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Four Principles of Memory Improvement: A Guide to Improving Learning Efficiency

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Recent advances in memory research suggest methods that can be applied to enhance educational practices. We outline four principles of memory improvement that have emerged from research: 1) process material actively, 2) practice retrieval, 3) use distributed practice, and 4) use metamemory. Our discussion of each principle describes current experimental research underlying the principle and explains how people can take advantage of the principle to improve their learning. The techniques that we suggest are designed to increase efficiency—that is, to allow a person to learn more, in the same unit of study time, than someone using less efficient memory strategies. A common thread uniting all four principles is that people learn best when they are active participants in their own learning.

Memory research has a 125-year history dating back to the seminal work of Ebbinghaus (1885/1964). In this time, the field has matured into a science with reliable data, firm principles, and well-established theories. In recent years, cognitive psychologists have increasingly shifted their focus towards identifying principles of learning and memory that can be used to make recommendations about enhancing educational practices (e.g. Metcalfe, Kornell, & Son, 2007; Roediger, 2009; Roediger & Karpicke, 2006a; Rohrer & Pashler, 2010; Willingham, 2009). While the approach has stemmed from cognitive science, educational psychologists have long grappled with similar objectives and issues (see Groninger, 1971; Richardson, 1998). Here, we attempt to organize -- in a style that is succinct and useful for both teachers and students -- the findings into four principles of memory improvement that can be applied to real-word educational problems. The principles can be defined broadly as follows: 1) process material actively, 2) practice retrieval 3) use distributed practice, and 4) use metamemory.

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PROCESS MATERIAL ACTIVELY

To process materials actively means to emphasize active and elaborative processing, sometimes also known as meaningful processing (see Craik & Lockhart, 1972). For example, in a now-classic study, Hyde and Jenkins (1969) presented two groups of participants with a list of words. One group rated each of the words for pleasantness, a judgment that oriented participants toward considering the meaning of the words. When tested later on all of the words, this group significantly outperformed a second group, who had made judgments about each word without processing them in a meaningful way; i.e. they merely estimated the number of letters in each word.

Experiments that simulate more realistic learning environments have shown similar outcomes. For example, Mathews and Tulving (1973) found that students who were asked to categorize word pairs (e.g., Is this a mammal?) learned more than did students who were asked to pay attention to the meaning of the pairs but were not asked to do the additional categorical processing. Similarly, the process of elaboration, or relating to-be-learned information to already-known information, also enhances learning (e.g., Hyde and Jenkins, 1969). Furthermore, focusing on distinctive aspects of stimuli, or those that make the stimulus unique, also leads to better memory (Hunt, 2006).

Some students may argue that they are already processing information deeply when they read their textbooks and engage in other study activities, so knowing about the first principle will not change how they learn. But even those students might benefit from processing information more actively. There is compelling evidence that when students read with the intention of learning the material as well as they can, they learn *less* than students instructed to learn the material so that they can teach it to someone else (Bargh & Schul, 1980). The benefit of preparing to teach is not that the students benefit from actual teaching—they never actually do any teaching—it is the attitude of *preparing* to teach that makes the difference. This attitude may increase people's focus on the organization and relationships within the material. It may also cause people to engage in self-explanation, which benefits learning (Chi, de Leeuw, Chiu, & LaVancher, 1994). Preparing to teach is also a relatively easy technique to apply when reading a textbook or other learning materials. To summarize, when we process material actively—by thinking deeply about meaning, relationships, and organization—we learn more than when we take a more passive approach to learning.

PRACTICE RETRIEVAL

To practice retrieval means to learn by recalling information from memory (e.g., learn by taking tests). Retrieval practice can lead to far more learning than re-studying (for a review, see Roediger, 2009; Roediger & Karpicke, 2006b; for early research on the topic, also see Gates 1917; Hogan & Kintsch, 1971; Spitzer, 1939). For example, Roediger and Karpicke (2006a) asked participants to read short prose passages concerning scientific information. One group of participants was given four chances to read a passage. A second group was given only one reading period, but then had three chances to practice recalling the passage. Participants tested immediately did better if they had been in the re-reading condition (see Figure 1). But one week later, the outcome reversed: The retrieval practice group outperformed the restudy group by more than 50%!

