

Memory (Encoding, Storage, Retrieval)

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Abstract

“Memory” is a single term but it reflects a number of different abilities—holding information briefly while working with it (working memory), remembering episodes of one’s life (episodic memory), and our general knowledge of facts of the world (semantic memory), among other types. Remembering episodes involves three processes: encoding information (perceiving it and relating it to past knowledge), storing it (maintaining it over time), and then retrieving it (accessing the information when needed). Failures can occur at any stage, leading to forgetting or to having false memories. The key to improving one’s memory is to improve processes of encoding and to use techniques that guarantee effective retrieval. Good encoding techniques include relating new information to what one already knows, forming mental images, and creating associations among information that needs to be remembered. The key to good retrieval is developing effective cues, ones that will lead the rememberer back to the encoded information. Classic mnemonic systems, known since the time of the ancient Greeks and still used by some today, can greatly improve one’s memory abilities.

Learning Objectives

- Define and note differences between the following forms of memory: working memory, episodic memory, semantic memory, collective memory.
- Describe the three stages in the process of learning and remembering.
- Describe strategies that can be used to enhance the original learning or encoding of information.
- Describe strategies that can improve the process of retrieval.
- Describe why the classic mnemonic device of the method of loci works so well.

Introduction

On a spring day in 2013, Simon Reinhard sat in a room at Washington University in St. Louis with about 60 people in the audience. The task given to the group was to remember digits, in particular increasingly long series of digits. On the first round, a computer generated 10 random digits—6 1 9 4 8 5 6 3 7 1—on a screen for 10 seconds. After the series disappeared, Simon typed them into his computer while those in the audience wrote them on sheets of paper and checked them against Simon's answers on the screen. (The computer checked Simon. He was perfect.) Simon asked how many people got them all correct; a smattering of hands went up. In the next phase, 20 digits appeared on the screen for 20 seconds. Simon got them all correct again. No one in the audience (mostly professors, graduate students, and undergraduate students) recalled the 20 digits perfectly. Then came 30 digits studied for 30 seconds; once again, Simon got them all correct and no one else did. For a final trial, 50 digits appeared on the screen for 50 seconds and again Simon got them all right while the people in the audience watched in amazement. Simon would have been happy to keep going—his record in this task, called forward digit span—is 240 digits (and in the case where he set this record, the situation was a bit more difficult because the digits were read aloud at a one-second rate rather than seen on a screen).

When most of us witness a performance like that of Simon Reinhard, we think one of two things: First, maybe he's cheating somehow. (No, he is not.) Second, Simon must have completely different abilities from the rest of humankind. After all, psychologists established many years ago that the normal memory span for adults is about 7 digits, with some of us able to get a few more and others of us getting a few less (Miller, 1956). That is why the first phone numbers were limited to 7 digits—psychologists determined that many errors were caused (costing the phone company money) when the number is increased to even 8 digits. But in normal testing, no one gets 50 digits correct in a row, much less 240. So does Simon Reinhard simply have a photographic memory? The answer is no. Simon has taught himself strategies for remembering that have greatly increased his capacity for remembering digits as well as for virtually any other type of material—words, faces and names, poetry, historical dates, and so on. Twelve years ago, before he started training his memory abilities, he had a digit span of 7, just like most of us. Simon has been training his abilities for about 10 years as of this writing and has risen to be in the top two of “memory athletes,” as aficionados of this sport like to call themselves. In 2012, he came in second in the World Memory Championships (composed of 11 tasks) held in London. He currently ranks second in the world, behind another German competitor, Johannes Mallow.

In this chapter, we reveal what psychologists and others have learned about memory, and we will also give you the general principles by which you can improve your own memory for factual material. At the end of the chapter, we give you references that would permit you to learn much more about this topic

than we can cover in a brief chapter. First we provide an overview of types of memory, because although we use a single term—“memory”—we often mean quite different things by it.

