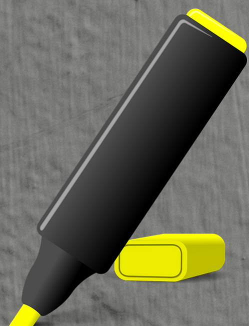
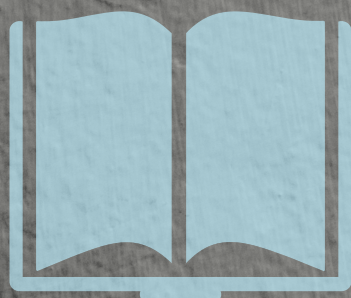
84% of students make this mistake...



just **HIGHLIGHTING** or



REREADING notes

ISN'T ENOUGH when studying.

TRY ADDING METHODS SUCH AS SELF-TESTING BY CREATING FLASHCARDS OR PRACTICE TESTS

Information from: Dunlosky, J. (2013). Strengthening the student toolbox: Study strategies to boost learning. American Educator, 37(3), 12-21.

Ineffective Study Methods

Dunlosky, J. (2013). Strengthening the student toolbox: Study strategies to boost learning. American Educator, 37(3), 12-21.

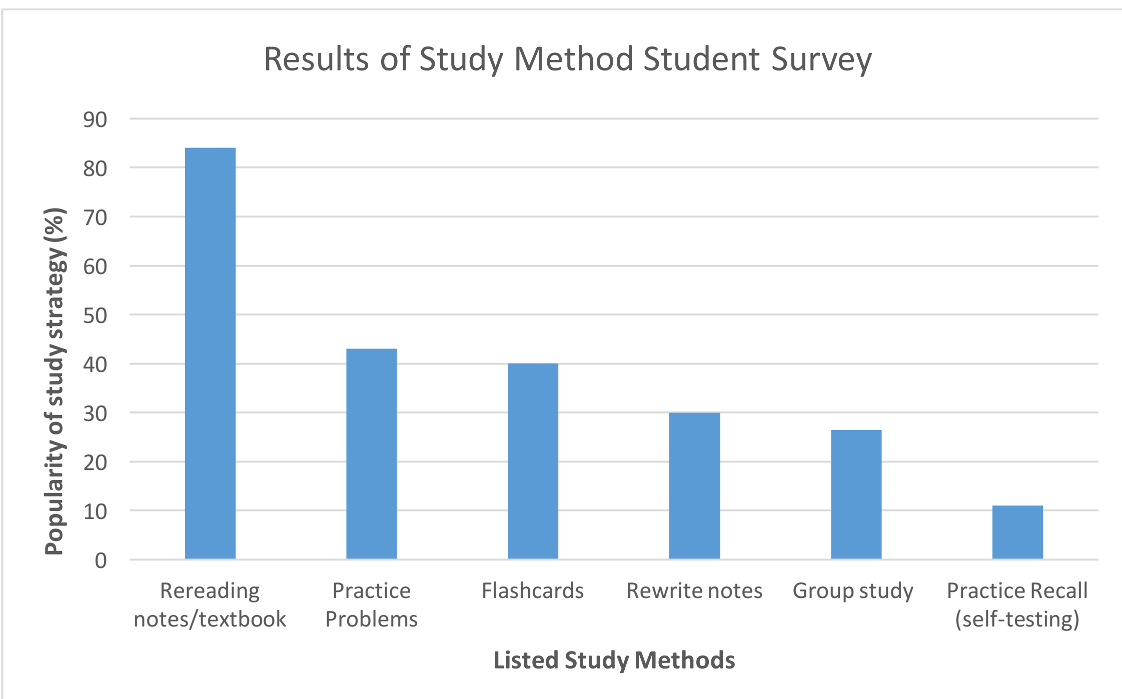
The above article is a summarization of researched study methods and is a resource for students looking to improve their learning. John Dunlosky is a professor of psychology whose research focuses on self-regulated learning. This 'student toolbox' drew on two papers to support the notion of 'highlighting' and 'rereading notes' as two of the least effective studying strategies:

Karpicke, J. D., Butler, A. C., & Roediger III, H. L. (2009). Metacognitive strategies in student learning: do students practise retrieval when they study on their own?. *Memory*, *17*(4), 471-479.

<u>Study Design:</u>

- 177 undergraduate students who were all participants in various learning/memory laboratory experiments
- each student completed the two-question survey at the end of their experimental session
- the survey questions focused on study habits and how/if the students practiced recalling information

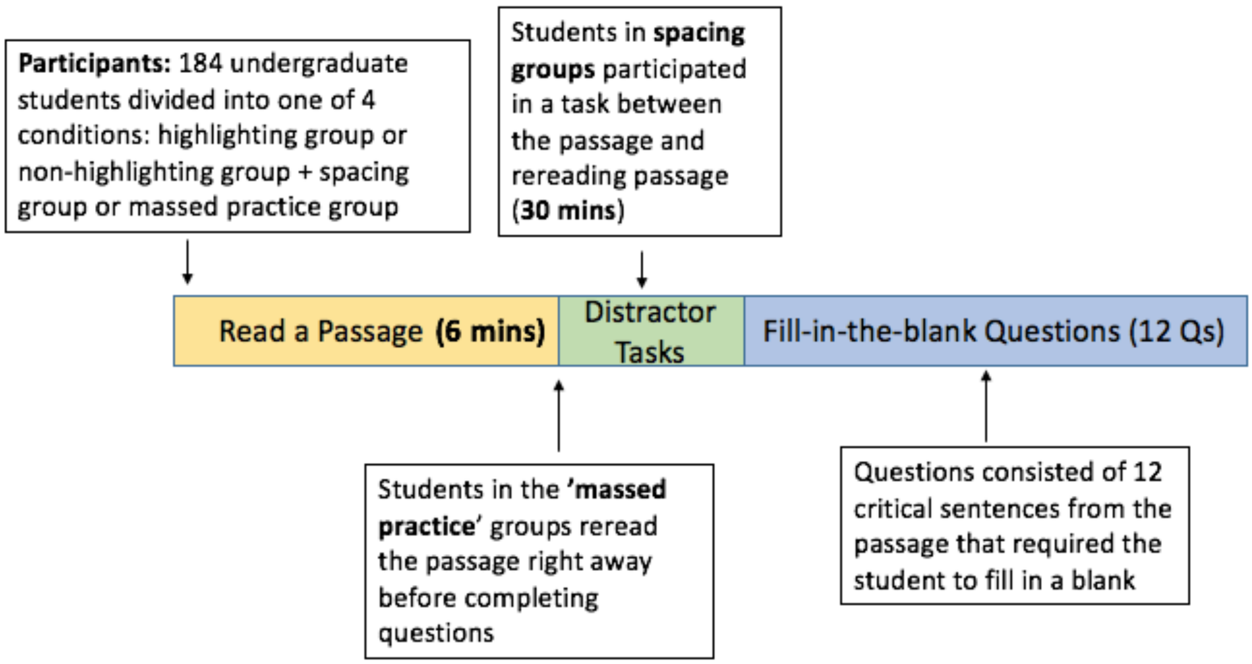
<u>Key Results:</u>



- results show that over 80% of students engage in rereading notes as one of their primary study methods
- relying on this study method produces an illusion that students know material better than they actually do
- rereading notes lacks the learning/retaining benefits that self-testing while studying produces

Yue, C. L., Storm, B. C., Kornell, N., & Bjork, E. L. (2015). Highlighting and its relation to distributed study and students' metacognitive beliefs. *Educational Psychology Review*, *27*(1), 69-78.

Study Design



Key Results

- Although highlighted material was better recalled in practice the participants who 'lightly highlighted' outperformed those who 'heavily highlighted' suggesting that the apparent benefits from highlighting information comes from a strategic process rather than a subconscious habit
- Highlighting appears to be more beneficial when students are engaging in massed study (ex. immediately rereading a passage)
- Relying on highlighting as a sole study method may give students a false competency of the studied material, because any benefit from highlighting is coming from changes in the student's perspective of the given material not the act itself

Strengthening the Student Toolbox

Study Strategies to Boost Learning

ILLUSTRATIONS BY DANIEL BAXTER

By John Dunlosky

It's the night before her biology exam, and the high school student has just begun to study. She takes out her highlighter and reads her textbook, marking it up as she goes along. She rereads sentences that seem most important and stays up most of the night, just hoping to get a good enough grasp of the material to do well on the exam. These are study strategies that she may have learned from her friends or her teachers or that she simply took to on her own. She is not unusual in this regard; many students rely on strategies such as highlighting, rereading, and cramming the night before an exam.

Quite often, students believe these relatively ineffective strategies are actually the most effective,[1] and at least on the surface they do seem sound, perhaps because, even after pulling an all-nighter, students manage to squeak by on exams. Unfortunately, in a recent review of the research, my colleagues and I found that these strategies are not that effective,[2] especially if students want to retain their learning and understanding of content well after the exam is over—obviously, an important educational goal.

So, why aren't students learning about the best strategies? I can only speculate, but several reasons seem likely. Curricula are developed to highlight the content that teachers should teach, so the focus is on providing content and not on training students how to effectively acquire it. Put differently, the emphasis is on *what* students need to learn, whereas little emphasis—if any—is placed on training students *how* they should go about learning the content and what skills will promote efficient studying to support robust learning. Nevertheless, teaching students *how* to learn is as important as teaching them content, because acquir-

John Dunlosky is a professor of psychology and the director of experimental training at Kent State University. His research focuses on self-regulated learning and how it can be used to improve student achievement across the lifespan.

ing both the right learning strategies and background knowledge is important—if not essential—for promoting lifelong learning.

Another reason many students may not be learning about effective strategies concerns teacher preparation. Learning strategies are discussed in almost every textbook on educational psychology, so many teachers likely have been introduced to at least some of them. Even so, my colleagues and I found that, in large part, the current textbooks do not adequately cover the strategies; some omit discussion of the most effective ones, and most do not provide guidelines on how to use them in the classroom or on how to teach students to use them. In some cases, the strategies discussed have limited applicability or benefit.[3] So I sympathize with teachers who want to devote some class time to teaching students how to learn, because teacher preparation typically does not emphasize the importance of teaching students to use effective learning strategies. Moreover, given the demands of day-to-day teaching, teachers do not have time to figure out which strategies are best.