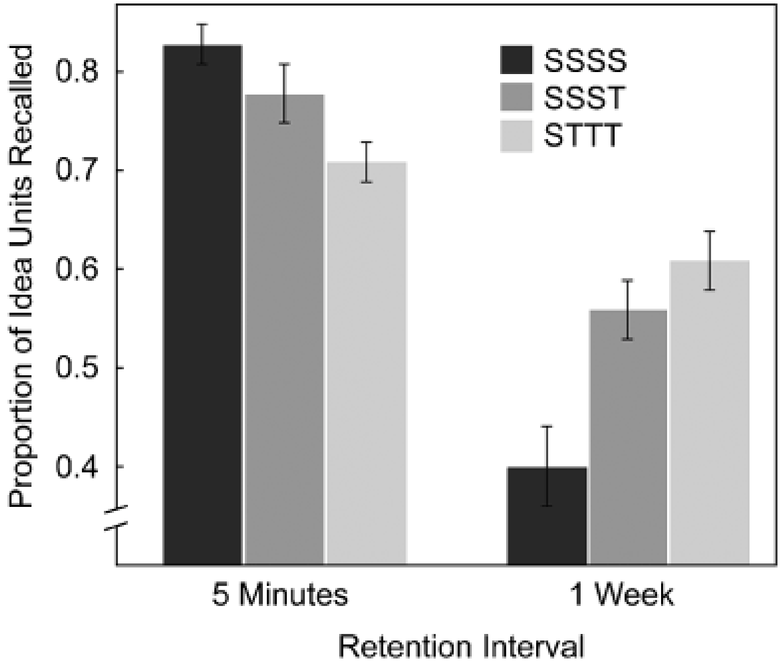

Figure 1. Roediger and Karpicke (2006a) Showed That Retrieval Practice Has Long-term Benefits for Learning at Longer Retention Intervals. SSSS = All Studying, SSS = Three Study Sessions Followed by 1 Testing. STTT = One Study Session, Followed by Three Testing Trials.

Are there situations where it is not advisable to test oneself? For example, it might seem pointless to take a test on something one has not yet started to learn—particularly because generating incorrect answers might seem like it would have harmful effects. Yet research indicates that even an unsuccessful retrieval attempt, if it is followed by feedback, can be more effective than an opportunity to study information without being tested (Finn & Metcalfe, 2010; Kornell, Hays, & Bjork, 2009; Richland, Kornell, & Kao, 2009). That is, even in a situation in which retrieval practice seems as if it might be counterproductive, it is actually effective.

Recent studies have shown that people do not necessarily recognize the benefits of tests (e.g., Karpicke, 2009). In one experiment, participants judged restudying to be more effective than testing, even though they actually learned more via testing (Kornell & Son, 2009). Fortunately, when given the choice of how to study, they preferred self-testing. They chose to test themselves, apparently, to see how well they were doing. Thus, in this case, people chose to self-test for a good reason, but not because they realized that self-testing is itself effective for learning (Karpicke, 2009). These recent findings go against an intuitive and deep-seated belief, among students and educators, in the value of errorless learning (but see Wilson, 2009, for the advantages of errorless learning in amnesic patients). However, it should be noted that in some situations, errors that are made on a test, especially if they are uncorrected, can persist into the future (see Richardson, 1998). The fact that self-testing is unintuitive makes it all the more important to communicate the moral of this research: test thyself!

USE DISTRIBUTED PRACTICE

Distributed practice is learning that is spread out across relatively long periods of time rather than massed all at once. Beginning with Ebbinghaus (1885/1964), hundreds of studies have demonstrated the benefits of distributed learning—the so-called *spacing effect* (see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; see Dempster, 1988). Spacing effects have been demonstrated in motor learning, verbal learning, mathematics learning, and in other educational settings (as described by Cepeda et al., 2006; Kornell, 2009). Distributed practice may be the most powerful method by which people can improve their memory without changing the amount of time spent studying (Baddeley & Longman, 1978; Bjork, 1988; Kornell, 2009).