Varieties of Memory

For most of us, remembering digits relies on short-term memory or working memory, the ability to hold information in mind for a brief time and work with it (e.g., multiplying 24×17 without using paper would rely on working memory). Another type of memory is **episodic memory**, the ability to remember the episodes of your life. If you were given the task of recalling everything you did 2 days ago, that would be a test of episodic memory; you would be required to mentally travel through the day in your mind and note the main events of your day. **Semantic memory** is your storehouse of more or less permanent knowledge, the meanings of words in the language (e.g., the meaning of “parasol”) and the huge collection of facts about the world (that Millard Fillmore was a U.S. President and that Benjamin Franklin was not). Collective memory refers to the kind of memory that people in a group share (whether family, community, schoolmates, citizens of a state or a country). People born and raised in Texas often share a strong Texan identity; they collectively remember the Alamo, the Battle of San Jacinto, Sam Houston, the 12 years when Texas was an independent country, the fabled Texas Rangers, and so on. These items and others constitute the collective memory of Texans.

The kinds of memories listed in the previous paragraphs represent only some of the distinctions that psychologists make. This chapter is largely about episodic memory, remembering the events in one's life. We shall refer to relatively recent events; remembering the events across the course of one's entire life (e.g., your year in sixth grade) is usually referred to as **autobiographical memory**. Psychologists debate the classification of types of memories and which ones rely on other types (Tulving, 2007), but for this chapter we will focus on episodic memory, which is the type of memory that most people have in mind when they hear the word "memory." For example, when people say that an older relative is "losing her memory" due to Alzheimer's disease, the type of memory loss they observe is the ability to remember events or episodic memory. Semantic memory is actually preserved in early-stage Alzheimer's disease.

Three Stages of the Learning/Memory Process

Psychologists distinguish among three necessary stages in the learning and memory process: encoding, storage, and retrieval (Melton, 1963). Encoding is defined as initial learning of information; **storage** refers to maintaining information over time; **retrieval** is the ability to access information when you need it. If you meet someone for the first time at a party, you need to encode her name (Lyn Goff) while you associate her name with her face. Then you need to maintain the information over time. If you see her a week later, you need to

recognize her face and have it serve as a cue to retrieve the name. Any successful act of remembering requires that all three stages be intact. However, two types of errors can also occur, as we are all too well aware. Forgetting is one type—you see the person you met at the party and you cannot recall her name—you just draw a blank. The other error is misremembering (false recall or false recognition). You might see someone who looks like Lyn Goff and call the person that name (false recognition of the face). Or you might see the real Lyn Goff, recognize her face, but then call her the name of some other woman you met at the party (misrecall her name).

Whenever forgetting or misremembering occurs, we can ask what stage in the learning/memory process the failure occurred, although it is often difficult to answer this question with precision. One reason for this ambiguity is that the three stages are not as discrete as implied by our description above. Rather, all three stages depend on one another. How we encode information determines how it will be stored and what cues will be effective when we try to retrieve it. The act of retrieval also changes the way information is subsequently remembered, usually aiding later recall of the retrieved information. The central point for now is that the three stages of encoding, storage, and retrieval affect one another and are inextricably bound together.

Encoding

Encoding refers to the initial experience of perceiving and learning events. Psychologists often study remembering by using tasks such as having students study a list of pictures or words (although sentences, stories and videos are also used). Encoding in these situations is usually straightforward, at least at first glance—you see some words but not others. However, in life encoding is much more challenging. As you walk across campus, you see myriad sights and sounds—friends pass by, as do strangers, people are off playing Frisbee on the lawn, others are lying on the grass reading or talking, music is in the air and you recognize the song, which leads you to remember having heard the same song at a party last week. The physical and mental environments are much too rich for you to encode all the happenings and sights and sounds around you or the internal thoughts you have in response to those sights and sounds. So an important first principle of encoding is that it is selective: You attend to some events in your environment and you ignore others. A second point about encoding is that it is promiscuous—you are always encoding the events of your life; every day is filled with events that you encode and can remember, at least for a while. We attend to the world, trying to understand it. Normally this presents no problem, as our days are filled with routine happenings. But if something happens that seems strange—during your daily walk across campus, you see a giraffe off to the side—then you pay close attention and try to understand why you are seeing what you are seeing. You may ask a friend and

discover that people from the local zoo are visiting and trying to drum up student volunteers. The giraffe came with them to help attract attention to the cause.

After your typical walk across campus from your dorm to class (one without appearance of a giraffe), you would be able to remember the events reasonably well if you were asked. You could say whom you bumped into and to whom you said hello, what song was playing from a radio and so on. However, suppose someone asked you to recall this particular journey a month later. You would not have a chance. You could doubtless recall a typical walk across campus, but not this particular walk (unless something distinctive had happened, like the appearance of the giraffe). Yet if you did see a giraffe while you were walking across campus, you would remember that event for a long time, perhaps for the rest of your life. You would tell your friends about it and on later occasions when you saw a giraffe, you might be reminded of that day one was on campus.

