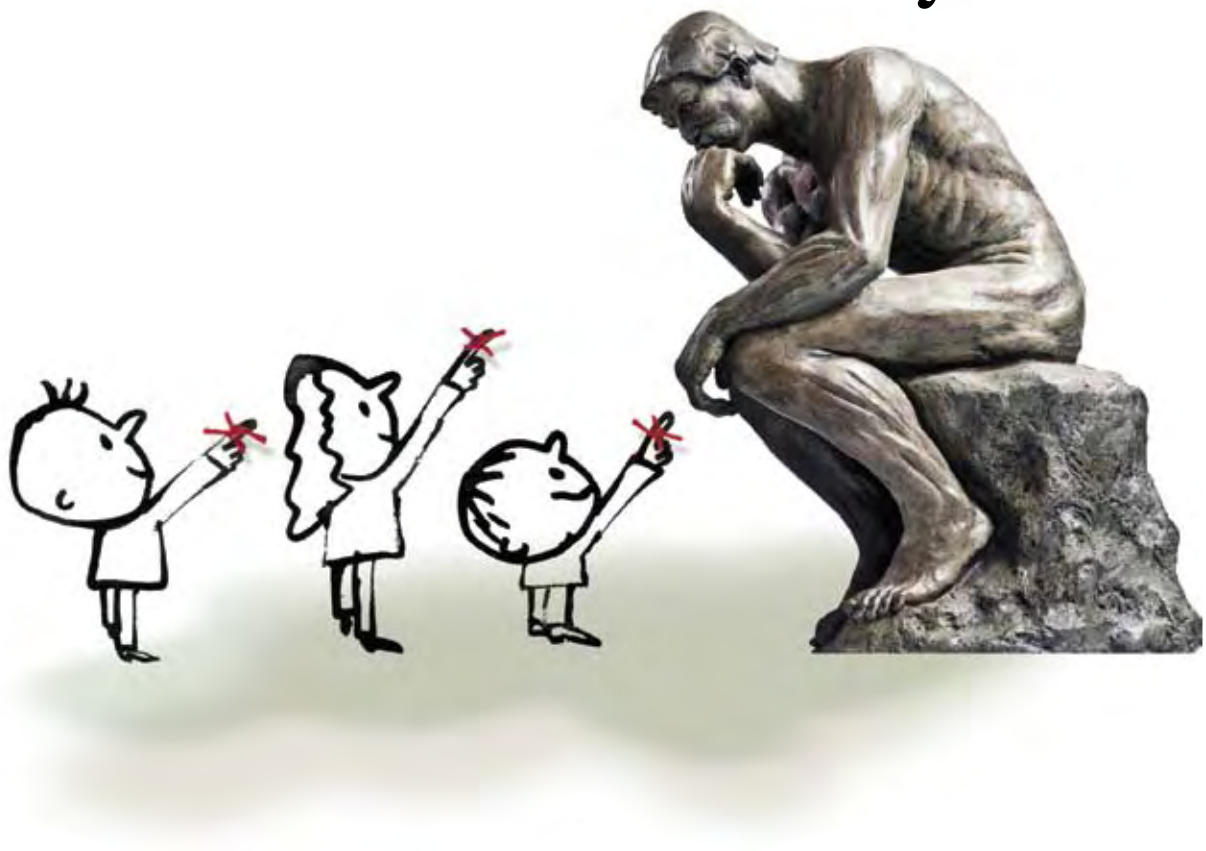
ASK THE COGNITIVE SCIENTIST

What Will Improve a Student's Memory?



How does the mind work—and especially how does it learn? Teachers' instructional decisions are based on a mix of theories learned in teacher education, trial and error, craft knowledge, and gut instinct. Such gut knowledge often serves us well, but is there anything sturdier to rely on?

Cognitive science is an interdisciplinary field of researchers from psychology, neuroscience, linguistics, philosophy, computer science, and anthropology who seek to understand the mind. In this regular American Educator *column, we consider findings from this field that are strong and clear enough to merit classroom application.*

By Daniel T. Willingham

Question: I often have students tell me that they studied for a test, meaning that they reviewed their notes and the textbook, but they still did not do well. If they have reviewed the material, why don't they remember it? Is there anything I can do to help them study more effectively?

Answer: Many of my students also tell me that they reviewed their notes and were quite surprised when they did not do well on the test. I've found that these students typically know little about how their memories work and, as a result, do not know how to study effectively.

In this article, I'll discuss what to tell your students about how memory works: how to commit things to memory, to avoid forgetting, and to know when they've studied enough. I'll provide examples for classroom demonstrations to make the abstract ideas more vivid for your students, and I'll describe how they can apply those abstract ideas when they study.

* * *

From the time a child enters school until she earns a diploma, her principal task is to learn new facts and skills. It would seem natural, therefore, that somewhere along the way (perhaps around sixth grade or so, when schoolwork really becomes demanding) she would be told

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ILLUSTRATED BY SERGE BLOCH

something about how her memory works—and something about how to make it work better. But that rarely happens. In fact, most college students report that they have improvised their own systems of study.[1] In this article, I will describe three principles of memory that are relevant to most of the learning that students do in elementary and secondary school (and, for that matter, most of the learning that adults need to do too). The three principles I'll describe apply equally to all sorts of learning—from memorizing new vocabulary words, to reading a novel so as to prepare for a class discussion the next day on its plot and style, to conducting a chemistry lab in the morning in order to compare the outcome with examples in a problem set to be handed out that afternoon.

Memory is a vast topic of study, and much is known about it. Let's take the broad question, what will improve a student's memory?, and break it into three more manageable parts: (1) How can I commit things to memory? (2) How can I avoid forgetting the things I have committed to memory? (3) How can I be certain that I have actually committed to memory the things I want to know? I will take up each of these questions in turn. Then, we'll apply what we've learned to the classroom.