In a recent study that involved a practical application of distributed practice, Kornell(2009) asked participants to study difficult word-synonym pairs using a computerized "flashcard" paradigm. On each trial, the computer displayed a relatively difficult word (e.g., effulgent); when the participant pressed a button the word's synonym appeared (e.g., brilliant). Participants studied each pair 8 times—half of the participants learned by massing; the other half by distributing trials over four days. At final test, cued recall was up to twice as accurate in the distributed condition as in the massed condition (see Figure 2). The advantage of distribution over massing was present in over 90% of the students. However, over 70% of participants judged massing as more effective than distributing at the outset of the experiment. Thus, the effects of distributed practice are strong, consistent, but unfortunately, counterintuitive.

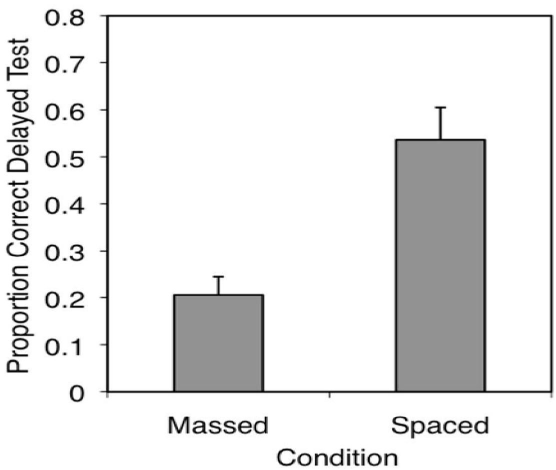

Figure 2. Proportion Correct on the Delayed Test in Kornell's (2009) Experiment 2. Participants Studied English Synonyms Either All at Once or Spaced Across Four Days. On the Fifth Day Their Learning Was Measured Using a Cued Recall Test.

Despite its benefits, learners often judge distributing practice to be ineffective (Baddeley & Longman, 1978; Kornell & Bjork, 2008; Zechmeister & Shaughnessy, 1980). Even for children, though, enforcing distributed study sessions—even when it goes against their decision to mass—can improve learning (Son, 2010; Vlach, Sandhofer, & Kornell, 2008).

For many students, the alternative to distributed learning is to procrastinate and then "cram" just before a test. And while cramming can work in the short term (Kornell, 2009), it does not produce long-term gains. It may be unrealistic to expect students, even those who know about distributed practice, to stop relying on cramming. However, educators may help their students by assigning topics in a way that lead to distributed practice (e.g., Taylor & Rohrer, 2010). To summarize, distributing one's study may take effort and resolve, but the person who does so will greatly improve their learning efficiency.

USE METAMEMORY

Metamemory refers to judgments and decisions we make about our own learning and memory (Karpicke, 2009; Metcalfe, 2009; Son, 2010). Beliefs and judgments are referred to as memory monitoring; decisions that we make based on monitoring are referred to as control. For example, students monitor their learning while they study, which allows them to make decisions about how to study, when to study, what resources to rely on, how much to study, and so forth. We will briefly outline the promise of metamemory for improving study habits and the pitfalls to avoid when making judgments and decisions about one's learning.

Judgments of learning (henceforth, JOLs) are predictions of future remembering made at the time of learning (Nelson & Leonesio, 1988). Implicit JOLs (e.g., am I ready for the test tomorrow?) can play an important role in people's study decisions. But those study decisions will tend to be flawed if they are based on inaccurate JOLs. Fortunately, testing oneself—not immediately after studying, but after a meaningful delay—greatly increases the accuracy of JOLs (Dunlosky & Nelson, 1992). In this context, tests are beneficial because they are an accurate way of diagnosing one's memory. However, tests have multiple advantages: retrieval directly enhances learning, and it increases monitoring accuracy.

JOLs are driven by heuristics, and like many other heuristic-based judgments, they are subject to systematic biases. One near-universal bias is overconfidence (e.g. Son & Kornell, 2010). Unfortunately, overconfidence is exacerbated by a human tendency to overlook a fundamental aspect of memory: forgetting. For example, Koriat, Bjork, Sheffer, and Bar (2004) asked one group of people how they would do on a test in five minutes and another how they would do on a test on one week. The groups made almost identical predictions—that is, participants acted like they would not forget anything over the course of a week. In reality, of course, they forgot a great deal, and so their initial judgments were highly overconfident. Overconfidence is problematic to learning because a student who is overconfident may stop studying prematurely.