Psychologists have long pinpointed **distinctiveness**—having an event stand out as quite different from a background of similar events—as a key to remembering events (Hunt, 2003). In addition, when vivid memories are tinged with strong emotional content, they often seem to leave an indelible mark on us. People who ran the Boston Marathon in 2013 have doubtless developed vivid memories of the event.

Even those of us who were not directly involved in those events may have vivid memories of the events, including memories of having first heard about the event. For example, you may remember how you heard that there had been a bombing at the marathon (e.g., where you were, who told you). The term

flashbulb memory was originally coined by Brown and Kulik (1977) to indicate this sort of vivid memory of finding out an important piece of news, where the memory seems to have been captured with the vividness of a photograph illuminated with a flash. The moment that people received the news seems etched in memory with great clarity. Later research has shown that although people have great confidence in their memories of such emotional, distinctive events, accuracy is far from perfect (Talarico & Rubin, 2003), so the great confidence is somewhat misplaced. Nonetheless, all other things being equal, distinctive events are well remembered.

Events do not leap from the world into a person's mind. We might say that we went to a party and remember it, but what we remember is (at best) what we encoded. As noted above, the process of encoding is selective and in complex situations, relatively few of many possible happenings are attended to and encoded. The process of encoding always involves **recoding**—that is, taking the information from one form as it is given to us and then converting in a way that makes sense to us. For example, you might try to remember the names of the U.S. Great Lakes by memorizing the acronym HOMES (Huron, Ontario, Michigan, Erie, and Superior). The process of recoding the lakes into a single word can help us to remember. However, recoding can also introduce errors when we add material while encoding and then remember the new material as if it had literally been presented (as discussed below).

Psychologists have studied many recoding strategies that can be used during study to improve retention. First, as we study, we should think of the meaning of the events (Craik & Lockhart, 1972) and we should try to relate new events to information we already know, to form associations that can help us retrieve information later. Second, imagining events also makes them more memorable. Creating vivid images of information (even verbal information) can greatly improve later retention (Bower & Reitman, 1972). Imagery forms part of the technique that Simon Reinhard uses to remember huge numbers of digits, but we can all use images to encode information more effectively. The basic idea behind good encoding tactics is to form distinctive memories (ones that stand out) and to form links or associations among memories to help later retrieval. Using these strategies together greatly aids retention of many sorts of material (Hunt & McDaniel, 1993). It is effortful to use study strategies such as the ones described here, but the effort is well worth it in terms of enhanced learning and retention.

We emphasized earlier that encoding can be selective—people cannot encode all information to which they are exposed. However, recoding can also add information that was not seen or heard. Several of the techniques described above, such as forming associations and making inferences, can happen without our awareness. This is one reason why people can remember events that were not literally there, because during the process of recoding we add the events. One common way of inducing false memories in the laboratory employs a word-list technique (Deese, 1959; Roediger & McDermott, 1995). Students heard lists of 15 words like door, glass, pane, shade, ledge, sill, house, open,

curtain, frame, view, breeze, sash, screen, and shutter. After hearing many such lists, students were given a test in which they got words from the lists (e.g., door, pane, frame) and words unrelated to any of the lists. One of the words on the test was window, which was not studied but which was related to the words that were. That is, many of the words in the list are associated to window although that word is not in the list. When subjects were tested, they correctly recognized the studied words (door, etc.) 72% of the time. That seems reasonably accurate. However, when window was on the test, they falsely recognized it as having been on the list 84% of the time (Stadler, Roediger, & McDermott, 1999). The same happened with many other lists the authors used, and the phenomenon is referred to as the DRM (for Deese-Roediger-McDermott) effect. One idea to explain such results is that while students listened to items in the list, the items often triggered the students to think about window even though window was never presented. In this way, people seem to encode events that were not actually a part of their experience.