How Can I Commit Things to Memory?

Some of what we experience day to day is stored away in our minds for future reference, but much of it is not. For example, you might describe in vivid detail the interior of a quaint ice cream parlor you visited last summer, but be unable to recall what flavor ice cream you had. Why would your memory system hold on to part of that experience—the parlor—and discard another—the flavor? The short answer is that you remember the part that you thought about.

One of the interesting features of your memory system is that you don't control what is stored. *Wanting* to remember something doesn't have much bearing on whether or not you will actually remember it.[2] Indeed, when you think about it, most of what you remember is not stuff that you consciously tried to store. Your knowledge of current events, of movie plots, of your friends' latest doings—you didn't try to commit any of that to memory. What you did do was think about those things. And here's how you should think about memory: it's the residue of thought, meaning that the more you think about something, the more likely it is that you'll remember it later.

But wait, before you think about that so much that you commit it to memory, let me clarify one point. It's only the most salient bit—the part you *really* think about—that turns into a memory. Back in that ice cream parlor, while you were selecting your ice cream and then eating it, you certainly devoted some thought to the flavor. But if it's the interior that you recall later on, then that's the part to which you devoted most of your attention and thought.

It can be hard to grasp just how specific, or narrow, your thoughts—and thus your memories—can be, so let's walk through one more example. Suppose you encounter a barking dog while on a walk. There are several aspects of the dog that you could think about. You could think about the *sound* of the dog's bark, what the dog *looked* like, or the *meaning* of the bark (why it's barking, whether it's barking at you, the likelihood that a barking dog will bite, and so on). Each of these thoughts will lead to different memories of the event the next day. If you think about the sound of the dog's bark, the next day you'll probably remember that quite well, but not its appearance.[3] Now, suppose that when you saw the barking dog, you thought mostly about what a nuisance the noise must be to the neighbors. If, the next day, I asked, "Did you see anything on your walk that could bite?" you might well say, "No, I don't think I did."[4] To put this example into broader terms, even simple concepts have multiple aspects of meaning; which one of these you think about will determine what you remember.

Thus, the first principle for students is that *memories are formed as the residue of thought*. You remember what you think about, but not every fleeting thought—only those matters to which you really devote some attention.

I'll discuss what this principle means for the classroom in more detail below, but it's worth pausing now to note an important implication. It is vital to know what you're going to want to remember later, because that dictates how you should think about the material. Most of the time, teachers want students to know what things mean. Thus, the advice offered to students should center on ways to help them think about meaning and avoid study methods that do not encourage them to think about meaning.

How Can I Avoid Forgetting the Things I Have Committed to Memory?

In my experience, people usually believe that forgetting happens over time; if you don't use a memory, you lose it. That may be a factor in forgetting, but it's probably not a major one. This may be hard to believe, but sometimes the memory isn't gone—it's just hard to get to. So, more important than the passage of time or disuse is the quality of the *cues* you have to get to the memory. Cues are bits of information that are the starting point for retrieving a memory. The good news is that the right cue can bring back a memory that you thought was lost. For example, you might believe that you remember very little of your childhood home, but when you visit as an adult, the sight of the house acts as a cue that brings memories flooding back. Or you may think that you have forgotten all of your high school Spanish, but a few days of constant exposure to Spanish when you visit Mexico leaves you understanding much more than you expected.

A poor cue, in contrast, will not get you access to a memory, even if you know that the memory is in the system. For example, suppose that I say to a friend, "Here's the $20 I owe you," whereupon he says, "You don't owe me $20." A better cue would offer more information, like this: "Remember, we were at Macy's and I wanted to buy that shirt but their computer wouldn't take my card so I had to borrow cash?" Your access to things that are stored in your memory will succeed or fail depending on the quality of the cues. One obvious source of forgetting, then, is poor cues. You haven't really forgotten—you just can't retrieve the memory at the moment because you don't have the right cues.

So far my examples have been cues that come from the environment (be it a house or a friend), but when you are trying to remember something, you generate your own cues. This process is sometimes obvious, as when you've lost something and you mentally try to retrace your steps. But sometimes it isn't: the

process can be so rapid that it's not very noticeable. For example, even a student who is very well prepared for an exam on American history must prompt her memory when answering a broad essay question on a test, such as, "Analyze the eventual impact of the Louisiana Purchase on the events leading to the American Civil War." The environment (that is, the exam) provides very few cues to memory—the student must generate her own. A well-prepared student will do this rapidly, with each bit of information recalled serving as a cue for another.

As we've seen, sometimes a cue isn't good because it doesn't offer enough detail or the right detail. At other times, a cue isn't good because it leads to more than one memory. For example, suppose I give you a list of words to remember and the list includes several fruits. You, clever memorizer that you are, mentally categorize the list, thinking, "Some of the words were fruits." Doing so lets you generate a good cue at recall ("Let's see, I know some of the words were fruits . . ."). But what happens if I give you a second list, which again includes some fruits? Now your cue ("some of the words were fruits") will not be so effective because it leads to two memories: fruits from the first list and fruits from the second list. How to untangle them?

Students face this problem all the time. Some to-be-remembered material interferes with other to-be-remembered material, and the greater the similarity between them, the more likely that the cues will be the same, and therefore the more ambiguous they will be. Thus, studying French vocabulary and then working some geometry problems probably won't cause much interference. But studying French vocabulary and then studying Spanish vocabulary will: for example, the cue *red* calls up both *rouge* and *rojo*.

So, our second principle is that *memories are inaccessible mostly due to missing or ambiguous cues*. Thus, to minimize forgetting, we will focus on ways to ensure that we have cues and that they are distinctive.

How Can I Be Certain That I Have Actually Committed to Memory the Things I Want to Know?

