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Studying and Encoding Memories
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Improving Memory

## Memory

Be thankful for your memory. We often take memory for granted, except when it malfunctions. But it is our memory that accounts for time and defines our life. It is our memory that enables us to recognize family members, speak our language, and find our way home. It is our memory that enables us to enjoy an experience and then mentally replay it to enjoy again. It is our memory that enables us to build histories with those we love. And it is our shared memories that bind us together as Irish or Iranian, Somalian or Samoan-and occasionally pit us against others whose offenses we cannot forget.

In large part, we are what we remember.
Without memory—our archive of accumulated learning-there would be no savoring of past
joys, no guilt or anger over painful recollections.
We would instead live in an enduring present, each moment fresh. Each person would be a stranger, every language foreign, every task-dressing, cooking, biking-a new challenge. You would even be a stranger to yourself, lacking that continuous sense of self that extends from your distant past to your momentary present.

Researchers study memory from many perspectives. We'll begin by looking at the measuring, modeling, and encoding of memories, and we will examine how memories are stored and retrieved. Then we'll explore what happens when our memories fail us, and look at ways to improve memory.

## $\Leftrightarrow$ Studying and Encoding Memories

## Studying Memory

LLEARNING OBJECTIVE QUESTION LOQ<br>8-1 What is memory, and how is it measured?

Memory is learning that persists over time; it is information that has been acquired and stored and can be retrieved. Research on memory's extremes has helped us understand how memory works. At age 92, my [DM's] father suffered a small stroke-like brain event that had but one peculiar effect. His genial personality was intact. He knew us and enjoyed poring over family photo albums and reminiscing about his past. But he had lost most of his ability to form new memories of conversations and everyday episodes. He could not tell me what day of the week it was, or what he'd had for lunch. Told repeatedly of his brother-in-law's recent death, he was surprised and saddened each time he heard the news.

Some disorders slowly strip away memory. Alzheimer's disease begins as difficulty remembering new information, progressing to an inability to do everyday tasks. Complex speech becomes simple sentences; family members and close friends become strangers; the brain's memory centers, once strong, become weak and wither away (Desikan et al., 2009). Over several years, those with Alzheimer's may become unknowing and unknowable. Their sense of self weakens, leaving them wondering, "Who am I?" (Ben Malek et al., 2019). Lost memory strikes at the core of their humanity, robbing them of their joy, meaning, and companionship.

At the other extreme are people who win gold medals in memory competitions. When two-time World Memory Champion Feng Wang was a 21 -year-old college student, he didn't need help from his phone to remember his friends' numbers. The average person can parrot back a string of about 7-maybe even 9—digits. If numbers were read about 1 per second, Feng could reliably repeat up to 200 (Ericsson et al., 2017).

Amazing? Yes, but consider your own impressive memory. You remember countless faces, places, and happenings; tastes, smells, and textures; voices, sounds, and songs. One study asked students to listen to snippets-a mere four-tenths of a second-from popular songs. How often did they recognize the artist and song? More than 25 percent of the time (Krumhansl, 2010). We often recognize songs as quickly as we recognize a familiar voice.

So, too, with faces and places. Imagine viewing more than 2500 slides of faces and places for 10 seconds each. Later, you see 280 of these slides, paired with others you've never seen. Actual participants recognized 90 percent of the slides they had viewed in the first round (Haber, 1970). In a follow-up experiment, people who viewed 2800 images for only 3 seconds each spotted the repeats with 82 percent accuracy (Konkle et al., 2010). Look for a target face in a sea of faces and you later will recognize other faces from the scene as well (Kaunitz et al., 2016).

The average person permanently stores and recognizes about 5000 faces (Jenkins et al., 2018). But some super-recognizers display an extraordinary face-recognition ability. By watching street footage, super-recognizers have helped British, Asian, and German police to solve difficult cases (Keefe, 2016; NPR, 2018). Eighteen months after viewing a video of an armed robbery, one super-recognizer police officer spotted and arrested the robber walking on a busy street (Davis et al., 2013). And it's not just humans who have shown remarkable memory for faces. Sheep remember faces, too (FIGURE 8.1). And so has at least one fish species-as demonstrated by their spitting at familiar faces to trigger a food reward (Newport et al., 2016).

How do we humans accomplish such memory feats? How does our brain pluck information from the world around us and tuck it away for later use? How can we remember things we have not thought about for years, yet forget the name of someone we just met? How are memories stored in our brain? Why will you be likely, later in this chapter, to misrecall this sentence: "The angry rioter threw the rock at the window"?


Extreme forgetting Alzheimer's disease severely damages the brain, and in the process strips away memory.

Want to test your memory? Try to memorize the first 10 digits of pi ( $\pi$ ): 3.141592653 . In 2015, Rajveer Meena of India broke the world record by reciting 70,000 digits of pi (Guinness World Records, 2019).