Because humans are creative, we are always going beyond the information we are given—we associate events, we make inferences about what is happening. Sometimes we can remember the inferences we make as if the inferred statements had actually been experienced. Brewer (1977) gave people sentences to remember that were designed to elicit pragmatic inferences. Consider “The baby stayed awake all night” and “The karate champion hit the cinder block.” After hearing or seeing such sentences and being given a memory test later, students tended to remember the statements as having been “The baby cried all night” and “The karate champion broke the cinder block.” These

remembered statements are not logical inferences in that it is perfectly possible that a karate champion could hit a cinder block without breaking it. Nonetheless, the pragmatic conclusion from hearing such a sentence is that likely the block was broken. Similarly, babies do not tend to stay awake all night without a fair amount of crying, although this conclusion, too, is a pragmatic inference. It may well be the meaning the speaker intended to convey, but if one looks strictly at what was said, there was no crying involved. The students remembered the inference they made while hearing the sentence as if it had actually occurred (see too McDermott & Chan, 2006).

Encoding—the initial registration of information—is important in the learning and memory process. Unless an event is encoded in some fashion, it will not be successfully remembered later. However, just because an event is encoded (even encoded well) is no guarantee that it will be remembered later.

Storage

Every experience we have changes our brains. That seems a bold, maybe even strange, claim at first sight, but it has to be true. We encode our experiences and these experiences must be represented in the nervous system, so they change it. Psychologists (and neurobiologists) say that experiences leave **memory traces** or **engrams** (the two terms are synonyms). The basic idea is that events create engrams through a process of **consolidation**, the neural changes that occur after learning over time to create the memory trace of an

experience. Although neurobiologists are concerned with exactly what neural processes change when memories are created, for psychologists the term memory trace simply refers to the change in the nervous system that represents our experience. The exact nature of that change is hard to discern by psychological means alone (Tulving & Bower, 1975). Something must change and persist over time to permit us to display our learning in the future, and the term “memory trace” serves that function for psychologists.

Although the need for a concept like engram or memory trace is indisputable, it is wrong to take the term too far. Psychologists and neuroscientists sometimes have a tendency to do so, but it is important to realize that memory traces are not little packets of information that lie dormant in the brain, waiting to be called forward to give an accurate report of past experience. We know this cannot be so, exactly, because remembering is often imprecise and is fraught with error. Memory traces do not act like video or audio recordings, capturing experience with great fidelity. Thus, it is wrong to think that remembering involves reading out a faithful record of past experience when we recount our experiences. Rather, we reconstruct past events as we remember with the aid of our memory traces but also with our current knowledge of what we think happened in the past. In a phrase, remembering is reconstructive (we reconstruct our past with the aid of memory traces) rather than purely reproductive (a perfect reproduction of the past). We consider this issue further in the section on retrieval.

Psychologists refer to the time between learning and testing as the retention interval. Memories can consolidate during that time, aiding retention. However, experiences can also occur that undermine the memory. One important feature is interference. Activities that interfere with memories during the retention interval cause **retroactive interference**. Think of relatively routine activities that you do every day. If I ask you to recall what you had for lunch yesterday, you could probably do it. However, if I ask you to recall what you had for lunch 17 days ago, you may well fail (assuming you have varied items for lunch and not the same thing every day). The 16 lunches you have had since that one create retroactive interference for that experience. On the other hand, the many lunches you had before that particular one also can cause interference; experiences occurring before a particular event that interfere with its retention is called proactive interference, although of course in this case the interfering events do not occur during the retention interval.

Retroactive interference is one of the main determinants of forgetting (McGeoch, 1932). In the chapter Eyewitness Misidentification and Memory Biases Elizabeth Loftus describes her fascinating work on eyewitness memory, in which she shows how memory for an event can be changed via misinformation supplied during the retention interval. This **misinformation effect** in eyewitness memory represents a type of retroactive interference that can occur during the retention interval (see Loftus [2005] for a review). Of course, if correct information is given during the retention interval, the witness's memory will usually be improved.

Although interference may arise from a manipulation between the occurrence of an event and the need to express it when someone asks, the effect itself is always expressed when we retrieve memories, the topic to which we turn next.