Do you know who played Han Solo in the film *Star Wars*? Do you know the atomic number for Iron? Do you know the name of the professional football team that plays in Seattle? We are usually able to provide rapid answers to such questions (even if the answer is "no"), and the way we do so might seem obvious. You use the question as a cue, and either there is, or is not, a relevant entry in your memory. But that can't be the whole story, because sometimes you have a *feeling* that you know the answer, even if you can't call it up right now.

Researchers have found that people's feeling-of-knowing is meaningful—if you feel that you know something, it is more likely that you do know it than if you feel that you don't—but it is an imperfect guide. One way to test the accuracy of feeling-of-knowing is to give people a series of general information questions like those above. For each, the person must say whether he would know the answer if he saw it. Often, instead of a simple yes or no, the person is asked to make a probability judgment, such as, "I'm 75 percent sure I know the answer." After each judgment, the person sees four possible answers and must choose one. If the person's feeling-of-knowing is accurate, his probability judgments should match the proportion of questions he gets right. For example, taking all the questions for which he professed 75 percent confidence, he should get 75 percent of those questions right (taking into account that he'll likely get 25 percent correct by guessing from among the four answers).

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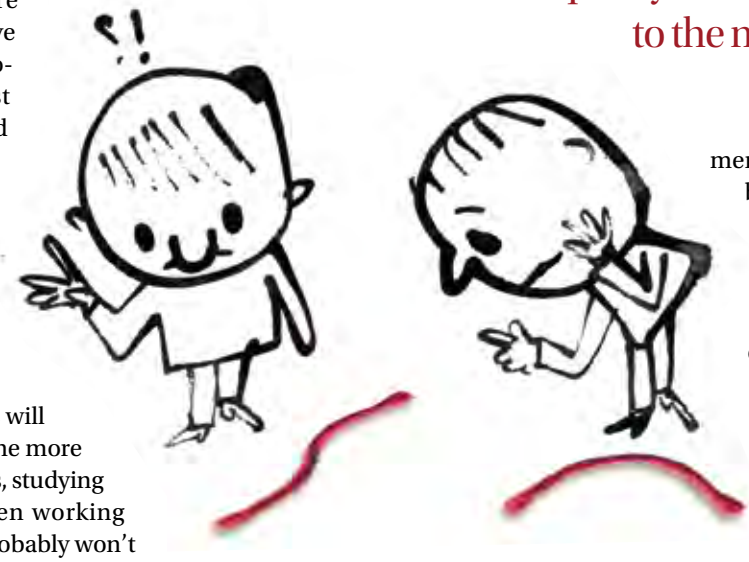

Experiments like this[5] show that most adults think they know more than they actually do.* Somewhat surprisingly, school-age children† are about as good as adults in gauging their knowledge.[7] Of course, given that adults are not so effective in judging what they know, it is no great compliment to children that they perform equally well.

This clearly poses a problem for a student trying to decide if he has studied enough. If students (like adults) tend to be more confident in their knowledge than is warranted, we would expect that they will, on average, not study enough. That prediction is borne out by experimental work. For example, in one study,[8] fourth- and fifth-grade students were given a passage

* The exception is when people judge that there is no chance that they know something. On occasion, they actually do know, and so in these cases people are underconfident.

† There are other ways of testing the accuracy of feeling-of-knowing, and children are worse than adults on some of these,[6] but these paradigms bear little resemblance to schoolwork.

of school-related material (either social studies or science) to be read and learned. All students were told that they should study so that they would know the material very well. After studying, they took a 10-item multiple choice test. The experimenters estimated how much studying each student needed to acquire such knowledge by using another passage and test of equal difficulty and seeing how much study time each student needed to get 100 percent on the test. Then they compared that required time with the amount of time students themselves allocated to the task. The key finding was that students allocated, on average, just 68 percent of the time needed to get the target score.[9]

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We can sum this up by saying the third principle is that *people tend to think their learning is more complete than it really is*. Thus, to help students study effectively, we need to find ways to get them to assess their knowledge more realistically.

Applying These Principles to Classroom Work

I've summarized three principles that are important to how your memory system operates. What concrete strategies can you suggest to your students to capitalize on these principles? I'll address these strategies in two broad categories: forming memories and retrieving memories.

Forming Memories

The first principle—memory is the residue of thought—describes how memories are formed. What remains in your memory from an experience depends mostly on what you thought about during the experience. Given that we typically want students to retain meaning, we will mostly want students to think about what things mean when they study. It would be nice if you could simply tell your class, "When you read your textbook, think about what it means." Naturally, you know that's not the case. The instruction to "think about meaning" is difficult to follow because it is not specific enough. A better strategy is for students to have a specific task that will force them to think about meaning.*

Through a series of studies, reading researcher Michael Pressley[11] figured out a way to do this that asked students to pose just one simple, specific question. He encouraged students to ask themselves "why?" at the end of each sentence as they read passages. In one study, fourth- through eighth-grade students read brief passages about animals.[12] For example, one began, "The Western Spotted Skunk lives in a hole in the ground. The skunk's hole is usually found on a sandy piece of farmland near crops." After reading each sentence, students were to ask themselves why that piece of information might be true. The researchers found that doing so produced a quite sizable benefit to memory, compared with students who were simply told to read the passage and remember it.

Although this strategy is effective for shorter passages, it's not clear that it would apply well to longer ones. I cannot imagine students asking themselves "why?" after each sentence of a textbook chapter—but I can imagine them asking why at the end of every few paragraphs or every section.

Another strategy that might achieve the same goal is to have students search for and write out the main ideas of a textbook chapter after they have read it. Next, they can identify how the author elaborates on these points. Students can draw a hierarchical diagram with the main chapter ideas at the top of the diagram, and branching down to subordinate ideas that support the main ideas. The point of this exercise is to get students thinking about what the main ideas of the chapter actually are, and to think about how the author supports those ideas. It is a broader-scale version of Pressley's strategy of getting students to ask "why?"