The good news is that decades of research has focused on evaluating the effectiveness of many promising strategies for helping students learn. Admittedly, the evidence for many of these strategies is immense and not easily deciphered, especially given the technical nature of the literature. Thus, to help promote the teaching and use of effective learning strategies, my colleagues* and I reviewed the efficacy of 10 learning strategies:

1. Practice testing: self-testing or taking practice tests on to-be-learned material.
2. Distributed practice: implementing a schedule of practice that spreads out study activities over time.
3. Interleaved practice: implementing a schedule of practice that mixes different kinds of problems, or a schedule of study that mixes different kinds of material, within a single study session.
4. Elaborative interrogation: generating an explanation for why an explicitly stated fact or concept is true.
5. Self-explanation: explaining how new information is related to known information, or explaining steps taken during problem solving.
6. Rereading: restudying text material again after an initial reading.
7. Highlighting and underlining: marking potentially important portions of to-be-learned materials while reading.
8. Summarization: writing summaries (of various lengths) of to-be-learned texts.
9. Keyword mnemonic: using keywords and mental imagery to associate verbal materials.
10. Imagery for text: attempting to form mental images of text materials while reading or listening.

Before describing the strategies in detail, I will put into context a few aspects of our review. First, our intent was to survey strategies that teachers could coach students to use without sacrificing too much class time and that any student could use. We excluded a variety of strategies and computer-driven tutors that show promise but require technologies that may be unavailable to many students. Although some of the strategies we reviewed can be implemented with computer software, they all can be used successfully by a motivated student who (at most) has access to a pen or pencil, some index cards, and perhaps a calendar.

Second, we chose to review some strategies (e.g., practice testing) because an initial survey suggested that they were relatively effective,[4] whereas we chose other strategies (e.g., rereading, highlighting) because students reported using them often yet we wondered about their effectiveness.

Finally, the strategies differ somewhat with respect to the kinds of learning they promote. For instance, some strategies (e.g., keyword mnemonic, imagery for text) are focused on improving students' memory for core concepts or facts. Others (e.g., self-explanation) may best serve to promote students' comprehension of what they are reading. And still others (e.g., practice testing) appear to be useful for enhancing both memory and comprehension.

In the following sections, I discuss each of the learning strategies, beginning with those that show the most promise for improving student achievement.

The Most Effective Learning Strategies

We rated two strategies—practice testing and distributed practice—as the most effective of those we reviewed because they can help students regardless of age, they can enhance learning and comprehension of a large range of materials, and, most important, they can boost student achievement.

*My collaborators on this project were cognitive and educational researchers Katherine A. Rawson, Elizabeth J. Marsh, Mitchell J. Nathan, and Daniel T. Willingham. Willingham regularly contributes to *American Educator* in his "Ask the Cognitive Scientist" column.

Practice Testing

Test, *exam*, and *quiz* are four-letter words that provoke anxiety in many students, if not some teachers as well. Such anxiety may not be misplaced, given the high stakes of statewide exams. However, by viewing tests as the end-all assessments administered only after learning is complete, teachers and students are missing out on the benefits of one of the most effective strategies for *improving* student learning.

In 1909, a doctoral student at the University of Illinois demonstrated that practice tests improve student performance,[5] and more than 100 years of research has revealed that taking practice tests (versus merely rereading the material to be learned) can substantially boost student learning. For instance, college students who reported using practice tests to study for upcoming exams earned higher grades,[6] and when middle school teachers administered daily practice tests for class content, their students performed better on future tests that tapped the content they had practiced during the daily tests.[7]

All of the strategies we reviewed can be used successfully by a motivated student who (at most) has access to a pen or pencil, some index cards, and perhaps a calendar.

The use of practice tests can improve student learning in both direct and indirect ways.[8] Consider two students who have just read a chapter in a textbook: Both students review the most important information in the chapter, but one student reads the information again, whereas the other student hides the answers and attempts to recall the information from memory. Compared with the first student, the second student, by testing himself, is boosting his long-term memory. Thus, unlike simply reading a text, when students correctly retrieve an answer from memory, the correct retrieval can have a direct effect on memory.

Practice tests can also have an indirect effect on student learning. When a student fails to retrieve a correct answer during a practice test, that failure signals that the answer needs to be restudied; in this way, practice tests can help students make better decisions about what needs further practice and what does not. In fact, most students who use practice tests report that they do so to figure out what they know and do not know.[9]

Based on the prevailing evidence, how might students use practice tests to best harness the power of retrieval practice? First, student learning can benefit from almost any kind of practice test, whether it involves completing a short essay where students need to retrieve content from memory or answering questions in a multiple-choice format. Research suggests, however, that students will benefit most from tests that require recall from memory, and not from tests that merely ask them to recognize the correct answer.[10] They may need to work a bit harder to recall key materials (especially lengthy ones) from memory, but the payoff will be great in the long run. Another benefit of encouraging students to recall key information from memory is that it does not require creating a bank of test questions to serve as practice tests.

Second, students should be encouraged to take notes in a manner that will foster practice tests. For instance, as they read a chapter in their textbook, they should be encouraged to make flashcards, with the key term on one side and the correct answer on the other. When taking notes in class, teachers should encourage students to leave room on each page (or on the back pages of notes) for practice tests. In both cases, as the material becomes more complex (and lengthy), teachers should encourage students to write down their answers when they are testing themselves. For instance, when they are studying concepts on flashcards, they should first write down the answer (or definition) of the concept they are studying, and then they should compare their written answer with the correct one. For notes, they can hide key ideas or concepts with their hand and then attempt to write them out in the remaining space; by using this strategy, they can compare their answer with the correct one and easily keep track of their progress.

Third, and perhaps most important, students should continue testing themselves, with feedback, until they correctly recall each concept at least once from memory. For flashcards, if they correctly recall an answer, they can pull the card from the stack; if they do not recall it correctly, they should place it at the back of the stack. For notes, they should try to recall all of the important ideas and concepts from memory, and then go back through their notes once again and attempt to correctly recall anything they did not get right during their first pass. If students persist until they recall each idea or concept correctly, they will enhance their chances of remembering the concepts during the actual exam. They should also be encouraged to "get it right" on more than one occasion, such as by returning to the deck of cards on another day and relearning the materials. Using practice tests may not come naturally to students, so teachers can play an important role in informing them about the power of practice tests and how they apply to the content being taught in class.

Not only can students benefit from using practice tests when studying alone, but teachers can give practice tests in the classroom. The idea is for teachers to choose the most important ideas and then take a couple minutes at the beginning or end of each class to test students. After all students answer a question, teachers can provide the correct answer and give feedback. The more closely the practice questions tap the same information that will be tested on the in-class examination, the better students will do. Thus, this in-class "testing time" should be devoted to the most critical information that will appear on the actual exam. Even using the same questions during practice and during the test is a reasonable strategy. It not only ensures that the students will be learning what teachers have decided is most important, but also affirms to students that they should take the in-class practice quizzes seriously.

Distributed Practice

A second highly effective strategy, distributed practice is a straightforward and easy-to-use technique. Consider the following examples:

A first-grader studies for a spelling test. Using a worksheet to guide her practice, she might take one of two approaches. She could practice spelling the words by writing each one several times directly below the word printed on the sheet. After practicing one word repeatedly, she would move on to the next one and practice writing that word several times below it. This kind of practice is called massed practice, because the student practices each word multiple times together, before moving to the next one.

An alternative strategy for the student would be to practice writing each word only once, and after transcribing the final word, going back and writing each one again, and so forth, until the practice is complete. This kind of practice is called distributed practice, because practice with any one word is distributed across time (and the time between practicing any one word is filled with another activity—in this case, writing other words).

In this example, the student either masses or distributes her practices during a single session. Now, imagine an eighth-grader trying to learn some basic concepts pertaining to geology for an upcoming in-class exam. He might read over his notes diligently, in a single session the night before the exam, until he thinks he is ready for the test—a study tactic called cramming, which practically all students use. Or, as an alternative, he might study his notes and texts during a shorter session several evenings before the exam and then study them again the evening before. In this case, the student distributes his studying across two sessions.

Students will retain knowledge and skills for a longer period of time when they distribute their practice than when they mass it,[11] even if they use the same amount of time massing and distributing their practice.* Unfortunately, however, many students believe that massed practice is better than distributed practice.[12]

One reason for this misconception is that students become familiar and facile with the target material quickly during a massed practice session, but learning appears to proceed more slowly with distributed practice. For instance, the first-grader quickly writes the correct word after practicing it several times in succession, but when the same practice is distributed, she may still struggle after several attempts. Likewise, the eighth-grader may quickly become familiar with his notes after reading them twice during a single session, but when distributing his practice across two study sessions, he may realize how much he has forgotten and use extra time getting back up to speed.

In both cases, learning itself feels tougher when it is distributed instead of massed, but the competency and learning that students may feel (and teachers may see) during massed practice is often ephemeral. By contrast, distributed practice may take more effort, but it is essential for obtaining knowledge in a manner that will be maintained (or easily relearned) over longer, educationally relevant periods of time.

Most students, whether they realize it or not, use distributed practice to master many different activities, but not when they are studying. For instance, when preparing for a dance recital, most would-be dancers will practice the routine nightly until they have it down; they will not just do all the practice the night before the recital, because everyone knows that this kind of practice will likely not be successful. Similarly, when playing video games, students see their abilities and skills improve dramatically over time in large part because they keep coming back to play the game in a distributed fashion. In these and many other cases, students realize that more practice or play during a current session will not help much, and they may even see their performance weaken near the end of a session, so, of course, they take a break and return to the activity later. However, for whatever reason, students don't typically use distributed practice as they work toward mastering course content.

The use of practice tests can improve student learning in both direct and indirect ways.

Not using distributed practice for study is unfortunate, because the empirical evidence for the benefits of distributed (over massed) practice is overwhelming, and the strategy itself is relatively easy to understand and use. Even so, I suspect that many students will need to learn how to use it, especially for distributing practice across multiple sessions. The difficulty is simply that most students begin to prepare and study only when they are reminded that the next exam is tomorrow. By that point, cramming is their only option. To distribute practice over time, students should set aside blocks of time throughout each week to study the content for each class. Each study block will be briefer than an all-night cram session, and it should involve studying (and using practice tests) for material that was recently introduced in class and for material they studied in previous sessions.

To use distributed practice successfully, teachers should focus on helping students map out how many study sessions they will

*To learn more about massed versus distributed practice, see Daniel T. Willingham's article, "Allocating Student Study Time," in the Summer 2002 issue of *American Educator*, available at www.aft.org/newspubs/periodicals/ae/summer2002/willingham.cfm.

need before an exam, when those sessions should take place (such as which evenings of the week), and what they should practice during each session. For any given class, two short study blocks per week may be enough to begin studying new material and to restudy previously covered material.

Students will retain knowledge for a longer period of time when they distribute their practice than when they mass it.