Retrieval

Retrieval of information is necessary for its use. If information is encoded and stored but cannot be retrieved, it is of no use. This is one reason that Endel Tulving argued that “the key process in memory is retrieval” (1991, p. 91). Why should retrieval be given more prominence than encoding or storage? After all, successful remembering involves all three processes. That is true, but the bottleneck in learning and memory is the retrieval process. As discussed in previous sections of the chapter, we basically encode and store nearly everything to which we attend—thousands of events, conversations, sights, and sounds are encoded every day, creating memory traces (although no one knows for sure how long they last). Most of this information is wasted, in the sense that it will never be retrieved. We access in the future only a tiny part of what we learned from our past, although those other events may shape our knowledge in more subtle ways than in conscious retrieval. Most of our memories will never be used, in the sense of brought back to mind consciously. This fact seems so typical that we rarely reflect on it. All those events that happened to you in the fourth grade that seemed so important then? Now,

many years later, you would struggle to remember even a few. Are traces of the memories still there in some latent form? With currently available methods, it is impossible to know, and it is difficult to see how this situation will change significantly in the near future.

Psychologists distinguish information that is available in memory and that which is accessible (Tulving & Pearlstone, 1966). Available information is the information that is stored in memory; almost by definition, we cannot know precisely how much and what types of information are stored. All we can know is what information we can retrieve; this is accessible information. The assumption is that accessible (retrievable) information represents only a tiny slice of information available in our brains. Most of us have had the experience of trying hard to remember some fact or event, giving up, and then having it come to us at some later time, even if we had given up. Similarly, we all know the experience of failing to recall a fact but then, if we are given several choices, as in a multiple-choice test, easily being able to recognize the fact.

What factors determine what information can be retrieved from memory? One critical factor is the type of hints or cues in the environment. You may hear a song on the radio that suddenly takes you back to some previous time in your life and provokes memories of that time (even if you were not trying to remember your earlier life when the song came on the radio). The song is tightly associated with that time in your life, so it brings the experience to mind.

The general principle that underlies the effectiveness of retrieval cues is the encoding specificity principle (Tulving & Thomson, 1973). This is a mouthful, so let us explain the core idea in simpler language. The assumption is that when people encode information, they do so in specific ways. To return to the example of the song that brought to mind an event from many years before, perhaps you heard the song while you were at an exciting party where you had just met someone with whom you would later fall in love. Thus the song is part and parcel of this whole complex experience. Years later, when you hear the song on the radio, it brings back the whole experience with a rush. In general, the **encoding specificity principle** states that to the extent that a retrieval cue (the song) matches the memory trace of the experience (the party, the person), to that extent will it be effective in provoking the memory. So cues help retrieval to the extent that they help match or recreate the original experience.

One proviso is that the cue cannot match too many other experiences (Nairne, 2002; Watkins, 1975). Consider a lab experiment. Suppose you study 99 words and a single picture (of a penguin) is item 50 in the list. Afterwards, the cue “recall the picture” would provoke “penguin” perfectly. No one would miss it. However, if the word penguin were placed in the same spot with other 99 words, its recall would be only 2%–3%. This outcome shows the power of distinctiveness we discussed in the section on encoding—one picture is perfectly recalled from among 99 words because it stands out. Now consider what would happen if the experiment were repeated but the number of pictures in the 100-item list were increased from 1 to 5 and then 10 and then 25, and so on. Although the picture of the penguin would still be in the list each time,

the probability of the cue “recall the pictures” as being useful for the penguin picture would drop correspondingly. Watkins (1975) referred to this outcome as reflecting the **cue overload principle**—to be effective, a retrieval cue cannot be overloaded with too many memories. For the cue “recall the picture” to be effective, it is best if the cue only matches one item in the target set (as in the one-picture, 99-word case).

To sum up the last two paragraphs, for a retrieval cue to be effective, a match must exist between the cue and the desired target memory; further, the cue-target relationship should be distinctive to produce the best retrieval. We will see how the encoding specificity principle can work in practice in the next section of the chapter.

Psychologists can measure memory performance by using production tests (involving recall) or recognition tests (involving selection of correct from incorrect information, as in a multiple-choice test or a true/false test). For example, to go back to our example of people studying a list of 100 words, one group could be asked to recall the list in any order (a test called free recall) and on another test a different group of people might see the 100 studied words mixed in with 100 nonstudied words and be asked to circle the old or studied words in the list. In this situation, the recognition test would permit greater performance (more correct) than a recall test (although the problem of just guessing is generally much more serious in recognition tests—what if a person circled 175 items of the 200 items, or even circled all 200? They would get many (or all of them) right but they would also get many wrong.