FIGURE 8.1
Other animals also display face smarts After food rewards are repeatedly associated with some sheep and human faces, but not with others, sheep remember food-associated faces for 2 years (Kendrick \& Feng, 2011; Knolle et al., 2017).

memory the persistence of learning over time through the encoding, storage, and retrieval of information.
"If any one faculty of our nature may be called more wonderful than the rest, I do think it is memory." -Jane Austen, Mansfield Park, 1814

Imagine having an injury that significantly impairs your ability to form new memories. Now imagine having a record-setting ability to remember, like Feng Wang. How would each condition affect your daily routine?

## Measuring Retention

To a psychologist, evidence that learning persists includes these three retention measures:

- recall-retrieving information that is not currently in your conscious awareness but that was learned at an earlier time. A fill-in-the-blank question tests your recall.
- recognition-identifying items previously learned. A multiple-choice question tests your recognition.
- relearning-learning something more quickly when you learn it a second or later time. When you review the first weeks of course work to prepare for your final exam, or engage a language used in early childhood, it will be easier to relearn the material than it was to learn it initially.
Long after you cannot recall most of the people in your high school graduating class, you may still be able to recognize their yearbook pictures and spot their names in a list of names. In one experiment, people who had graduated 25 years earlier could not recall many of their old classmates. But they could recognize 90 percent of their pictures and names (Bahrick et al., 1975). If you are like most students, you, too, could probably recognize more names of Snow White's seven dwarfs than you could recall (Miserandino, 1991).

Our recognition memory is impressively quick and vast. "Is your friend wearing a new or old outfit?" Old. "Have you read this textbook material before?" No. "Have you ever seen this person before?" No. Before the mouth can form our answer to any of millions of such questions, the mind knows, and knows that it knows.

Our response speed when recalling or recognizing information indicates memory strength, as does our speed at relearning. Pioneering memory researcher Hermann Ebbinghaus (1850-1909) showed this in the nineteenth century using nonsense syllables. He randomly selected a sample of syllables, practiced them, and tested himself. To get a feel for his experiments, rapidly read aloud, eight times over, the following list of syllables (from Baddeley, 1982). Then, look away and try to recall the items:

> JIH, BAZ, FUB, YOX, SUJ, XIR, DAX, LEQ, VUM, PID, KEL, WAV, TUV, ZOF, GEK, HIW.

The day after learning such a list, Ebbinghaus could recall few of the syllables. But they weren't entirely forgotten. As FIGURE 8.2 portrays, the more frequently he repeated the list aloud on Day 1, the less time he required to relearn the list on Day 2. Additional rehearsal (overlearning) of verbal information increases retention-especially when practice is distributed over time. For students, this means that it helps to rehearse course material over time, even after you know it. Better to rehearse and overlearn than relax and remember too little.

The point to remember: Tests of recognition and of time spent relearning demonstrate that we remember more than we can recall.

RETRIEVE IT
RI-1 Multiple-choice questions test our $\qquad$ Fill-in-the-blank questions test our $\qquad$
RI-2 If you want to be sure to remember what you're learning for an upcoming test, would it be better to use recall or recognition to check your memory? Why?

ANSWERS IN APPENDIX F

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## Memory Models

LOQ 8-2 How do memory models help us study memory, and how has later research updated the three-stage model?

Architects create virtual models to help clients imagine their future homes. Similarly, psychologists create memory models. Such models aren't perfect, but they help us think about how our brain forms and retrieves memories. History has offered varied memory models: a wax tablet (Aristotle); a "mystic writing pad" (Freud); a house, a library, a telephone switchboard, a videotape (Roediger, 1980). Today's information-processing model likens human memory to computer operations. Thus, to remember, we must

- encode-get information into our brain.
- store-retain that information.
- retrieve-later get the information back out.

Like all analogies, computer models have their limits. Our memories are less literal and more fragile than a computer's. Most computers also process information sequentially, even while alternating between tasks. Our agile brain processes many things simultaneously (some of them unconsciously) using parallel processing (see Chapter 3). To focus on this multitrack processing, one information-processing model, connectionism, views memories as products of interconnected neural networks. Specific memories arise from particular activation patterns within these networks. Every time you learn something new, your brain's neural connections change-an example of neuroplasticity (see Chapter 2)-forming and strengthening pathways that allow you to interact with and learn from your constantly changing environment.

To explain our memory-forming process, Richard Atkinson and Richard Shiffrin (1968, 2016) proposed a three-stage model:

1. We first record to-be-remembered information as a fleeting sensory memory.
2. From there, we process information into short-term memory, where we encode it through rehearsal.
3. Finally, information moves into long-term memory for later retrieval.

This model has since been updated (FIGURE 8.3) with important newer concepts, including working memory and automatic processing.

## ASK YOURSELF

What has your memory system encoded, stored, and retrieved today?

WORKING MEMORY Atkinson and Shiffrin saw short-term memory merely as a space for briefly storing recent thoughts and experiences. Alan Baddeley and others (Baddeley, 2002; Barrouillet et al., 2011; Engle, 2002) extended our understanding. They began calling this stage working memory, a stage where short-term memories combine with longterm memories. Baddeley likened working memory to an active "scratch pad" where our brain makes sense of new experiences and links them with our long-term memories. This "system for holding information in mind and working on it" (Oberauer et al., 2018) also functions in the opposite direction, by retrieving and processing previously stored information.