Ideally, students will use practice tests to study the previously covered material. If they do, they will quickly retrieve the previously learned material after just a handful of sessions, which will leave more time for studying new material. Of course, students may need help setting up their study schedules (especially when they are younger), and they may need some encouragement to use the strategy. But by using distributed practice (especially if it is combined with practice testing), many students will begin to master material they never thought they could learn.

Teachers can also use distributed practice in the classroom. The idea is to return to the most important material and concepts repeatedly across class days. For instance, if weekly quizzes are already being administered, a teacher could easily include content that repeats across quizzes so students will relearn some concepts in a distributed manner. Repeating key points across lectures not only highlights the importance of the content but also gives students distributed practice. Administering a cumulative exam that forces students to review the most important information is another way to encourage them to study content in a distributed fashion. Admittedly, using cumulative exams may seem punitive, but if the teacher highlights which content is most likely to be retested (because it is the most important content for students to retain), then preparing for a cumulative exam does not need to be daunting. In fact, if students continue to use a distributed practice schedule throughout a class, they may find preparing for a final cumulative exam to be less difficult than it would be otherwise because they will already be well versed in the material.

Strategies with Much Promise

We rated three additional strategies as promising but stopped short of calling them the most effective because we wanted to see additional research about how broadly they improve student learning.

Interleaved Practice

Interleaved practice involves not only distributing practice across a study session but also mixing up the order of materials across different topics. As I discussed above, distributed practice trumps massed practice, but the former typically refers to distributing the practice of the *same* problem across time. Thus, for spelling, a student would benefit from writing each word on a worksheet once, and then cycling through the words until each has been spelled correctly several times. Interleaved practice is similar to distributed practice in that it involves spacing one's practice across time, but it specifically refers to practicing *different types* of problems across time.

Consider how a standard math textbook (or most any science textbook) encourages massed practice: In a text for pre-algebra, students may learn about adding and subtracting real numbers, and then spend a block of practice adding real numbers, followed by a block of practice subtracting. The next chapter would introduce multiplying and dividing real numbers, and then practice would focus first on multiplying real numbers, and then on dividing them, and so forth. Thus, students are massing their practice of similar problems. They practice several instances of one type of math problem (e.g., addition) before practicing the next type (e.g., subtraction). In this example, interleaving would involve solving one problem from each type (adding, subtracting, multiplying, and dividing) before solving a new problem from each type.

One aspect of massed practice that students may find appealing is that their performance will quickly improve as they work with a particular problem. Unfortunately, such fluent performance can be misleading; students believe that they have learned a problem well when in fact their learning is fleeting.

Interleaved practice has not been explored nearly as much as practice tests or distributed practice, but initial research outcomes have shown that interleaved practice can dramatically improve student achievement, especially in the domain of problem solving.

A study in which college students learned to compute the volume of four different geometric solids illustrates this advantage.[13] In two practice sessions (separated by a week), a student either had massed practice or interleaved practice. For massed practice, students had a brief tutorial on solving for the volume of one kind of solid (e.g., a wedge), and then immediately practiced solving for the volume of four different versions of the particular solid (e.g., finding the volume of four different wedges). They then received a tutorial on finding the volume of another kind of solid (e.g., a spherical cone), and immediately practiced solving four versions of that solid (e.g., finding the volume of four different spherical cones). They repeated this massed practice for two more kinds of solids.

For interleaved practice, students first were given a tutorial on how to solve for the volume of each of the four solids, and then they practiced solving for each of the four versions of solids in turn. They never practiced the same kind of solid twice in a row; they practiced solving for the volume of a wedge, followed by a spherical cone, followed by a spheroid, and so forth, until they had practiced four problems of each type. Regardless of whether practice was massed or interleaved, all students practiced solving four problems of each type.

How did the students fare? The results presented in Figure 1 (on the right) show that during the practice sessions, performance finding the correct volumes was considerably higher for massed practice than for interleaved practice, which is why some students (and teachers) may prefer massed practice. The reason not to stick with massed practice is revealed when we examine performance on the exam, which occurred one week after the final practice session. As shown in the bars on the far right of Figure 1, students who massed practice performed horribly. By contrast, those who interleaved did three times better on the exam, and their performance did not decline compared with the original practice session! If students who interleaved had practiced just a couple more times, no doubt they would have performed even better, but the message is clear: massed practice leads to quick learning and quick forgetting, whereas interleaved practice slows learning but leads to much greater retention.

Research shows that teachers can also use this promising strategy with their students. Across 25 sessions,[14] college students with poor math skills were taught algebra rules, such as how to multiply variables with exponents, how to divide variables with exponents, and how to raise variables with exponents to a power. In different sessions, either a single rule was introduced or a rule that had already been introduced was reviewed. Most important, during review sessions, students either (a) practiced the rule from the previous session (which was analogous to massed practice), or (b) practiced the rule from the previous session intermixed with the practice of rules from even earlier sessions (which was analogous to interleaved practice).

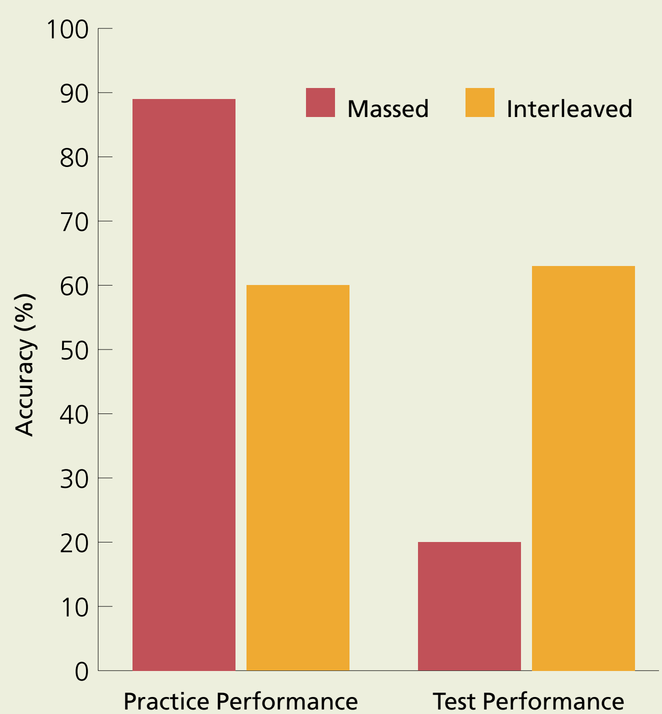
During the first practice sessions, the two groups achieved at about the same level. By contrast, on the final test, performance was substantially better for students who had interleaved practice than for those who had massed practice. This interleaving advantage was evident both for application of the rules to new algebra problems (i.e., different versions of those that the students had practiced) and on problems that required the novel combination of rules. Given that the review sessions were basically practice tests, one recommendation is sound: when creating practice tests for students (whether to be completed in class or at home), it is best to mix up problems of different kinds. Even though students initially may struggle a bit more, they will benefit in the long run.

Why does interleaving work so well? In contrast to massed practice, interleaving problems requires distributing practice, which by itself benefits student achievement. Moreover, massed practice robs students of the opportunity to practice identifying problems, whereas interleaved practice forces students to practice doing so. When students use massed practice, after they correctly solve a problem or two of a certain type, they can almost robotically apply the same steps to the next problem. That is, they do not have to figure out what kind of problem they are solving; they just have to apply the same rules to the next prob-

For interleaved practice, when a new problem is presented, students need to first figure out which kind of problem it is and what steps they need to take to solve it.

Figure 1

Differences in Performance When Students Used Massed Practice versus Interleaved Practice

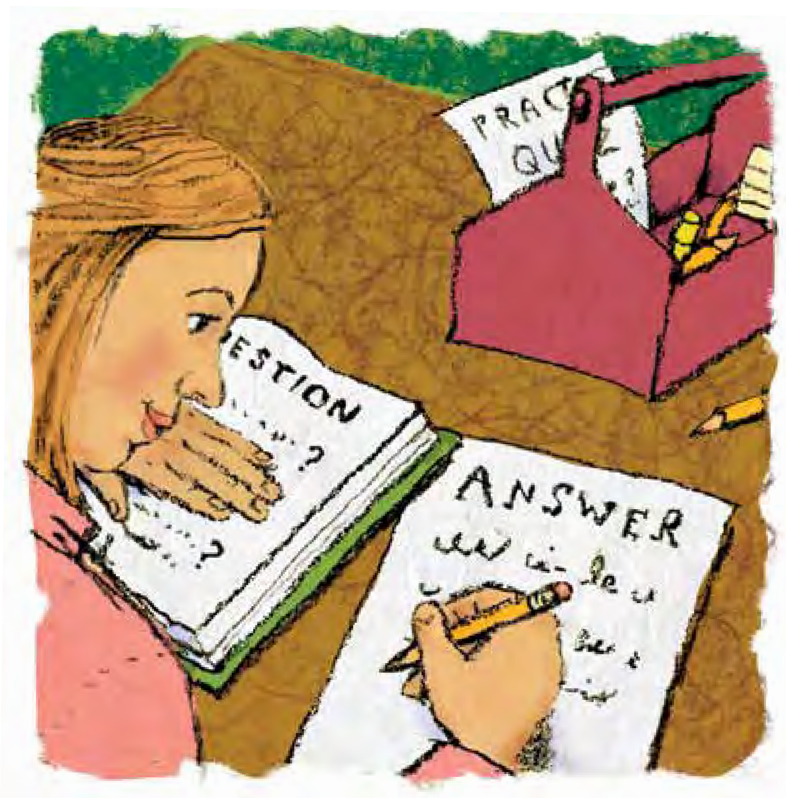


Accuracy at solving problems during practice session and on the delayed criterion test.

SOURCE: JOHN DUNLOSKY, KATHERINE A. RAWSON, ELIZABETH J. MARSH, MITCHELL J. NATHAN, AND DANIEL T. WILLINGHAM, "IMPROVING STUDENTS' LEARNING WITH EFFECTIVE LEARNING TECHNIQUES: PROMISING DIRECTIONS FROM COGNITIVE AND EDUCATIONAL PSYCHOLOGY," *PSYCHOLOGICAL SCIENCE IN THE PUBLIC INTEREST* 14, NO. 1 (2013): 40. DATA FROM DOUG ROHRER AND KELLI TAYLOR, "THE SHUFFLING OF MATHEMATICS PROBLEMS IMPROVES LEARNING," *INSTRUCTIONAL SCIENCE* 35, NO. 6 (2007): 481–498. REPRINTED BY PERMISSION OF SAGE PUBLICATIONS.

lem. For interleaving, when a new problem is presented, students need to first figure out which kind of problem it is and what steps they need to take to solve it. This is often a difficult aspect of solving problems.