We usually think of recognition tests as being quite easy, because the cue for retrieval represents a copy of the actual event that was presented for studying. What could be a better cue than the exact target that the person is trying to access? In many cases, this statement is true, but at the same time, a recognition test does not provide a perfect index of what is stored in memory. That is, you can fail to recognize a target staring you right in the face, but be able to recall it later with a different set of cues (Watkins & Tulving, 1975). Suppose I were to give you the task of recognizing the surnames of famous American under two different conditions. In one case I gave you the actual last names of people, whereas in the other case I give you a different cue. You might think that the actual last name cue would always be best, but research has shown that this is sometimes not so (Muter, 1984). For example, I might give you names such as Franklin, Ross, Washington, and Bell. Subjects might well say that Franklin and Washington are famous Americans, whereas Ross and Bell are not. However, when given a cued recall test using first names, people often recall items (produce them) that they had failed to recognize. For example, a cue like Alexander Graham _____ will often lead to recall of “Bell” even though people failed to recognize Bell as a famous American name. Yet when given the cue “George” people may not come up with Washington because George is a common name that matches many people (the cue overload principle at work). This strange fact—that recall can sometimes lead to better performance than recognition—can be explained by the encoding specificity principle. Alexander Graham _____ as a cue matches the way the famous inventor is stored in memory better than does his surname, Bell, by itself (even

though it is the target). Further, the match is quite distinctive with Alexander Graham _____ , but the cue George _____ is much more overloaded (George Clooney, George Harrison, George Jones, George Carlin). The phenomenon we have been describing is called the recognition failure of recallable words, because it was first shown in word-list experiments rather than with famous names (Tulving & Thomson, 1973). The point is that the cues that work best to evoke retrieval are those that recreate the event or name to be remembered, and sometimes the target itself, such as Bell in the above example, is not the best cue. Which cue will be most effective depends on how the information has been encoded.

Whenever we think of information from our past, we have engaged in the act of retrieval. We usually think that retrieval is a neutral act because we implicitly believe in trace theory; we think we retrieve the memory (like taking it off a shelf) and then it is still the same (like putting it back on the shelf). However, research shows that this assumption is just not so; every time we retrieve a memory, it changes. Changes can be both positive and negative, depending on the situation. On the positive side, the act of retrieval (of a fact, concept, or event) makes the retrieved memory much more likely to be retrieved again, a phenomenon called the testing effect or the retrieval practice effect (Pyc & Rawson, 2009; Roediger & Karpicke, 2006). We need to practice retrieving information that we want to have readily accessible (the names and faces of your class, if you are a teacher). However, retrieval practice of some information can cause forgetting of information related to it, a phenomenon called retrieval-induced forgetting (Anderson, Bjork, & Bjork, 1994). Thus the act of retrieval

can be a double-edged sword—improving the information just retrieved (usually by a large amount) but harming related information (although often this effect is relatively small).

Retrieval of distant memories is reconstructive. We use the concrete bits and pieces of the events and weave them into a coherent story (Bartlett, 1932). If we inject some errors while we reconstruct a story (say, of our birthday party when we were 10) and if we retrieve the event this way several times, the interjected bit will become like a fact to us, something that happened. Just as retrieval practice enhances accurate memories, so will it increase errors or false memories (McDermott, 2006). Sometimes memories can be manufactured just from a vivid story. Consider the following episode recounted by Jean Piaget, the famous developmental psychologist, from his childhood:

One of my first memories would date, if it were true, from my second year. I can still see, most clearly, the following scene, in which I believed until I was about 15. I was sitting in my pram . . . when a man tried to kidnap me. I was held in by the strap fastened round me while my nurse bravely tried to stand between me and the thief. She received various scratches, and I can still vaguely see those on her face. . . . When I was about 15, my parents received a letter from my former nurse saying that she had been converted to the Salvation Army. She wanted to confess her past faults, and in particular to return the watch she had been given as a reward on this occasion. She had made up the whole story, faking the scratches. I therefore must have heard, as a child, this story, which my parents believed, and projected it into the past in the form of a visual memory. . . . Many real memories are doubtless of the same order.