As you integrate new information with your existing long-term memory, your attention is focused. In Baddeley's (2002) model, a central executive coordinates this focused processing. Without focused attention, information typically fades. If you think you can look something up later, you attend to it less and forget it more quickly. In one
recall a measure of memory in which the person must retrieve information learned earlier, as on a fill-in-the-blank test.
recognition a measure of memory in which the person identifies items previously learned, as on a multiple-choice test.
relearning a measure of memory that assesses the amount of time saved when learning material again.
encoding the process of getting information into the memory system-for example, by extracting meaning.
storage the process of retaining encoded information over time.
retrieval the process of getting information out of memory storage.
parallel processing processing multiple aspects of a stimulus or problem simultaneously.
sensory memory the immediate, very brief recording of sensory information in the memory system.
short-term memory briefly activated memory of a few items (such as digits of a phone number while calling) that is later stored or forgotten.
long-term memory the relatively permanent and limitless archive of the memory system. Includes knowledge, skills, and experiences.
working memory a newer understanding of short-term memory; conscious, active processing of both (1) incoming sensory information and (2) information retrieved from long-term memory.

FIGURE 8.3
A modified three-stage model of memory Atkinson and Shiffrin's classic three-stage model helps us to think about how memories are processed, but researchers now recognize other ways that long-term memories form. For example, some information slips into long-term memory via a "back door," without our consciously attending to it (automatic processing). And so much active processing occurs in the short-term memory stage that we now call it working memory.


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Achie/e For a 14-minute explanation and demonstration of our memory systems, see the Video: Models of Memory.
explicit memory retention of facts and experiences that we can consciously know and "declare." (Also called declarative memory.)
effortful processing encoding that requires attention and conscious effort.
automatic processing unconscious encoding of incidental information, such as space, time, and frequency, and of familiar or well-learned information, such as sounds, smells, and word meanings.
implicit memory retention of learned skills or classically conditioned associations independent of conscious recollection. (Also called nondeclarative memory.)
iconic memory a momentary sensory memory of visual stimuli; a photographic or picture-image memory lasting no more than a few tenths of a second.
echoic memory a momentary sensory memory of auditory stimuli; if attention is elsewhere, sounds and words can still be recalled within 3 or 4 seconds.
experiment, people read and typed new bits of trivia they would later need, such as "an ostrich's eye is bigger than its brain." If they knew the information would be available online, they invested less energy and remembered it less well (Wegner \& Ward, 2013). Online, out of mind.

Right now, your working memory is actively linking what you're reading with what you already know (Cowan, 2010, 2016; deBettencourt et al., 2019). If you hear "eye-screem," you may encode it as ice cream or I scream, depending on both your experiences and the context (snack shop or horror film).

For most of you, what you are reading enters working memory through vision. You might also repeat the information using auditory rehearsal. Some groups, such as Inuit in northern Canada, use repeated oral histories to help younger group members remember important information. In one dramatic case, repeated information passed down through many generations was crucial to the archeological discovery of the doomed ships of the 1845 Franklin Expedition, which sank near where local Inuit lived (Neatby \& Mercer, 2018). Whether we soak up information with our eyes or our ears, working memory helps us integrate our previous experiences to make smart decisions.

RETRIEVEIT
RI-3 How does the working memory concept update the classic Atkinson-Shiffrin three-stage model?
RI-4 What are two basic functions of working memory?
ANSWERS IN APPENDIX F

## Encoding Memories

## Dual-Track Memory: Effortful Versus Automatic Processing

LOQ 8-3 How do explicit and implicit memories differ?
Explicit (declarative) memories are the facts and experiences we can consciously know and "declare." We encode many explicit memories through conscious effortful processing. But behind the scenes, other information skips the conscious encoding track and barges directly into storage. This automatic processing, which happens without our awareness, produces our implicit (nondeclarative) memories.

Our two-track mind, then, helps us encode, retain, and retrieve information through both effortful and automatic tracks. Let's see how automatic processing assists the formation of implicit memories.

## Automatic Processing and Implicit Memories

## LOQ 8-4 What information do we process automatically?

Our implicit memories include procedural memory for automatic skills (such as how to ride a bike) and classically conditioned associations among stimuli. If once attacked by a dog, years later you may, without recalling the conditioned association, automatically tense up as a dog approaches.

Without conscious effort you also automatically process information about

- space. While studying, you often encode the place where certain material appears; later, you may visualize its location when you want to retrieve the information.
- time. While going about your day, you unintentionally note the sequence of its events. Later, realizing you've left your phone somewhere, the event sequence your brain automatically encoded will enable you to retrace your steps.
- frequency. You effortlessly keep track of how many times things happen, as when you realize, "This is the third time I've run into her today!"
Our two-track mind engages in impressively efficient information processing. As one track automatically tucks away routine details, the other track is free to focus on conscious, effortful processing. Mental feats such as vision, thinking, and memory may seem to be single abilities, but they are not. Rather, we split information into different components for separate and simultaneous processing.