Interleaving has been shown to improve performance (as compared with massed practice) in multiple domains, including fourth-graders learning to solve math problems, engineering students learning to diagnose system failures, college students learning artists' styles, and even medical students learning to interpret electrocardiograms to diagnose various diseases. Nevertheless, the benefits do not extend to all disciplines; for instance, in one study,[15] college students learned French vocabulary from different categories (body parts, dinnerware, foods, etc.), and students did just as well when their practice was massed within a category as when it was interleaved across categories. In another study, interleaving did not help high school students learn various rules for comma usage.[16]



Certainly, much more research is needed to better understand when interleaving will be most effective. Nevertheless, interleaved practice has shown more than enough promise for boosting student achievement to encourage its use, especially given that it does not hurt learning. To that end, I suggest that teachers revise worksheets that involve practice problems, by rearranging the order of problems to encourage interleaved practice. Also, for any in-class reviews, teachers should do their best to interleave questions and problems from newly taught materials with those from prior classes. Doing so not only will allow students to practice solving individual problems, but it also will help them practice the difficult tasks of identifying problems and choosing the correct steps needed to solve them.

Elaborative Interrogation and Self-Explanation

Elaborative interrogation and self-explanation are two additional learning strategies that show a lot of promise. Imagine a student reading an introductory passage on photosynthesis: "It is a process in which a plant converts carbon dioxide and water into sugar, which is its food. The process gives off oxygen." If the student were using elaborative interrogation while reading, she would try to explain why this fact is true. In this case, she might think that it must be true because everything that lives needs some kind of food, and sugar is something that she eats as food. She may not come up with exactly the right explanation, but trying to elaborate on why a fact may be true, even when the explanations are not entirely on the mark, can still benefit understanding and retention.

Students who solve new problems that involve transferring what was learned during practice perform better when they use self-explanation techniques.

If the student were using self-explanation, then she would try to explain how this new information is related to information that she already knows. In this case, perhaps she might consider how the conversion is like how her own body changes food into energy and other (not-so-pleasant-as-oxygen) fumes. Students can also self-explain when they solve problems of any sort and decide how to proceed; they merely explain to themselves why they made a particular decision.

While practicing problems, the success rate of solving them is no different for students who self-explain their decisions compared with those who do not. However, in solving new problems that involve transferring what one has learned during practice, those who initially used self-explanation perform better than those who did not use this technique. In fact, in one experiment where students learned to solve logical-reasoning problems, final test performance was three times better (about 90 percent versus less than 30 percent) for students who self-explained during practice than for those who did not.[17]

One reason these two strategies can promote learning and comprehension and boost problem-solving performance is that they encourage students to actively process the content they are focusing on and integrate it with their prior knowledge. Even young students should have little trouble using elaborative interrogation, because it simply involves encouraging them to ask the question "why?" when they are studying. The difference between this type of "why" and the "why" asked in early childhood (when this is a common question to parents) is that students must take the time to develop answers. This strategy may be especially useful as students are reading lengthy texts in which a set of concepts builds across a chapter, although admittedly the bulk of the research on elaborative interrogation has been conducted with isolated facts. At a minimum, the research has shown that encouraging students to ask "why" questions about facts or simple concepts that arise in class and in lengthy discussions benefits their learning and understanding.

In most of the research on self-explanation, students are given little instruction on how to use the strategy; instead, they are just told to use a particular question prompt that is most relevant to what they are studying. For instance, if they are solving a problem, they might be instructed to ask themselves, "Why did I just decide to do X?" (where X is any move relevant to solving the problem at hand). And if they were reading a text, they might be instructed to ask, "What does this sentence mean to me? What new information does the sentence provide, and how does it relate to what I already know?" To take full advantage of this strategy, students need to try to self-explain and not merely paraphrase (or summarize) what they are doing or reading, because the latter strategies (as I discuss below) do not consistently boost performance.

Rereading has inconsistent effects on student learning, and benefits may not be long-lasting.

Some potential limitations of using these strategies are rather intuitive. For instance, students with no relevant knowledge about a new content area may find it difficult—if not impossible—to use elaborative interrogation, because these students may not be able to generate any explanation about why a particular (new) fact is true.* Thus, although research shows that students as young as those in the upper elementary grades can successfully use elaborative interrogation, the technique may not be so useful for younger students with low levels of background knowledge. As students learn more about a particular topic, elaborative interrogation should be easier to use and will support more learning.

As for self-explanation, it should not be too difficult, or require much time, to teach most students how to take advantage of this strategy. Nevertheless, younger students or those who need more support may benefit from some coaching. For instance, as noted above, paraphrases and self-explanations are not the same and lead to different learning outcomes, so teachers should help younger students distinguish between an explanation of an idea and its paraphrase. Even so, a gentle reminder to use elaborative interrogation or self-explanation may be all most students need to keep them using these strategies as they learn new course content and prepare for examinations.

Because they show promise, I recommend that teachers tell their students about these strategies and explain the conditions under which each may be most useful. For instance, they might instruct students to use elaborative interrogation when studying general facts about a topic, or to use self-explanation when reading or solving practice problems in math and science.

Teachers should keep in mind that these two strategies did not receive the highest rating in our team's assessment of learning strategies.[18] Our lower marks for these strategies, however, stemmed from the fact that we wanted to see even more evidence that established their promise in several key areas relevant to

education. Only a couple of experiments have demonstrated that elaborative interrogation can improve students' comprehension, and only a few investigations have established their efficacy within a classroom. So, in writing our review, we were conservative scientists who wanted every piece in place before declaring that a strategy is one that students should absolutely use. Nevertheless, other cognitive scientists who have studied the same evidence enthusiastically promote the use of these strategies,[19] and as a teacher myself, the overall promise of these strategies is impressive enough that I encourage my students to use them.

Less Useful Strategies (That Students Use a Lot)

Besides the promising strategies discussed above, we also reviewed several others that have not fared so well when considered with an eye toward effectiveness. These include rereading, highlighting, summarizing, and using imagery during study.

Rereading and Highlighting

These two strategies are particularly popular with students. A survey conducted at an elite university revealed that 84 percent of the students studied by rereading their notes or textbooks.[20] Despite its popularity, rereading has inconsistent effects on student learning: whereas students typically benefit from rereading

*For more on why reading comprehension depends largely on knowledge, see "Building Knowledge" and "How Knowledge Helps" in the Spring 2006 issue of *American Educator*, available at www.aft.org/newspubs/periodicals/ae/spring2006/index.cfm.

when they must later recall texts from memory, rereading does not always enhance students' understanding of what they read, and any benefits of rereading (over just a single reading) may not be long-lasting. So, rereading may be relatively easy for students to do, but they should be encouraged to use other strategies (such as practice testing, distributed practice, or self-explanation) when they revisit their text and notes.

Students need to know that highlighting is only the beginning of the journey.

The use of highlighters seems universal—I even have a favorite one that I use when reading articles. As compared with simply reading a text, however, highlighting has been shown to have failed to help students of all sorts, including Air Force trainees, children, and undergraduate students. Even worse, one study reported that students who highlighted while reading performed worse on tests of comprehension wherein they needed to make inferences that required connecting different ideas across the text.[21] In this case, by focusing on individual concepts while highlighting, students may have spent less time thinking about connections across concepts. Still, I would not take away highlighters from students; they are a security blanket for reading and studying. However, students need to know that highlighting is only the beginning of the journey, and that after they read and highlight, they should then restudy the material using more-effective strategies.

Summarization

Summarization involves paraphrasing the most important ideas within a text. It has shown some success at helping undergraduate students learn, although younger students who have difficulties writing high-quality summaries may need extensive help to benefit from this strategy.

In one study,[22] teachers received 90 minutes of training on how to teach their students to summarize. The teachers were trained to provide direct instruction, which included explicitly describing the summarization strategy to students, modeling the strategy for students, having students practice summarizing and providing feedback, and encouraging students to monitor and check their work. Students completed five sessions (about 50 minutes each) of coaching, which began with them learning to summarize short paragraphs and slowly progressed to them using the strategy to take effective notes and ultimately to summarize a text chapter. Students who received coaching recalled more important points from a chapter as compared with students who were not coached. And other studies have also shown that training students to summarize can benefit student performance.

Nevertheless, the need for extensive training will make the use of this strategy less feasible in many contexts, and although summarizing can be an important skill in its own right, relying on it as a strategy to improve learning and comprehension may not be as effective as using other less-demanding strategies.

Keyword Mnemonic and Imagery for Text

Finally, the last two techniques involve mental imagery (i.e., developing internal images that elaborate on what one is studying). Students who are studying foreign-language vocabulary, for example, may use images to link words within a pair (e.g., for the pair "la dent–tooth," students may mentally picture a dentist (for "la dent") extracting an extra-large tooth). This strategy is called keyword mnemonic, because it involves developing a keyword to represent the foreign term (in this case, "dentist" for "la dent") that is then linked to the translation using mental imagery.

Imagery can also be used with more complex text materials as well. For instance, students can develop mental images of the content as they read, such as trying to imagine the sequence of processes in photosynthesis or the moving parts of an engine. This strategy is called imagery for text.

Mental imagery does increase retention of the material being studied, especially when students are tested soon after studying. However, research has shown that the benefits of imagery can be short-lived,[23] and the strategy itself is not widely appli-

Table 1 Effectiveness of Techniques Reviewed

Technique	Extent and Conditions of Effectiveness
Practice testing	Very effective under a wide array of situations
Distributed practice	Very effective under a wide array of situations
Interleaved practice	Promising for math and concept learning, but needs more research
Elaborative interrogation	Promising, but needs more research
Self-explanation	Promising, but needs more research
Rereading	Distributed rereading can be helpful, but time could be better spent using another strategy
Highlighting and underlining	Not particularly helpful, but can be used as a first step toward further study
Summarization	Helpful only with training on how to summarize
Keyword mnemonic	Somewhat helpful for learning languages, but benefits are short-lived
Imagery for text	Benefits limited to imagery-friendly text, and needs more research

cable. Concerning the latter, younger students may have difficulties generating images for complex materials, and for that matter, much content in school is not imagery friendly, such as when the ideas are abstract or the content is complex enough that it cannot be easily imagined. Certainly, for students who enjoy using imagery and for materials that afford its use, it likely will not hurt (and may even improve) learning. But as compared with some of the better strategies, the benefits of imagery are relatively limited.

> Even the best strategies will only be effective if students are motivated to use them correctly.