Still another technique is to ask students to write an outline of a textbook chapter or of their notes from a unit. Then ask students to try to write a *different* outline. Is there another way to organize the material? Students might also use a different format: if they used the standard outline format (alternating numbers and letters), they might use a flow diagram, or a hierarchy, or a cross-referenced document like a Web site. Again, the goal is to give students a concrete task that they cannot complete without considering which ideas have been covered and how they relate to one another.

Knowing that memory is the residue of thought also gives us some insight into what study strategies will *not* work. Unfortunately, these include the two that I most often encounter as a college instructor. When I ask a student how he studied for a test, the typical answer is that he copied his notes (or marked them with a highlighter) and read over the textbook. Neither strategy guarantees that the student will think about what the material means. Even worse, viewing the material several times leads to the illusion that one knows it because it seems increasingly

* This is, of course, the basic idea behind SQ3R and similar study strategies. The acronym stands for five things to do as you read: Survey what you will read, generate Questions as you survey, as you Read try to answer the questions, Recite the important information as you progress, and Review when you have finished reading. There are many other similar strategies, each with its own acronym. There is some evidence that they are effective,[10] but much less than one might expect. These methods are widely taught; so if what I've said is right, wouldn't they be highly effective, and therefore frequently used? I think the problem with these methods is that they are difficult to do well. It's hard to know what questions to ask before you know what you're reading, and it's hard to remember to answer the questions as you're trying to understand the text. Students need a strategy that is more specific.

familiar, but viewing the material does not give it much sticking power in memory. For example, how well do you know what a penny looks like? Is "Liberty" written on the front or the back? Is Lincoln wearing a tie? Most people don't know the details of a penny's appearance,[13] despite having seen thousands of pennies. Repetition (like copying notes or rereading a text) is helpful, but only when one repeats thinking about meaning. "Shallow" repetition (i.e., that does not focus on meaning) is not as helpful as it seems.

"Think about meaning" sounds like good advice, but there are things to be learned that are, essentially, meaningless. For example, what should students do when learning that *rojo* is the Spanish word for *red*? Meaningless material is difficult to learn because it is hard to find a good cue. As discussed above, remembering is prompted by cues, and it is hard to associate the cue (the Spanish word for *red*) with the target memory (*rojo*) when the cue and memory have no meaningful relation. Ironically, learning something by rote memorization is a great time to get creative. The memorization strategies (called mnemonics) listed in the table on page 23 give students ways to make up meaningful relationships. And the more creative or distinctive, the better.

Mnemonics work largely (but not exclusively) by using the first two principles described earlier. Mnemonics make meaningless material more meaningful, giving you something to think about and a good cue. For example, the acrostic and acronym techniques give you the first letter of the to-be-remembered item, an excellent cue. Then too, many of the mnemonics encourage the use of visual imagery. Imagery is helpful because it makes cues more distinctive and less ambiguous. When you create a visual image of a duck, you must think of a *particular* duck. You must specify its size, proportions, coloring, posture, etc. All of these details make the duck more distinctive, and thus

Myths of Memory

Myth 1: Subliminal learning or sleep learning is possible. "Subliminal" means outside of awareness. For example, you might listen to a recording of music that has a simultaneous, almost inaudible track of someone reading an informative essay. If you listen to this recording enough times, will you come to know the content of the essay, even if the voice was always subliminal? No. Stimuli that are outside of awareness can have a subtle impact on some types of behavior,[1] but you won't be able to consciously access the memory the way you would access a regular memory. Sleep learning—in which the essay would be played as you slept with the hope that you would remember it upon waking—unfortunately works no better than subliminal learning.[2]

Myth 2: Memory is like a video recording. One sometimes reads that all of your experiences are recorded perfectly in your memory and you only forget things because you don't have the right cues. One also sometimes hears, as supporting evidence, that hypnosis can improve memory; it's as though the hypnotic state gives you direct access to the memory without the need for cues. This idea seems plausible, given what we've said in the main article about the importance of cues, and it is, of course, impossible to disprove—a supporter of the idea can always claim that every experience is stored away, just waiting for the right cue. But most memory researchers don't believe that this is true. It would be an odd and terribly inefficient way to design a memory system. The hypnosis claim is testable, and has been shown to be wrong. Hypnosis doesn't make memory any more accurate, although it does make people more confident that they are right.

Myth 3: There are herbal supplements or pharmaceuticals that can enhance memory or attenuate the cognitive decline associated with aging. There are a few—a very few—suggestive findings, and there are a lot of claims that go far beyond what the data support. Simply put, we are not there yet.[3]

Myth 4: Memory depends on the input modality. You have probably seen some version of this: "We remember 10 percent of what we read, 20 percent of what we hear, 30 percent of what we see, 50 percent of what we see and hear, 70 percent of what we discuss with others, 80 percent of what we personally experience, and 95 percent of what we teach others." In the main article, I've argued that the most important factor determining whether or not a memory is long lasting is how much you think about it. The ordering of the activities may roughly correspond—you will definitely think about material carefully if you teach it to others—but the ordering could easily change. There are many things that I read (e.g., professional journal articles) that I remember much better than things I experience (e.g., my drive to work this morning).[4]

–D.T.W.

Endnotes

1. Laurie T. Butler and Dianne C. Berry, "Understanding the Relationship between Repetition Priming and Mere Exposure," *British Journal of Psychology* 95 (2004): 467–87.

2. Louis Aarons, "Sleep-Assisted Instruction," *Psychological Bulletin* 83 (1976): 1–40.

3. Peter H. Canter and Edward Ernst, "*Ginkgo biloba* Is Not a Smart Drug: An Updated Systematic Review of Randomized Clinical Trials Testing the Nootropic Effects of *G. biloba* Extracts in Healthy People," *Human Psychopharmacology: Clinical and Experimental* 22 (2007): 265–78; and Mark A. McDaniel, Steven F. Maier, and Gilles O. Einstein, "'Brain-Specific' Nutrients: A Memory Cure?" *Psychological Science in the Public Interest* 3 (2002): 12–38.