Even if judgments are accurate, they are only a first step toward improving learning; making effective study decisions is an additional challenge. One adaptive strategy is based on Kornell and Metcalfe's(2006) Region of Proximal Learning model, which states that efficient learning occurs when people study the easiest items that have not yet been mastered (also see Metcalfe et al., 2007). These items are most likely to make the crucial transition from being unknown to being memorable later.

Consider how this strategy might apply to a student studying for an exam. The student may begin studying for an exam, only to have her study session interfered with by any number of factors (a party, a family emergency, etc). If the student had focused on the most difficult items, she might not have mastered anything, thus leading to poor test performance (and low learning efficiency). But if she had prioritized learning the easier items, she would be likely to remember those items the next day.

To illustrate this point, Son and Kornell (2009) asked participants to make JOLs on GRE word-synonym pairs (e.g., ignominious – shameful). Participants then had the opportunity to choose which items to study, and for how long. In support of the proximal learning model, participants focused on the easier items first, studying them in advance of the more difficult items. However, participants shifted their focus from the easy items to the difficult items and studied the latter more often (see Figure 3).

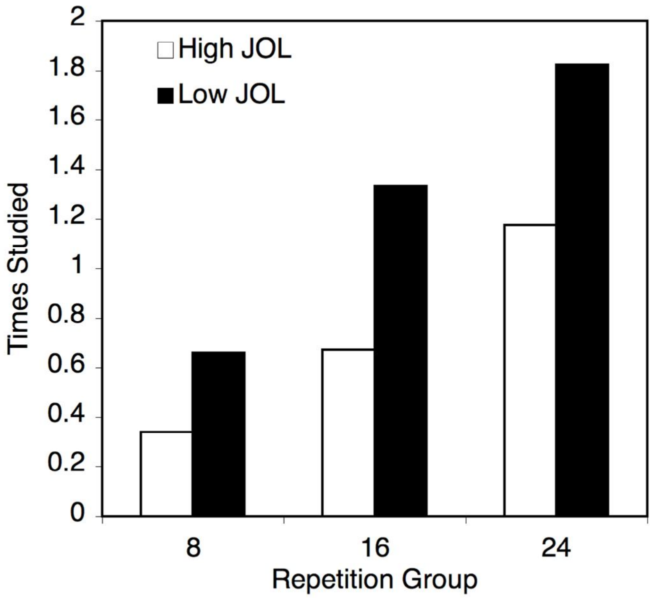

Figure 3. Data from Son and Kornell (2009). Participants Studied 16 Total Items. Depending on Group, They Could Then Re-study 8, 16, or 24 Times. The Mean Number of Times An Item Was Studied is Plotted as a Function of Whether the Participant Gave the Item a High or Low JOL. Items Deemed More Difficult by the Participants Were Studied More Often; the Data Also Showed, However, That among Items Selected for Study, Easier Items Tended to be Selected Relatively Early.

In addition to which items to study and for how long, students also face crucial decisions about *how* to study. The present article provides guidance for such decisions: People should focus on meaning, practice retrieval, distribute practice, and use metamemory. Teachers can encourage these techniques using homework assignments and in-class guidance. Likewise, students can use them when they are deciding for themselves how to study.

In summary, metamemory—both in terms of judgments and strategy decisions—plays an important role in self-regulated study. Students should try to judge their memories in ways that are diagnostic (e.g., by testing themselves) and should be wary of systematic biases such as overconfidence. Finally, students should be realistic when they study, and focus on the information that they will be able to learn and remember.

CONCLUSION

It is impossible to overstate the importance of education. It is a huge undertaking from primary and secondary education to college and beyond. Education and training occur in every industry, and people of all ages and occupations need to continuously learn and re-learn. Increasing learning efficiency, even by small amounts, can save time (and therefore, money), and it can simultaneously increase overall learning. We believe that learners can increase the efficiency of their learning by taking advantage of the four principles described herein: process material actively, practice retrieval, distribute study, and use metacognition.

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