Using learning strategies can increase student understanding and achievement. For some ideas on how the best strategies can be used, see the box "Tips for Using Effective Learning Strategies" (on the right). Of course, all strategies are not created equal. As shown in Table 1 (on page 20), while some strategies are broadly applicable and effective, such as practice testing and distributed practice, others do not provide much—if any—bang for the buck. Importantly, even the best strategies will only be effective if students are motivated to use them correctly, and even then, the strategies will not solve many of the problems that hamper student progress and success. With these caveats in mind, the age-old adage about teaching people to fish (versus just giving them a fish) applies here: teaching students content may help them succeed in any given class, but teaching them how to guide their learning of content using effective strategies will allow them to successfully learn throughout their lifetime. ☐

Tips for Using Effective Learning Strategies

Based on our review of the literature, here are a handful of suggestions for teachers to help students take advantage of more-effective strategies:

- Give a low-stakes quiz at the beginning of each class and focus on the most important material. Consider calling it a "review" to make it less intimidating.
- Give a cumulative examination, which should encourage students to restudy the most important material in a distributed fashion.
- Encourage students to develop a "study planner," so they can distribute their study throughout a class and rely less on cramming.
- Encourage students to use practice retrieval when studying instead of passively rereading their books and notes.
- Encourage students to elaborate on what they are reading, such as by asking "why" questions.
- Mix it up in math class: when assigning practice problems, be sure to mix problems from earlier units with new ones, so that students can practice identifying problems and their solutions.
- Tell students that highlighting is fine but only the beginning of the learning journey.

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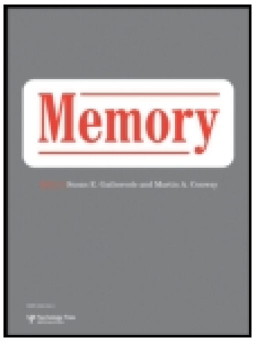

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Metacognitive strategies in student learning: Do students practise retrieval when they study on their own?

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Metacognitive strategies in student learning: Do students practise retrieval when they study on their own?

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Basic research on human learning and memory has shown that practising retrieval of information (by testing the information) has powerful effects on learning and long-term retention. Repeated testing enhances learning more than repeated reading, which often confers limited benefit beyond that gained from the initial reading of the material. Laboratory research also suggests that students lack metacognitive awareness of the mnemonic benefits of testing. The implication is that in real-world educational settings students may not engage in retrieval practise to enhance learning. To investigate students' real-world study behaviours, we surveyed 177 college students and asked them (1) to list strategies they used when studying (an open-ended, free report question) and (2) to choose whether they would reread or practise recall after studying a textbook chapter (a forced report question). The results of both questions point to the same conclusion: A majority of students repeatedly read their notes or textbook (despite the limited benefits of this strategy), but relatively few engage in self-testing or retrieval practise while studying. We propose that many students experience *illusions of competence* while studying and that these illusions have significant consequences for the strategies students select when they monitor and regulate their own learning.

Keywords: Testing effect; Retrieval; Metacognition; Strategies.

A powerful way to enhance student learning is by testing information. When students have been tested on material they remember more in the long term than if they had repeatedly studied it. This phenomenon is known as the *testing effect* and shows that the act of retrieving information from memory has a potent effect on learning, enhancing long-term retention of the tested information (for review, see Roediger & Karpicke, 2006a). The testing effect is especially striking in light of current findings showing limited benefits of repeated reading for student learning (see Callender & McDaniel, 2009; McDaniel & Callender, 2008). Our recent research has generalised the testing effect to educational materials (Butler & Roediger, 2007; Karpicke & Roediger, 2007, 2008; Roediger & Karpicke, 2006b) and real-world classroom environments (see McDaniel, Roediger, & McDermott, 2007). Testing enhances learning not only if instructors give tests and quizzes in the classroom but also if students practise recall while they study

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on their own. If students were to practise retrieval of information while studying this strategy would have the potential to greatly improve academic performance. However, we do not know the extent to which students practise recall while they study in real-world educational settings (relative to other less-effective strategies like repeated reading) or whether students who practise recall do so because they are aware of the mnemonic benefits. These are important and practically relevant research questions but few studies have been aimed at answering them (see, e.g., Kornell & Bjork, 2007).

The objective of this research was to determine the extent to which students practise recall relative to other study strategies in real-world educational settings. In addition we wanted to examine whether students who choose to engage in retrieval practice do so because they know that testing promotes long-term retention. Another reason students may use testing during studying is to determine what information is known and what is not known so that future study time can be allocated to the unknown material (see Dunlosky, Hertzog, Kennedy, & Thiede, 2005; Dunlosky, Rawson, & McDonald, 2002). This is a fine justification for testing but it differs from using testing as a learning device in its own right. To accomplish these goals we created a new study strategies questionnaire and surveyed a large sample of undergraduate students. Although there are a variety of study strategy inventories in the education literature (see Entwistle & McCune, 2004; Pintrich, Smith, Garcia, & McKeachie, 1993; Weinstein, Schulte, & Palmer, 1987) these and other inventories do not specifically assess whether students practise retrieval while studying. Our survey included a free report question asking students to list the strategies they use while studying and a forced report question that asked them to choose between repeated reading or repeated testing. The purpose of including both forced and free report question formats was to gain converging evidence aimed at the target issue and to circumvent possible response biases created by using either format alone (see Schuman & Presser, 1996; Schwarz, 1999). We predicted that relatively few students would report self-testing as a study strategy and that the majority of students would report choosing to reread or engage in some other non-testing activity when forced to choose a study strategy. We also predicted that most students who selected self-testing would be unaware of the mnemonic benefits of testing.

In the first section of this paper we provide a brief overview of relevant research on repeated reading, repeated testing, and students' metacognitive awareness of the testing effect. Next we present the results of our survey of study strategies. In the final section we interpret the survey results in light of current theories of metacognition and self-regulated learning and then discuss the practical and educational implications of our findings.

MOTIVATION FOR THE SURVEY: PRIOR RESEARCH ON REPEATED READING VS REPEATED TESTING

The testing effect refers to the finding that taking a test enhances long-term retention more than spending an equivalent amount of time repeatedly studying. There are clear and direct implications of the testing effect for student learning. One way for students to enhance their learning would be to practise recalling information while studying. However, research on the testing effect has also shown that when students are asked to assess their own learning they sometimes fail to predict that testing enhances learning more than repeated reading (e.g., Karpicke & Roediger, 2008). In short, there is a rapidly growing body of research (briefly reviewed below) indicating that testing has powerful effects on learning but students lack metacognitive awareness of the testing effect.

Students often report that they repeatedly read their notes or textbook while studying (Carrier, 2003; Pressley, Van Etten, Yokoi, Freebern, & Van Meter, 1998; Van Etten, Freebern, & Pressley, 1997). Yet there are several reasons to question the effectiveness of repetitive reading beyond reading a single time. Basic research on memory has shown that spending extra time maintaining or holding items in memory does not by itself promote learning (Craik & Watkins, 1973) and students may spend large amounts of additional time studying despite no gain in later memory for the items, a phenomenon called "labour-in-vain" during learning (Nelson & Leonesio, 1988). Recent research with educationally relevant materials has shown that repeatedly reading prose passages produces limited benefits beyond a single reading (Amlund, Kardash, & Kulhavy, 1986; Callender & McDaniel, 2009).

This is especially true when repeated readings are massed together in a single learning session, although spaced rereading tends to produce positive effects (Rawson & Kintsch, 2005). In short, memory research has shown many times that repetitive reading by itself is not an effective strategy for promoting learning and long-term retention (for review, see McDaniel & Callender, 2008).

In contrast, several studies have shown that repeated testing is a potent method for producing robust learning. In one of our studies (Karpicke & Roediger, 2008) we had students learn a set of Swahili vocabulary words across alternating study and test periods. In study periods students studied a Swahili word and its English translation (*mashua – boat*) and in test periods they saw the Swahili words as cues to recall the English words (*mashua* –?). The students learned the words in one of four conditions and students in all conditions took a final test 1 week after initial learning. In two learning conditions, once a word was correctly recalled it was dropped from further test periods. The students who recalled each word only once in these two conditions recalled just 35% of the items on the final test a week later. In the other two conditions students continued to repeatedly recall words even after they had recalled them once. Students who repeatedly recalled the words during learning recalled about 80% of the items on the final test. Repeated retrieval practice—even after students were able to successfully recall items in the learning phase—produced large positive effects on long-term retention.

Were students aware of the effect of repeated testing on long-term retention? At the end of the initial learning phase we asked students to predict how many pairs they would recall on the final test a week later. There was no difference in average predictions across the four conditions: All groups predicted they would recall about 50% of the items. Despite the large effect of repeated retrieval on retention, students were not aware of the mnemonic benefit of testing. Similar findings have occurred in other experiments examining the testing effect and students' judgements of learning (e.g., Agarwal, Karpicke, Kang, Roediger, & McDermott, 2008; Karpicke, McCabe, & Roediger, 2006; Roediger & Karpicke, 2006b).

In sum, basic laboratory research on human learning and memory has shown that (1) repeated reading by itself is a questionable and often ineffective study strategy, (2) repeated retrieval practice produces robust learning and long-term retention, but (3) students appear to lack metacognitive awareness of the testing effect. The implication of this basic research is that students may not practise retrieval when they study in real-world educational settings. Instead they may spend their time repeatedly reading material when they study. The objective of our survey was to examine the prevalence of retrieval practice, relative to other study strategies, in students' real-world study behaviours and students' metacognitive awareness of the benefits of self-testing.

A SURVEY OF STUDENTS' LEARNING STRATEGIES

One reaction we have encountered when we present our research on the testing effect goes something like this: "This is completely obvious. Of course testing enhances learning. We already knew this. None of this is new or surprising." Perhaps the testing effect is obvious to some instructors—but is it obvious to students? If so we would expect students to report that they frequently practise recall while studying. But our basic laboratory research has consistently shown that students lack metacognitive awareness of the testing effect. In fact students sometimes predict that repeated reading will produce better long-term retention than repeated testing (Roediger & Karpicke, 2006b). The intent of our survey was to determine whether students' self-reported study behaviours would converge with our laboratory findings.

Method

We surveyed 177 undergraduate students at Washington University in St. Louis about the strategies they use to study for exams. The students were participants in various learning and memory experiments in our laboratory and they completed the survey at the very end of their experimental session. Washington University students are a select group with average SAT scores greater than 1400 (Verbal + Quantitative). Our survey included two questions aimed at identifying how often the students practised recalling information while studying. Question 1 was an open-ended free report question in which students listed the strategies they used when studying and then rank ordered the strategies in terms of how frequently they used them. All 177 students answered Question 1. Question 2 was a forced report question that asked students to imagine they were studying a textbook chapter for an exam and to choose one of three alternatives: (1) repeated reading of the chapter, (2) practising recall of material from the chapter (with or without the opportunity to reread the chapter, in different versions of this question), or (3) engaging in some other study activity. A total of 101 students answered Version 1 of Question 2 (testing without restudy) and the other 76 students answered Version 2 (testing with restudy). Students completed the entire questionnaire in about 5 to 10 minutes. Our goals were to identify students' typical study strategies and to assess how frequently they repeatedly read material or engaged in retrieval practice, and our analysis focused on the frequency with which students reported these particular strategies.