4. For interesting detective work on the origins of this memory myth, see Will Thalheimer, "People Remember 10%, 20% ... Oh Really?" May 1, 2006, **www.willatworklearning.com/2006/05/people_remember.html** (accessed August 5, 2008).

less likely to be confused with other ducks, and therefore a better cue to the target memory.

Retrieving Memories

How can students ensure that what they learn is not forgotten? There are a few things students might do. One, which is explained in the table on mnemonics, is to select distinctive cues so as to decrease the likelihood that they will be ambiguous. Another way to make memories longer lasting is to distribute studying over time—in other words, don't cram. Students will sometimes (with perverse pride) brag that they studied immediately before a test, scored well, but soon forgot what they had learned. Research bears out their boasts. Studying at several different times means that you are used to cuing and retrieving the memory at lots of different points in time. But if learning is all crammed into the same time, you have always cued and retrieved the memory during the same time. When you cram, the memory becomes associated with the particular time you study, making the memory harder to retrieve later on (although this is not the only factor[14]). But if you distribute studying, the memory doesn't have that association because you keep studying it at different times. Naturally, this sound advice—study early and often—is difficult for students to follow. Small wonder that most books on study skills have a chapter on time management.

Mnemonics work largely (but not exclusively) by giving you something to think about and a good cue. Imagery is helpful because it makes cues less ambiguous. When you create a visual image of a duck, you must think of a *particular* duck. The details make the duck more distinctive, and therefore a better cue to the target memory.

The final strategy to avoid forgetting is to overlearn. Students know that they forget, so if they study just to the point that they know the material, what will happen when they take a quiz the next day? Some forgetting will have occurred—they won't know the material as well as they did the night before. This should be obvious to students once it's pointed out to them—but just as students tend to overestimate how complete their learning is, they also tend to underestimate their own forgetting.[15] The solution is straightforward. Students should study until they know the material and then keep studying. How long they should continue studying depends on how long they hope to retain the material, how they will be tested, and other factors, but a good rule of thumb is to put in another 20 percent of the time it took to master the material.

This advice—to continue studying after you know the material—requires that you can accurately gauge how complete your knowledge is. What can be done to help students better know what it is they know? The most important advice for them is to test themselves the way they will be tested. Students tend to gauge their knowledge based on their feeling-of-knowing; as they "read over their notes," they get an increasing feeling of familiarity. But a feeling of familiarity is not the same thing as being able to reproduce the material on a test.[16] How many teachers have heard a student say, "I *know* it, I just can't explain it"? Most likely, the student understands it when *you* explain it, but doesn't understand it well enough to explain it herself. The best way to test oneself is to explain the material to another person, ideally one who can ask sensible follow-up questions. This method will provide a much better metric for the student as to what she really knows. As an added bonus, testing yourself in this manner helps the material stay in memory.

The box below summarizes the three principles of memory and the corresponding recommendations. Much more could be written about memory, but the topic can quickly become overwhelming. The three principles discussed here are the most important for students. Naturally, these principles will be more meaningful to your students if they see them in action, so see page 24 for some classroom demonstration ideas. ☐

1. Memories are formed as a residue of thought.
   - If you want to remember what things mean, you must select a mental task that will ensure that you think about their meaning.
   - If what you want to remember has little meaning, use a mnemonic.
2. Memories are lost mostly due to missing or ambiguous cues.
   - Make your memories distinctive.
   - Distribute your studying over time.
   - Plan for forgetting by continuing to study even after you know the material.
3. Individuals' assessments of their own knowledge are fallible.
   - Don't use an internal feeling to gauge whether you have studied enough. Test yourself, and do so using the same type of test you'll take in class.

(Additional resources and endnotes on page 44)

