically studying minds and behavior (**Figure 1.20**). In considering what current evidence reveals about cognition, it's important to always keep in mind that the case is not yet closed—there are many cognitive mysteries yet to be solved.

Current Practices of Cognitive Psychologists

In the early days of scientific research, there were few guidelines about how researchers should conduct studies of cognitive processes. Self-studies were common.

In the 1600s, Isaac Newton (1643–1727) investigated color vision by shoving a long sewing needle into his eye socket, which he reported caused him to see colored circles (Newton, 1972). Hermann Ebbinghaus (1850–1909) spent several years memorizing lists of nonsense words in the late 1800s so that he could later test his ability to recall and relearn the lists (Ebbinghaus, 1885/1964).

Modern cognitive psychologists rarely go to such extremes in exploring cognitive processes. More typically, they recruit a bunch of undergraduates (usually students in psychology courses) and

(continued...)

INDEX

Page references in italics indicate figures.

D

E

I