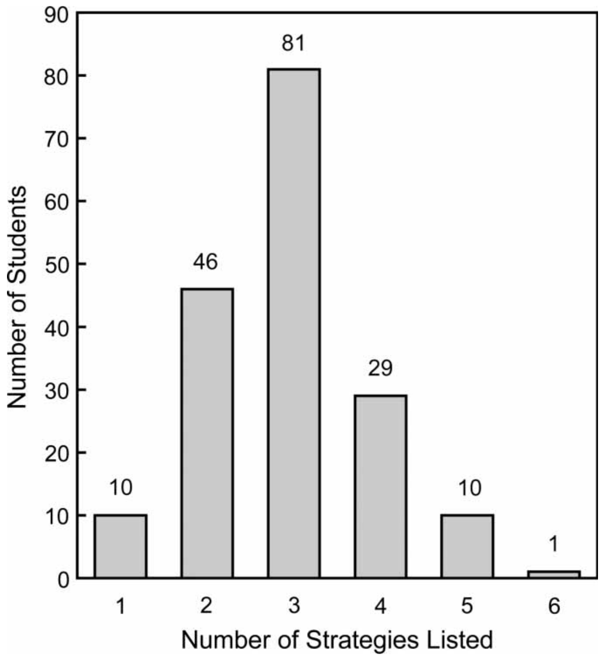

Figure 1. Frequency distribution showing the number of strategies listed by students.

Results

Question 1: Students' free report of study strategies. The first question on the survey asked: "What kind of strategies do you use when you are studying? List as many strategies as you use and rank-order them from strategies you use most often to strategies you use least often." We initially reviewed all responses from all students. Based on our initial assessment we identified 11 strategies that occurred relatively frequently (more than once across all student responses). Two independent raters then categorised all responses. There was close to 100% agreement between the two raters and the first author resolved any scoring discrepancies.

Figure 1 shows the frequency distribution of the number of strategies listed by students in response to Question 1. The figure shows that most students listed and described three strategies ($M = 2.9$). Table 1 shows the 11 strategies and the percent of students who listed each strategy. The table also shows the percent of students who ranked each strategy as their number one strategy and the mean rank of each strategy. Repeated reading was by far the most frequently listed strategy with 84% of students reporting it. Not only did students indicate that they repeatedly read while studying but they also indicated that rereading was a favoured strategy—55% of students reported that rereading was the number one strategy they used when studying. Table 1 also shows another key finding: Only 11% of students (19 of 177) reported that they practised retrieval while studying. These students unambiguously indicated in their list of strategies that they practised testing themselves by recalling information while they studied. Only 1% (2 of 177 students) identified practising recall as their number one strategy. The results in Table 1 clearly show that a large majority of students repeatedly read their textbook or notes but relatively few students engage in self-testing by practicing recall while studying.

Table 1 also shows that students reported other strategies that could be interpreted as forms of self-testing. For example, 43% of students indicated that they answer practice problems while studying and 40% reported using flashcards. Each activity could be interpreted as a type of self-testing, but of course there are ways students might use these study methods without engaging in retrieval practice. For example, students may read practice questions and then look up and copy answers from the text. This would qualify as answering practice problems but students who do this would not be practising or even attempting recall of the answers. Likewise, students may write facts on flashcards and repeatedly read them rather than practising recall. A clear limitation of the free response question is that our procedure did not prompt each student to

TABLE 1
Results of Question 1

Strategy	*Percent who list strategy*		*Percent who rank as #1 strategy*		*Mean rank*
1. Rereading notes or textbook	83.6	(148)	54.8	(97)	1.5
2. Do practice problems	42.9	(76)	12.4	(22)	2.1
3. Flashcards	40.1	(71)	6.2	(11)	2.6
4. Rewrite notes	29.9	(53)	12.4	(22)	1.8
5. Study with a group of students	26.5	(47)	0.5	(1)	2.9
6. "Memorise"	18.6	(33)	5.6	(10)	2.0
7. Mnemonics (acronyms, rhymes, etc)	13.5	(24)	2.8	(5)	2.4
8. Make outlines or review sheets	12.9	(23)	3.9	(7)	2.1
9. Practise recall (self-testing)	10.7	(19)	1.1	(2)	2.5
10. Highlight (in notes or book)	6.2	(11)	1.6	(3)	2.3
11. Think of real life examples	4.5	(8)	0.5	(1)	2.8

Percent of students listing different learning strategies, percent who ranked strategies as their #1 strategy, and mean rankings of strategies. Raw numbers of students are in parentheses.

Mean number of strategies listed was 2.9 ($SD = 0.96$). Percentages of students indicating their #1 strategy do not add to 100% because some students merged multiple strategies when reporting their #1 strategy (e.g., indicating that rereading and rewriting notes were their #1 strategy).

elaborate on potentially ambiguous answers (cf. the ethnographic interviewing technique of Pressley and colleagues; Pressley et al., 1998; Van Etten et al., 1997). Nevertheless, even if we considered the 40% of students who use flashcards or the 43% who answer practice problems as students engaging in forms of self-testing, these percentages are dwarfed by the 84% of students who repeatedly read while studying.

The results of Question 1 indicate that repeated reading is the most popular study strategy among college students (see too Carrier, 2003), far more popular than practising retrieval, even though retrieval practice is a more effective study strategy. Students listed a variety of study strategies but indicated that they use these alternative study strategies far less frequently than repeated reading. Question 2 asked students to choose repeated reading or self-testing and prompted them to explain the reasoning behind their choice. By including a second question in forced report format we hoped to find converging evidence and to resolve ambiguities inherent in our first open-ended free report question.

Question 2: Forced report questions about repeated studying vs testing. Question 2 was a forced report question about repeated studying versus repeated testing. There were two versions of the question. Version 1 asked students to consider testing without going back and restudying, and Version 2 involved testing followed by restudying (to get feedback after attempting recall). The first version was given to 101 students and the second version was given to 76 students. Version 1 of Question 2 was as follows:

> Imagine you are reading a textbook chapter for an upcoming exam. After you have read the chapter one time, would you rather:
> A. Go back and restudy either the entire chapter or certain parts of the chapter.
> B. Try to recall material from the chapter (without the possibility of restudying the material).
> C. Use some other study technique.

The students were asked to select one alternative and write a brief explanation for their choice. The scenario described in the question was based directly on our research showing that taking a recall test, even without feedback, enhances long-term retention more than spending the same amount of time restudying (Roediger & Karpicke, 2006b).

Table 2 shows the percentage of students who chose to restudy, self-test, or do something else after reading a textbook chapter. Most students unambiguously selected an alternative and explained their choice, but four students gave ambiguous responses that could not be scored. The table shows that 57% of students chose to restudy (option A) and 21% indicated that they would use some other study technique (option C). Thus 78% of students indicated they would *not* want to test themselves after reading a textbook chapter. Only 18% of the students indicated that they would self-test after studying (option B). To examine students' metacognitive awareness of the

TABLE 2
Version 1 of Question 2

Imagine you are reading a textbook chapter for an upcoming exam. After you have read the chapter one time, would you rather:	*Overall*		*Test for feedback*		*Test to practise recall*	
A. Go back and restudy either the entire chapter or certain parts of the chapter	57.4	(58)				
B. Try to recall material from the chapter (without the possibility of restudying the material)	17.8	(18)	9.9	(10)	7.9	(8)
C. Use some other study technique	20.7	(21)				

Percent of students who chose to restudy, self-test (without restudying), or do something else after reading a textbook chapter. Raw numbers of students are in parentheses ($N = 101$).

We were unable to score ambiguous responses given by four students.

mnemonic benefits of testing we separated students' responses based on their explanation for why they chose self-testing. This analysis showed that 10% of all students (or more than half of those who chose self-testing) reported they would self-test to generate feedback and guide their future studying (even though Version 1 of this question stated that students could not restudy after testing). Only 8% of all students indicated that they would test themselves because practising retrieval would help them do well on the upcoming exam. This pattern of responding suggests that most students were unaware of the mnemonic benefits of self-testing. The results of Version 1 of this forced report question provide converging evidence with our first free report question. Relatively few students reported that they would test themselves after studying a textbook chapter and even fewer indicated they would test themselves because they knew the act of practising recall was valuable for learning.

In Version 2 of Question 2 the scenario and alternatives were identical to Version 1 except that option B read "Try to recall material from the chapter (with the possibility of restudying afterward)." We imagined this would increase the number of students choosing testing perhaps to levels near ceiling if students recognised that testing followed by rereading would produce far superior learning to rereading without testing. Table 3 shows the percent of students who chose each option. The percentage of students choosing self-testing increased when students could reread after the test (42% in Question 2 vs 18% in Question 1) and the percentage was about equal to the percentage of students choosing repeated reading (42% vs 41%). Students' explanations of their choices indicated that the increased likelihood of choosing testing was due to the possibility of restudying after the test. Of the 32 students who chose self-testing, 25 provided unambiguous explanations that we categorised as testing for feedback or testing to practise recall. A total of 23 students (30%) indicated that they would test themselves to generate feedback they could use when restudying whereas only two students (3%) chose testing because they believed the act of practising recall would help them remember in the future. The results of Version 2 of Question 2 expand on the results of Version 1 by showing that students were more likely to select self-testing when they could restudy after testing but that very few students are aware that the act of practising recall itself enhances learning. What is perhaps most striking about the data in Table 3 is that even when students had the option of rereading after self-testing, the majority of students (58%) continued to indicate that they would *not* test themselves.