Mnemonic	How It Works	Example	Principle Used
Pegword	Useful for memorizing lists of unrelated items in order. You create a visual image of each item in the list with a "peg" word. You have already committed the pegs to memory, so they provide cues for the to-be-remembered items.	Pegs are usually easy to learn because they rhyme with numbers. "One is a bun, two is a shoe, three is a tree," and so on. If you wanted to remember the list *onion, duck, artist,* you would associate *onion* with a bun (e.g., a man making a face because his sandwich contains only onion), *duck* with shoes (e.g., a duck trying to paddle on a pond with big tennis shoes on), and *artist* with a tree (e.g., a man with a beret and a palette who made his artist's smock into a hammock between two maple trees).	The pegs provide cues to memory. Using bizarre imagery helps to ensure that the cues are distinctive and unlikely to be confused with other cues.
Method of Loci	Useful for memorizing lists of unrelated items in order. You commit a "mental walk" to memory—a familiar route with separate, identifiable locations—then create a visual image that associates each item on the list with a location on the mental walk.	Here's a mental walk from my front door to my driveway. The first location is my front porch, which has a bird's nest by the door, the second is the sidewalk, which has a large crack, the third is my asphalt driveway with a red paint stain. To memorize the list *onion, duck, artist,* I would associate *onion* with my front door, perhaps by putting onions in the nest instead of eggs. Then I'd associate *duck* with the sidewalk by imagining the duck with its beak stuck in the crack, and *artist* with an artist admiring the paint stain on the asphalt.	The stations on the walk provide cues to memory. As with the pegword strategy, using bizarre imagery helps to ensure that the cues are distinctive and unlikely to be confused with other cues.
Acronym	Create an acronym using the first letter of each of the to-be-remembered items; if you can remember the acronym, you have a good cue for each of the items.	The Great Lakes can be remembered with HOMES (Huron, Ontario, Michigan, Erie, Superior), the wavelength order of the visible spectrum of light with ROY G. BIV (red, orange, yellow, green, blue, indigo, violet).	The first letter of each item is a good cue to memory, and using a word (such as *homes*) is meaningful, and therefore easier to remember than a random set of letters would be.
Acrostic	Create an easy-to-remember sentence in which the first letter of each word provides a cue for the to-be-remembered material. A sentence is always easier to remember than disconnected words, and often one can create a vivid visual image of it, which makes it memorable.	To remember the order of the notes on the treble clef, countless children have memorized "Every Good Boy Does Fine." Likewise, the order for operations in arithmetic can be remembered with "Bless My Dear Aunt Sally" (brackets, multiplication, division, addition, subtraction).	Like the acronym method, acrostics provide a good cue for each item and are easy to remember because they are formed with meaningful material, in this case a sentence.
Music or Rhymes	The to-be-remembered material is set to a familiar tune, set to a rhythm, or made into a rhyme.	Music and rhymes are used a lot with young children, as in learning the alphabet with the ABC song and in learning how many days are in each month with the rhyme "30 days hath September…."	If you forget the words, the melody can provide a cue to help you remember it. A rhyming cue ("another month must rhyme with September") is also useful.
Mnemonic Associations	Something in the to-be-remembered material is associated with an aspect of the material that is hard to remember.	These are often useful in spelling. To remember that the administrator of a school is spelled with a final *pal* (not *ple*), note that she is your *pal*. To remember how to spell *grammar* (not *grammer*), think "don't *mar* your work with bad gram*mar*." Here's one more: "stala**c**tites grow from the **c**eiling; stala**g**mites from the **g**round."	These associations inject meaning into meaningless associations. The last three letters of principal are meaningless when considered as separate letters, but the mnemonic makes them into the meaningful word *pal*.
Keyword	Often used for foreign vocabulary words. Find an English word that is close in sound to the foreign vocabulary word. Then create a visual image that connects the English sound-alike word to the translation of the foreign word.	The Spanish word for *mushrooms* is *champiñones,* which sounds like the English word *champions*. Create a visual image of a boxing champion in the ring, arms aloft in victory, wearing big mushrooms on his hands instead of gloves.	This mnemonic uses a two-step process. The image creates an association between the cue word, *mushroom*, and another word, *champion*, which then is used as a sound cue for the to-be-remembered material *champiñones*.

Demonstrations of the Three Principles

If you'd like to teach your students about how memory works, it may be useful to illustrate the three principles from the main article in your class. Here are some demonstrations you might use.

DEMONSTRATION 1

This exercise illustrates that (1) students do not need to try to remember in order for things to get in memory, and (2) thinking about meaning is much more effective for getting material into memory than thinking about other aspects of the content.

What to tell your students:

Please get out a blank piece of paper and number the lines from 1 to 30, so that you have 30 places to put answers. [Wait until they have completed this task. To save time, you can distribute sheets with numbered lines.] *I'm going to read aloud 30 words and for each word you just have to perform one of three tasks. Each task is really simple.*

The first is called spoken to the left. *If I turn my head to the left like this* [demonstrate] *when I say the word, then you should write "y" on your paper for "yes." But if I keep my head looking straight at the class, then you should write "n" for "no." So for example, I might say, "Spoken to the left?* [Turn your head to the left as you say the next word.] *Shell." And you would write "y" on your paper. Okay?*

The second task is called A or U. *If I say "A or U?" you should write "y" for "yes" if the following word has* either *an A or a U in it. So if I say, "A or U? Doctor." You would write "n" for "no."*

The third task is called rate for pleasantness. *For that one, I want you to listen to the word I say, and think of whether it makes you think of pleasant things or unpleasant things. Then write a number from 1 to 7 showing how pleasant the word is. A 1 means it's really unpleasant—for example, the word "injury" might get a 1. Write a 7 if it's really pleasant—for example, "birthday." Use numbers between 1 and 7 for medium pleasantness.*

You have to listen carefully because there are three tasks, and I'm going to mix them up. I'll tell you right before each word which task you should do for that word. Let's try a couple of each for practice; you don't need to write your answers for these.

A or U? Save
Spoken to the left? [Keep your head straight.] *Worth*
Rate for pleasantness: Coin
Rate for pleasantness: Tiny
A or U? Moral
Spoken to the left? [Turn your head to the left.] *Upper*

Any questions?

What to do:

Read each item and then pause for students to answer, which should only take a moment.

1. *Spoken to the left?* [Keep your head straight.] *Hundred*
2. *Rate for pleasantness: Corn*
3. *A or U? Cool*
4. *Spoken to the left?* [Keep your head straight.] *Rate*
5. *A or U? Jump*
6. *Spoken to the left?* [Turn your head to the left.] *Place*
7. *Rate for pleasantness: Urge*
8. *A or U? Country*
9. *Spoken to the left?* [Turn your head to the left.] *Entirely*
10. *A or U? About*
11. *Rate for pleasantness: Diamond*
12. *Spoken to the left?* [Keep your head straight.] *Into*
13. *Rate for pleasantness: Welcome*
14. *A or U? Window*
15. *Spoken to the left?* [Turn your head to the left.] *Hold*
16. *Rate for pleasantness: Airplane*
17. *Spoken to the left?* [Keep your head straight.] *Thread*
18. *A or U? Match*
19. *Spoken to the left?* [Turn your head to the left.] *Fleet*
20. *Rate for pleasantness: Fruit*
21. *A or U? Melt*
22. *Spoken to the left?* [Turn your head to the left.] *Training*
23. *Rate for pleasantness: Race*
24. *A or U? Only*
25. *Rate for pleasantness: Winter*
26. *A or U? Single*
27. *Rate for pleasantness: Disease*
28. *A or U? Yourself*
29. *Spoken to the left?* [Keep your head straight.] *Else*
30. *Rate for pleasantness: Camp*

Then tell your students:

Now I'd like you to try to remember all of the words that you were asked to judge. You can omit the practice words, but see how many of the others you can remember. Turn over the paper you just used, and write down as many as you can.