(Piaget, 1962, pp. 187–188)

Piaget's vivid memory represents a case of a pure reconstructive memory. He heard the tale told repeatedly and doubtless told it (and thought about it) himself. The repeated telling cemented the events as though they had really happened, which leaves open to each of us the possibility that "many real memories are of the same order." The fact that one can remember precise visual details (the location of the memory, scratches) does not necessarily indicate that the memory is true, and this point has been confirmed in laboratory studies, too (e.g., Norman & Schacter, 1997).

Putting It All Together: Improving Your Memory

A central theme of this chapter has been the importance of encoding and retrieval processes and their interaction. Briefly, to improve learning and memory, we need to encode material in a meaningful, distinctive way and to provide ourselves with excellent cues that will bring back the remembered events when we need them. That sounds fine as a general rule, but how do we implement it? Actually, there are many ways, and the specific technique depends on what one needs to remember and for how long. Keep in mind the two critical principles we have discussed: To maximize retrieval, we should construct meaningful cues that remind us of the original experience, but cues that are distinctive and not confusable with other cues. These two conditions are critical in maximizing cue effectiveness (Nairne, 2002).

But how can these principles be adapted for use in many situations? Let's go back to how we started the chapter, with Simon Reinhard's ability to memorize huge numbers of digits presented at the fast rate of 1/second. Although it was not obvious, he used these same general principles in a different way. In fact, all **mnemonic devices** or memory aids rely on these principles. In the typical case, the person learns perfectly a set of cues and then uses these cues to learn and remember information. Consider the set of 20 items below that are easy to learn and remember (Bower & Reitman, 1972).

- 1 is a gun. 11 is penny-one, hot dog bun.
- 2 is a shoe. 12 is penny-two, airplane glue.
- 3 is a tree. 13 is penny-three, bumble bee.
- 4 is a door. 14 is penny-four, grocery store.
- 5 is knives. 15 is penny-five, big beehive.
- 6 is sticks. 16 is penny-six, magic tricks.
- 7 is oven. 17 is penny-seven, go to heaven.
- 8 is plate. 18 is penny-eight, golden gate.
- 9 is wine. 19 is penny-nine, ball of twine.
- 10 is hen. 20 is penny-ten, ballpoint pen.

It would probably take you less than 10 minutes to learn this list and practice recalling it several times (remember to use retrieval practice!). If you took this trouble, you would have a set of peg words on which you can "hang" memories, so this mnemonic device is called the peg word technique. If you now need to remember some discrete items—say a grocery list or points you want to make in a speech or simply a list of words you are given—this method will let you do

so in a very precise yet flexible way. Suppose you had to remember bread, peanut butter, bananas, lettuce, and so on. The way to use the method is to form a vivid image of what you want to remember and imagine it interacting with all your peg words (or as many as you need). For example, for these items, you might imagine a large gun (the first peg word) shooting a loaf of bread, then a jar of peanut butter inside a shoe, then large bunches of bananas hanging from a tree, then a door slamming on a head of lettuce with leaves flying everywhere. The idea is to provide good, distinctive encoding of the information you need to remember while you are learning the information. If you do this, then retrieval at some point later is relatively easy. You know your cues perfectly (one is gun, etc.), so you simply go through your cue word list and “look” in your mind’s eye at the image stored there (bread, in this case).

This peg word method sounds strange at first, but it works quite well even with little training (Roediger, 1980). One proviso, though, is that the items to be remembered need to be presented relatively slowly at first until you have practice associating them to the cue word. People get faster with time. Another interesting aspect of this technique is that it is just as easy to recall the items in backwards order as forwards; if you want to show off, you could recall the odd-numbered items in a forward order and the even-numbered items in a backwards order. The reason is that the 20 peg words provide direct access to the memorized items.

How did Simon Reinhard remember those digits? Essentially he has a much more complex system based on these same principles. In his case, he uses memory palaces (elaborate scenes with discrete places) combined with huge sets of images for digits. For example, imagine mentally walking through the house or apartment where you grew up and identifying as many discrete scenes as possible. Simon has hundreds of such “memory palaces” as this that he can use. Next, for remembering digits, he has memorized a set of 10,000 images. Every four-digit number for him immediately brings forth a mental image, so 6187 might be Michael Jackson. When Simon hears all the numbers coming at him, he places an image of every four digits into the places in his memory palace. He can do this at the incredibly rapid rate of faster than 4 digits per 4 seconds when they are flashed visually, as in the demonstration at the beginning. As noted, his record is 240 digits presented and recalled in their exact order. Simon also holds the world record in the event called speed cards, which is memorizing a random deck of cards. Simon was able to do this in 21.19 seconds! Again, he uses his memory palaces and he encodes groups of cards into one image.