DISCUSSION

The objective of this research was to collect benchmark data on college students' real-world study behaviours to assess how often students use retrieval practice relative to other strategies and whether they know about the mnemonic benefits of self-testing. Our basic laboratory studies suggested that students are not aware of the testing effect, leading us to predict that they may not practise retrieval while studying in real-world settings. The results of our survey support this prediction. The majority of students indicated that they repeatedly read their notes or textbook while studying. Relatively few reported that they

TABLE 3
Version 2 of Question 2

Imagine you are reading a textbook chapter for an upcoming exam. After you have read the chapter one time, would you rather:	*Overall*		*Test for feedback*		*Test to practise recall*	
A. Go back and restudy either the entire chapter or certain parts of the chapter	40.8	(31)				
B. Try to recall material from the chapter (with the possibility of restudying afterward)	42.1	(32)	30.3	(23)	2.6	(2)
C. Use some other study technique	17.1	(13)				

Percent of students who chose to restudy, self-test followed by restudying, or do something else after reading a textbook chapter. Raw numbers of students are in parentheses ($N = 76$).

tested themselves and of those who engaged in self-testing only a handful reported doing so because they believed the act of practising retrieval would improve their learning. Our survey results point to the conclusion that many students do not view retrieval practice as a strategy that promotes learning. If students do practise recall or test themselves while studying they do it to generate feedback or knowledge about the status of their own learning, not because they believe practising recall itself enhances learning.

Our results agree with laboratory experiments showing that students lack metacognitive awareness of the testing effect when they monitor their own learning. A growing body of research has shown that students sometimes predict that practising retrieval will produce no effect on retention (Karpicke & Roediger, 2008) or that they will remember more in the long term if they repeatedly study material rather than test it (Agarwal et al., 2008; Karpicke et al., 2006; Roediger & Karpicke, 2006b). If we assume that metacognitive monitoring processes guide students' decisions to choose different learning strategies—an assumption at the core of the influential monitoring-and-control framework of metacognition (Nelson & Narens, 1990)—then the implication of these laboratory results is that students may not choose to test themselves when they regulate their own learning in real-world educational settings. Our survey data confirm that this lack of awareness of the testing effect has consequences for students' real-world study behaviours.

In addition to agreeing with basic laboratory findings our survey results also agree to some extent with a recent survey by Kornell and Bjork (2007). They surveyed college students about their study behaviours and asked the students, "If you quiz yourself while you study ... why do you do so?" The students selected one of four alternatives: 18% selected "I learn more that way than I would through rereading"; 68% selected "To figure out how well I have learned the information I'm studying"; 4% indicated "I find quizzing more enjoyable than rereading"; and 9% said "I usually do not quiz myself." Kornell and Bjork's data indicate that the majority of students (91%) do quiz themselves while studying but few do so because they view the act of quizzing itself as a method of enhancing learning (Kornell and Bjork reasoned that the 18% of students who selected "I learn more that way than I would through rereading" believed that quizzing produced a direct mnemonic benefit; cf. Roediger & Karpicke, 2006a). Likewise, our survey data indicate that few students view practising recall as an activity that enhances learning. However, far more students indicated that they tested themselves in the Kornell and Bjork survey than in our study, and this may be due to a difference in survey procedures. Whereas we used a combination of free and forced report questions to gauge how often students practise retrieval, Kornell and Bjork used one question focused on why students might quiz themselves and the framing of this question may have influenced students' responses (see Schuman & Presser, 1996; Schwarz, 1999). It is well known that a single question can be framed in different ways and alter the choices and decisions people make (Tversky & Kahneman, 1981). Nevertheless our results generally agree with those of Kornell and Bjork in showing that few students view retrieval practice as a method of enhancing learning. Further, the differences between the two sets of results highlight potentially important differences between free and forced report methods of questioning.

Our results fit with the broad theoretical notion that students experience illusions of competence when monitoring their own learning (Bjork, 1999; Jacoby, Bjork, & Kelley, 1994; Koriat & Bjork, 2005). Koriat and Bjork (2005) argued that illusions of competence tend to occur when students' judgements of learning are biased by information available during study but not available during testing (see also Jacoby et al., 1994). Several experimental findings are consistent with this view. For example, students' judgements of learning are less accurate when made in study trials than in test trials (Dunlosky & Nelson, 1992). Students are less accurate at judging the difficulty of anagrams when the solution is present than when it is not (Kelley & Jacoby, 1996). We believe repeated reading produces a similar illusion of competence. Specifically, repeatedly reading material like text passages increases the fluency or ease with which students process the text. Students may base their assessments of their learning and comprehension on fluency even though their current processing fluency with the text right in front of them, is not diagnostic of their future retention. Our survey results show that the illusions students experience during learning may have important consequences and implications for the decisions they make and the strategies they choose when studying on their own.

Students generally exhibit little awareness of the fact that practising retrieval enhances learning. A clear practical implication is that instructors should inform students about the benefits of self-testing and explain why testing enhances learning. When students rely purely on their subjective experience while they study (e.g., their fluency of processing during rereading) they may fall prey to illusions of competence and believe they know the material better than they actually do. A challenge for instructional practice is to encourage students to base their study strategies on theories about why a particular strategy—like practising repeated retrieval—promotes learning and long-term retention.

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Highlighting and Its Relation to Distributed Study and Students' Metacognitive Beliefs

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RESEARCH INTO PRACTICE

Highlighting and Its Relation to Distributed Study and Students' Metacognitive Beliefs

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Abstract Use of highlighting is a prevalent study strategy among students, but evidence regarding its benefit for learning is mixed. We examined highlighting in relation to distributed study and students' attitudes about highlighting as a study strategy. Participants read a text passage twice while highlighting or not, with their readings either distributed or massed, and followed by a week-delayed test. An overall benefit of highlighting occurred, with highlighting being especially beneficial with massed readings of the passages. Importantly, highlighting did not impair knowledge of non-highlighted information. Interestingly, those students reporting that they did not think highlighting was beneficial or were unsure about its benefits actually benefitted more from highlighting than did students who were pro-highlighting. Overall, our results indicate that under some conditions, highlighting can be a beneficial study strategy for learning and argue for students being trained in how to optimize the potential benefits of their highlighting behavior.

Keywords Highlighting · Spacing · Text marking · Metacognitive beliefs about study strategies

One needs only to browse through used textbooks in a college bookstore to see that text-marking, either by highlighting or underlining, is a ubiquitous practice among students, with many believing that marking text will help them remember the selected information better or make a later study session more effective. Whether text-marking actually does benefit later recall, however, is debatable: Several studies have shown a significant benefit for underlined or highlighted text (e.g., Fass and Schumacher 1978; Fowler and Barker 1974; Nist and Hogrebe

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1987; Nist and Simpson 1988; Johnson 1988; Rickards and August 1975), whereas others have not (e.g., Arnold 1942; Hoon 1974; Idstein and Jenkins 1972; Peterson 1992; Stordahl and Christensen 1956; Wade and Trathen 1989). Given the prevalence of highlighting as a study technique among students, however, learning more about the circumstances under which it might be (or could be made to be) a more effective strategy seems a worthwhile goal from an educational standpoint, particularly if such research might reveal guidelines that could be given to students regarding how to make highlighting more beneficial for their learning.

Potential Advantages of Highlighting

There are several reasons to expect text-marking to benefit learning. From a depth-of-processing perspective, just the act of deciding what to mark and what not to mark may lead students to process textual information at a deeper, more evaluative level than they would when simply reading it (Craik and Lockhart 1972; Nist and Hogrebe 1987). Consistent with this idea, learner-generated highlighting tends to produce better test performance than experimenter-generated highlighting (Fowler and Barker 1974; Rickards and August 1975; Rickards and Denner 1979; but see Nist and Hogrebe 1987). Additionally, when students are trained in highlighting techniques (i.e., to read a paragraph, decide what is conceptually important, and then highlight that information), they perform better than students who do not receive such training (Leutner et al. 2007), indicating that appropriate cognitive activity during highlighting can enhance its benefits.

Another potential benefit of text-marking could be a type of von Restorff effect (Wallace 1965). Specifically, highlighting may make the marked portion of text more memorable because it stands out from the surrounding non-highlighted text. Indeed, some evidence supports this type of role for highlighting: When students read pre-highlighted passages, they recall more of the highlighted information and less of the non-highlighted information compared to students who receive an unmarked copy of the same passage (Fowler and Barker 1974; Silvers and Kreiner 1997).

Highlighting might also enhance the effectiveness of re-study opportunities via encoding variability. Varying the context or particular processes involved in repeated learning opportunities has been found to facilitate performance on later tests of retention and transfer, the explanation being that learning is less likely to become contextualized under such circumstances (e.g., Smith et al. 1978). Variability is presumed to be effective because it increases the likelihood that participants will encode to-be-learned information in slightly different ways, thus increasing their ability to retrieve that information when tested in another context in the future. By selectively marking text, learners change the text as they read it; consequently, when re-reading marked text, learners may read and encode that text in a new way, thereby making it more memorable.

Potential Disadvantages of Highlighting

In contrast to these arguments, others have argued that selectively highlighting text might be ineffective or even detrimental to learning (Dunlosky et al. 2013; Idstein and Jenkins 1972; Peterson 1992; Stordahl and Christensen 1956). One argument is that students often do not know how to highlight effectively, so such activity primarily amounts to a mechanism for tracking progress and does not involve deeper processing (Stordahl and Christensen 1956; Bell and Limber 2010). Another relevant factor is whether students are accustomed to using a highlighter (Brown and Smiley 1978). Forcing readers who never use highlighters to do so may interfere with their learning and prevent them from employing the type of encoding techniques they usually find beneficial (Howe and Singer 1975).

Additionally, students' metacognitive beliefs about highlighting may limit its effectiveness as a learning tool. Students who rely on highlighters and think they are particularly effective, for example, may suffer from an illusion of knowing or competence (Bjork 1999, 2013; Koriat and Bjork 2005). Specifically, such students may process highlighted material in a less meaningful way when re-reading than if that material were not highlighted. While re-reading, such students may only quickly glance over highlighted text, incorrectly assuming that because they have already highlighted that information, it is deeply encoded in memory, a misbelief that is probably supported by the apparent processing fluency that learners would experience during such re-reading. In this way, highlighting could ironically impair memory for critical information by preventing students from restudying the information in a way that effectively promotes long-term retention (cf. Peterson 1992).

Highlighting and the Distribution of Study

In evaluating the efficacy of text-marking, it is important to consider that students often mark text for the purpose of guiding their future study. For example, in a survey of 472 undergraduates, 60 % reported using marked passages as a guide for later restudy (Kornell and Bjork 2007). Thus, it seems critical to examine how text-marking might interact with the spacing of study activities. Distributed study, or spacing, is a *desirable difficulty* in that it typically results in greater long-term retention even though it can make learning feel more difficult during encoding (Bjork 1994; Bjork and Bjork 2011). Indeed, spaced study of educationally relevant materials has been repeatedly shown to improve retention compared to massed study (e.g., Dempster 1996; Kornell 2009; Sobel et al. 2011).