How to score the data:

It is easiest to have the students score their own papers. Show them (for example, on an overhead projector) the 30 words, grouped by task—there are 10 of each. Ask them to count how many words out of 10 they got right for each of the three tasks. Then ask for a show of hands: how many people got the most right for the *rate for pleasantness* task, then the *A or U* task, and then the *spoken to the left* task? (You can let students raise their hands twice if there is a tie.)

How to interpret what happened:

It's a very good bet that students will remember the most from the pleasantness task. You can highlight two points to students. First, they remembered lots of words even though they were *not* trying to remember them. You might also point out how much of what is in their memory is not stuff that they tried to remember, as described in the main article. Second, you should point out that the pleasantness task was the "winner" because it forced students to think about what the words meant. Students could answer the *spoken to the left* question without even listening to the word, and they could answer the *A or U* question by just thinking of the spelling. But on the *rate for pleasantness* task, they had to think of meaning, and that's what really helps memory.

DEMONSTRATION 2

This exercise demonstrates the interference that occurs when you continually use the same cue to try to remember more and more material. Thus, it shows that it is important to try to use different, distinctive cues.

What to tell your students:

I'm going to read a list of words to you. All you need to do is listen to the words and then, when I say "go," write down as many as you can remember. We'll do several of these lists. For each one, you

only need to remember the words from the list that I just read to you. [Students should have a piece of paper and a pencil or pen ready.]

What to do:

Read each of the lists below at a rate of about one second per word. At the end of the list, say "go." There is a natural tendency to use a slightly different tone (usually higher pitch) for the last word of the list. Try to resist that tendency and to read the last word just as you read the others. After you say "go," give the students some time to try to recall the words, but it needn't be terribly long (perhaps 15 or 20 seconds). Given a longer time they probably will not remember much more. After each list, ask students to draw a line on their paper or indicate in some other way that they are remembering a new list.

List 1: Apple, Blueberry, Grape, Orange, Raspberry, Watermelon, Fig
List 2: Lime, Pear, Cherry, Strawberry, Honeydew, Mango, Kiwi
List 3: Apricot, Banana, Peach, Lemon, Grapefruit, Blackberry, Plum
List 4: Firefighter, Teacher, Chef, Secretary, Police Officer, Tailor, Doctor

How to score the data:

For this one you probably don't even need to have them score their answers as correct (although you certainly could). Just ask students to count how many words they remembered from each list. Then ask, "How many got more words right on the first list than on the third list?" Most should. Then ask, "How many got more words right on the third list than on the first list?" There should be very few of these. Finally ask, "How many got more words right on the fourth list than on the third list?" Again, most students should have done so.

How to interpret what happened:

Students will, of course, remember that the list consisted of fruits, so when they try to remember the words on the list, they try to think of fruits. But that cue becomes more ambiguous with each new list, because the cue "fruits that the teacher just read to me" gets crowded with words that are correct (the current list) and words that are incorrect (words from the previous list). But students use a different, unambiguous cue for the final list (occupations) and so recall improves.

DEMONSTRATION 3

This demonstration shows that people are generally more likely to be overconfident about what they know than underconfident.

What to tell your students:

I'm going to ask you to make some judgments about what you know. For each question, I want you to take just a second or two and then write down "yes" or "no," regarding whether you think you know that information. You won't have time to actually try to remember it, just make a quick judgment about whether you think you could, if you had enough time.

What to do:

Obviously, this demonstration will not work if you pose questions that are too easy or too hard—students will confidently say that they can or cannot answer them, and they will be right! Here are some ideas for questions that might work, but if they look too easy or difficult to you, replace them with more suitable questions. Make sure that you don't pose questions with just one answer (e.g., "Who was the first actor to play James Bond?"), because such questions encourage students to consult their memory for the answer, and to make their judgment on that basis. Here are some ideas for questions.

1. *Can you name the seven dwarfs?* (Dopey, Grumpy, Doc, Happy, Bashful, Sneezy, Sleepy)
2. *Can you name the world's continents?* (North America, South America, Antarctica, Africa, Europe, Asia, Australia)
3. *Can you name five [or four, or seven] recent presidents?* (G. W. Bush, Clinton, G. H. W. Bush, Reagan, Carter, Ford, Nixon, etc.)
4. *Can you name the presidents on Mount Rushmore?* (Lincoln, Washington, Jefferson, Teddy Roosevelt)
5. *Can you name the members of the Beatles?* (John Lennon, Paul McCartney, George Harrison, Ringo Starr)
6. *Can you name the states on the eastern seaboard?* (Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida)
7. *Can you name the first four elements of the periodic table?* (Hydrogen, Helium, Lithium, Beryllium)
8. *Can you name the titles of the seven Harry Potter books? (*Harry Potter and the Sorcerer's Stone*,* Harry Potter and the Chamber of Secrets*,* Harry Potter and the Prisoner of Azkaban*,* Harry Potter and the Goblet of Fire*,* Harry Potter and the Order of the Phoenix*,* Harry Potter and the Half-Blood Prince*,* Harry Potter and the Deathly Hallows)

After students make their judgments for two or three questions, ask them to go ahead and write down the answers. Even if they said that they couldn't remember, they should try their best and guess if necessary.

How to score the data:

For this demonstration it is important that students know whether their memory was accurate, so you must give them the correct answers for scoring. Once they know whether their memory was accurate, ask for a show of hands: how many students, for any of the questions, judged that they *would* be able to answer the question but then were not able to? Next, ask for a show of hands for all those who thought they would *not* be able to answer the question correctly, but actually were able to do so. There ought to be more of the former than the latter, reflecting the general overconfidence of memory.