Many books exist on how to improve memory using mnemonic devices, but all involve forming distinctive encoding operations and then having an infallible set of memory cues. We should add that to develop and use these memory systems beyond the basic peg system outlined above takes a great amount of time and concentration. The World Memory Championships are held every year and the records keep improving. However, for most common purposes, just keep in mind that to remember well you need to encode information in a distinctive way and to have good cues for retrieval. You can adapt a system that

will meet most any purpose.

Outside Resources

Book: Brown, P.C., Roediger, H. L. & McDaniel, M. A. (2014). Smarter, sooner, longer: Effective strategies for learning and remembering. Cambridge, MA: Harvard University Press.

Student Video 1: Eureka Foong's - The Misinformation Effect. This is a student-made video illustrating this phenomenon of altered memory. It was one of the winning entries in the 2014 Noba Student Video Award.

<https://www.youtube.com/watch?v=iMPIWkFtd88>

Student Video 2: Kara McCord's - Flashbulb Memories. This is a student-made video illustrating this phenomenon of autobiographical memory. It was one of the winning entries in the 2014 Noba Student Video Award.

<https://www.youtube.com/watch?v=mPhW9bUI4F0>

Student Video 3: Ang Rui Xia & Ong Jun Hao's - The Misinformation Effect. Another student-made video exploring the misinformation effect. Also an award winner from 2014.

<https://www.youtube.com/watch?v=gsn9iKmOJLQ>

Video: Simon Reinhard breaking the world record in speedcards.

<http://vimeo.com/12516465>

Discussion Questions

1. Mnemonists like Simon Reinhard develop mental “journeys,” which enable them to use the method of loci. Develop your own journey, which contains 20 places, in order, that you know well. One example might be: the front walkway to your parents’ apartment; their doorbell; the couch in their living room; etc. Be sure to use a set of places that you know well and that have a natural order to them (e.g., the walkway comes before the doorbell). Now you are more than halfway toward being able to memorize a set of 20 nouns, in order, rather quickly. As an optional second step, have a friend make a list of 20 such nouns and read them to you, slowly (e.g., one every 5 seconds). Use the method to attempt to remember the 20 items.
2. Recall a recent argument or misunderstanding you have had about memory (e.g., a debate over whether your girlfriend/boyfriend had agreed to something). In light of what you have just learned about memory, how do you think about it? Is it possible that the disagreement can be understood by one of you making a pragmatic inference?
3. Think about what you’ve just learned in this chapter and about how you study for tests. On the basis of what you have just learned, is there something that you want to try that might help your study habits?

Vocabulary

Autobiographical memory

Memory for the events of one's life.

Consolidation

The process occurring after encoding that is believed to stabilize memory traces.

Cue overload principle

The principle stating that the more memories that are associated to a particular retrieval cue, the less effective the cue will be in prompting retrieval of any one memory.

Distinctiveness

The principle that unusual events (in a context of similar events) will be recalled and recognized better than uniform (nondistinctive) events.

Encoding specificity principle

The hypothesis that a retrieval cue will be effective to the extent that information encoded from the cue overlaps or matches information in the engram or memory trace.

Engrams

A term indicating the change in the nervous system representing an event; also, memory trace.

Episodic memory

Memory for events in a particular time and place.

Flashbulb memory

Vivid personal memories of receiving the news of some momentous (and usually emotional) event.

Memory traces

A term indicating the change in the nervous system representing an event.

Misinformation effect

When erroneous information occurring after an event is remembered as having been part of the original event.

Mnemonic devices

A strategy for remembering large amounts of information, usually involving imaging events occurring on a journey or with some other set of memorized cues.

Recoding

The ubiquitous process during learning of taking information in one form and converting it to another form, usually one more easily remembered.

Retrieval

The process of accessing stored information.

Retroactive interference

The phenomenon whereby events that occur after some particular event of interest will usually cause forgetting of the original event.

Semantic memory

The more or less permanent store of knowledge that people have.

Storage

The stage in the learning/memory process that bridges encoding and retrieval; the persistence of memory over time.

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