How to interpret what happened:

Tell your students that overconfidence about what we know is a pervasive feature of memory. The consequence is that we *think* we know things that we actually don't quite know. This means that you can't rely on your gut feeling when trying to judge whether or not you know something—for example, when trying to judge whether you are prepared for a test or need to study a little more. The only way to combat the problem is to test yourself, and see whether the material is actually in your memory.

–D.T.W.

Improving Memory

(Continued from page 22)

For Further Reading

For more information about memory, I recommend these books:

Alan Baddeley, *Your Memory: A User's Guide* (Richmond Hill, Ontario: Firefly Books, 2004).

Kenneth L. Higbee, *Your Memory: How It Works and How to Improve It*, 2nd ed. (New York: Marlowe, 2001).

See also the following "Ask the Cognitive Scientist" columns:

"Practice Makes Perfect—But Only If You Practice Beyond the Point of Perfection," *American Educator*, Spring 2004, **www.aft.org/pubs-reports/american_educator/spring2004/cogsci.html**.

"Why Students Think They Understand—When They Don't," *American Educator*, Winter 2003-04, **www.aft.org/pubs-reports/american_educator/winter03-04/cognitive.html**.

"Students Remember ... What They Think About," *American Educator*, Summer 2003, **www.aft.org/pubs-reports/american_educator/summer2003/cogsci.html**.

"Allocating Student Study Time: 'Massed' versus 'Distributed' Practice," *American Educator*, Summer 2002, **www.aft.org/pubs-reports/american_educator/summer2002/askcognitivescientist.html**.

Endnotes

1. Nate Kornell and Robert A. Bjork, "Optimizing Self-Regulated Study: The Benefits—and Costs—of Dropping Flashcards," *Memory* 16 (2008): 125–36.

2. See, for example, Thomas S. Hyde and James J. Jenkins, "Differential Effects of Incidental Tasks on the Organization of Recall of a List of Highly Associated Words," *Journal of Experimental Psychology* 82 (1969): 472–81; Michael E. J. Masson and Mark A. McDaniel, "The Role of Organizational Processes in Long-Term Retention," *Journal of Experimental Psychology: Human Learning and Memory* 7 (1981): 100–110; and Thomas O. Nelson and Susan K. Vining, "Effect of Semantic versus Structural Processing on Long-Term Retention," *Journal of Experimental Psychology: Human Learning and Memory* 4 (1978): 198–209.

3. C. Donald Morris, John D. Bransford, and Jeffery J. Franks, "Levels of Processing versus Transfer Appropriate Processing," *Journal of Verbal Learning and Verbal Behavior* 16 (1977): 519–33.

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6. Claudia M. Roebers, "Confidence Judgments in Children's and Adults' Event Recall and Suggestibility," *Developmental Psychology* 38 (2002): 1052–67.

7. Earl C. Butterfield, Thomas O. Nelson, and Virginia Peck, "Developmental Aspects of the Feeling of Knowing," *Developmental Psychology* 24 (1988): 654–63; and Kathrin Lockl and Wolfgang Schneider, "Developmental Trends in Children's Feeling-of-Knowing Judgements," *International Journal of Behavioral Development* 26 (2002): 327–33.

8. Maribeth Gettinger, "Time Allocated and Time Spent Relative to Time Needed for Learning as Determinants of Achievement," *Journal of Educational Psychology* 77 (1985): 3–11.

9. See also Linda Leal, Nancy Crays, and Barbara E. Moely, "Training Children to Use a Self-Monitoring Study Strategy in Preparation for Recall: Maintenance and Generalization Effects," *Child Development* 56 (1985): 643–53; and Nate Kornell and Robert A. Bjork, "The Promise and Perils of Self-Regulated Study," *Psychonomic Bulletin and Review* 14 (2007): 219–24.

10. See, for example, Michael Allen Martin, "Students' Applications of Self-Questioning Study Techniques: An Investigation of Their Efficacy," *Reading Psychology* 6 (1985): 69–83.

11. See, for example, Michael Pressley and Pamela Beard El-Dinary, "Memory Strategy Instruction That Promotes Good Information Processing," in *Memory Improvement: Implications for Memory Theory*, ed. Douglas J. Herrmann, Herbert Weingartner, Alan Searleman, and Cathy McEvoy (New York: Springer-Verlag, 1992), 79–100; and Michael Pressley, Sonya Symons, Mark A. McDaniel, Barbara L. Snyder, and James E. Turnure, "Elaborative Interrogation Facilitates Acquisition of Confusing Facts," *Journal of Educational Psychology* 80 (1988): 268–78.

12. Eileen Wood, Michael Pressley, and Philip H. Winne, "Elaborative Interrogation Effects on Children's Learning of Factual Content," *Journal of Educational Psychology* 82 (1990): 741–48.

13. Raymond S. Nickerson and Marilyn Jager Adams, "Long-Term Memory for a Common Object," *Cognitive Psychology* 11 (1979): 287–307.

14. For a review, see Nicholas J. Cepeda, Harold Pashler, Edward Vul, John T. Wixted, and Doug Rohrer, "Distributed Practice in Verbal Recall Tasks: A Review and Quantitative Synthesis," *Psychological Bulletin* 132 (2006): 354–80.

15. Asher Koriat, Robert A. Bjork, Limor Sheffer, and Sarah K. Bar, "Predicting One's Own Forgetting: The Role of Experience-Based and Theory-Based Processes," *Journal of Experimental Psychology: General* 133 (2004): 643–56.

16. Andrew P. Yonelinas, "The Nature of Recollection and Familiarity: A Review of 30 Years of Research," *Journal of Memory and Language* 46 (2002): 441–517.

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