Highlighting, however, might actually be more beneficial in massed conditions than in spaced conditions. Massed study is often presumed to be inferior to spaced study because it involves less encoding variability and because it limits the effectiveness of the second study opportunity (Hintzman 1974). If highlighting attenuates these disadvantages by leading learners to encode the passage differently in a second reading, such beneficial effects should be relatively greater in massed than spaced conditions. Moreover, active highlighting might possibly dispel the misleading effects of fluency that tend to discourage deep processing of information upon re-reading. If so, because the sense of fluency would be stronger the closer in time the second reading follows the first, such an effect of highlighting should be more beneficial the sooner the second reading follows the first.

Overview of the Present Study

The goals of the present research were to assess possible benefits of highlighting as well as individual differences in the use of highlighting and to explore effects of highlighting in relation to distributed study and metacognitive beliefs about highlighting as a study tool. To this end, we asked students to study a passage twice, either massed (i.e., back-to-back with no separation between study opportunities) or spaced (i.e., successive study opportunities separated by a 30-min interval), with half studying the passages without using a highlighter and half studying the passage using a highlighter. All participants then took a test after a 1-week delay. We also collected data on students' highlighting preferences.

Method

Participants

A total of 184 UCLA undergraduates (M_{age}=19.9) participated for partial credit in a psychology course.

Materials

Participants read a passage about ground water (856 words) from the U.S. Geological Survey website. Twelve critical phrases, each containing a different keyword, were selected from the passage (e.g., the term *recharge* was the keyword in the phrase: *Water seeping down from the land surface adds to the ground water and is called recharge water.*). Then, 12 fill-in-the-blank questions were created from these phrases by deleting the keyword and asking participants to provide it on the final test (e.g., *Water seeping down from the land surface adds to the ground water and is called* __________ *water*).

Design and Procedure

Participants were randomly assigned to either the highlighting or no-highlighting conditions and to either the massed or spaced re-reading conditions; thus, our design employed two between-subject variables: highlighting and spacing.[1]

Upon arrival, participants were seated alone at a desk and asked to read the passage in its entirety, which they were given 6 min to do. Participants in the highlighting condition received a standard yellow highlighter and told to use it however they typically would while studying material for a class. Participants in the no-highlighting condition were not given a highlighter and were simply instructed to read the passage as though they were studying material for a class.

After the initial reading, participants in the massed condition were immediately asked to study the passage again, while those in the spaced condition participated in a 30-min unrelated distractor activity before re-studying the passage. In the highlighting condition, participants re-read their previously highlighted passage (with their markings still there) and were again told to use the highlighter however they typically would while studying for a class. Participants in the no-highlighting condition were simply instructed to re-read the passage as though they were studying for a class.

After the second reading, all participants were given a brief questionnaire asking them to indicate the extent to which they either agreed or disagreed with a set of statements exploring their metacognitive beliefs about learning and study strategies, such as, "I feel that highlighters

[1] As a separate manipulation, we also explored whether the benefits of testing (Roediger and Karpicke 2006) might interact with highlighting. Specifically, participants were given an immediate test on six of the twelve fill-in-the-blank questions shortly after the second reading of the passage. All twelve questions were then tested after the 1-week delay, allowing us to assess the benefits of the earlier test. Although we observed a large benefit of testing, $F(1, 180)=102.99$, MSE=4.24, $p<0.001$, with keywords tested immediately remembered significantly better on the delayed test (M=0.47, SE=0.02) than were keywords not tested immediately (M=0.26, SE=0.02), the effect of testing did not interact with either the spacing (p=0.83) or highlighting (p=0.33) manipulations. Consequently, for the sake of succinctness, and because educators are most likely to be interested in how highlighting affects long-term learning and performance, we collapsed all data from the tested versus non-tested conditions and report only one score to reflect the week-delayed final recall performance.

are an important part of my studying." One week later, all participants were given the fill-in-the-blank test for the 12 critical phrases from the passage.

Results and Discussion

How Do Highlighting and Spacing Affect Learning?

Average correct performance obtained on the final fill-in-the-blank test in each of our four conditions is illustrated in Fig. 1, and as indicated there, one of our pre-study conjectures—that highlighting might be more beneficial in massed than spaced conditions—did receive some support. Planned-comparison *t*-tests revealed that whereas a nonsignificant benefit of highlighting was observed in the spaced condition (M=0.04 benefit), $t(90)=0.92$, $p=0.36$, $d=0.19$, a robust and significant benefit of highlighting was observed in the massed condition (M=0.12 benefit), $t(90)=2.89$, $p<0.01$, $d=0.60$.

Additionally, we performed an overall analysis on our data using a 2 (spaced vs. massed) × 2 (highlighting vs. no-highlighting) between-subjects ANOVA. Not surprisingly, given the pattern of results shown in Fig. 1, there was no main effect of spacing, $F(1, 180)<1$, MSE= 0.03, with performance averaged across the two massed conditions (M=0.37, SE=0.02) not differing from that averaged across the two spaced condition (M=0.36, SE=0.02); but, there was a significant main effect of highlighting, with the average performance of highlighters (M=0.40; SE=0.02) being significantly better than the average performance of non-highlighters (M=0.32; SE=0.02), $F(1, 180)=7.22$, MSE=0.57, $p<0.01$. The interaction between highlighting and spacing, however, did not reach statistical significance, $F(1, 180)=1.93$, MSE=0.15, $p=0.17$.

Given the typical robustness of the spacing effect that we did not find a benefit of spacing even for the non-highlighters would suggest that our particular spacing manipulation was not sufficiently strong. Indeed, because our to-be-leaned material was a three-page text passage requiring up to 6 min to read once, a participant's re-encountering of given key phrases would have been spaced by several minutes even in our massed condition. Thus, the interval between spaced encounters of the same key phrases may have not been sufficiently increased in our spacing condition versus our massed condition to allow a spacing benefit to emerge.

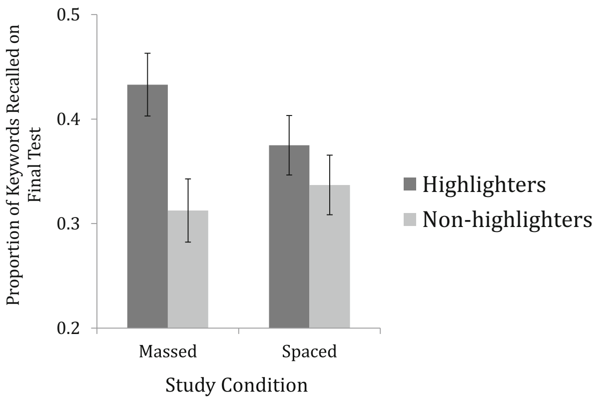

Fig. 1 Final test performance by spacing and highlighting conditions

How Do Individual Differences in Highlighting Behavior Affect Learning?

Overall, participants highlighted an average of 191.9 (SE=13.5) words (Mdn=175), and their highlighting behavior was quite efficient. Despite participants highlighting only 22.4 % of the passage, an average of 8.7 (SE=0.27) or 72.5 % of the 12 critical keywords were included in their highlighting. Eighty-one participants highlighted some keywords but not others, allowing for within-subjects comparisons of recall for highlighted versus non-highlighted keywords. We first examined whether highlighted information was better recalled than non-highlighted information, and importantly, it was. Participants were more likely to answer a test question correctly if they had highlighted information relevant to that question ($M=0.44$) than if they had not ($M=0.30$), $t(80)=3.67$, $p<0.01$, $d=0.50$. Furthermore, recall performance of highlighting participants for non-highlighted material was no different from the recall performance of non-highlighting participants ($M=0.32$), $t(174)=0.56$, $p=0.58$. Thus, highlighting appears to improve the retention of highlighted material without significant cost to the retention of the non-highlighted material—a finding inconsistent with the von Restorff effect.

To explore a possible relationship between highlighting activity and later recall, we conducted a median-split analysis separating participants into heavy highlighters and light highlighters. As shown in Table 1, heavy highlighters marked significantly more words than light highlighters, $t(90)=9.41$, $p<0.001$, $d=1.96$, including more keywords, $t(90)=3.81$, $p<0.001$, $d=0.97$. Importantly, however, heavy highlighters did not outperform light highlighters at final test. If anything, light highlighters numerically outperformed heavy highlighters, suggesting that the benefits of highlighting do not stem from the mere act of highlighting alone.

Possibly, the light highlighters put more cognitive effort and analysis into deciding what to highlight, resulting in fewer highlighted words, but deeper processing of those words compared to words highlighted by heavy highlighters. We explored this conjecture by calculating an efficiency score: the number of keywords highlighted divided by the total number of words highlighted. By this measure, light highlighters were significantly more efficient ($M=0.08$, SE=0.01) than heavy highlighters ($M=0.03$, SE=0.01), $t(89)=7.20$, $p<0.01$, $d=1.50$. Thus, it would appear that light highlighters were more selective in their highlighting than heavy highlighters, perhaps reflecting more cognitive effort being given to their highlighting decisions.

How do Students' Beliefs about Highlighting Relate to the Benefits of Highlighting?

According to the questionnaire responses, many students use highlighters and believe them to be an important component of their studying. When asked to rate the statement, "I typically read my text books while using a highlighter" on a scale from 1–9—with 1 meaning "completely disagree," 5 meaning "unsure," and 9 meaning "completely agree"—48 % of

Table 1 Highlighting activity and final test performance by highlighting-classification group

Highlighting classification	Total words highlighted (SE)	Keywords highlighted (SE)	Final test performance (SE)
Heavy highlighters	282.8 (17.7)	9.7 (0.3)	0.39 (0.03)
Light highlighters	101.0 (7.8)	7.8 (0.4)	0.41 (0.03)

the participants selected a 7 or above (M=5.5; SD=2.8). Furthermore, when asked to rate the statement, "I feel that highlighters are an important part of my studying" using the same 1-9 scale, 41 % of the participants selected a 7 or above (M=5.3; SD=2.6). If anything, these ratings probably underestimate student text-marking behavior, as participants may have restricted their responses to highlighting, discounting similar text-marking activities such as underlining.

To see whether differences in opinions about highlighting predicted differences in highlighting activity or recall performance, we separated participants into three groups: pro-highlighters, unsure, and anti-highlighters. Pro-highlighters were the 74 participants rating the statement, "I feel that highlighters are an important part of my studying" with a 7 or above; unsure participants were the 55 participants rating the statement between 4 and 6, and anti-highlighters were the 55 participants rating the statement 3 or below. Unsurprisingly, a main effect of group was observed on highlighting activity, $F(2,89)=4.39$, MSE=68,812.20, $p<0.05$. As shown in Table 2, pro-highlighters and those who were unsure highlighted significantly more words than did anti-highlighters, $t(63)=3.35$, $p<0.01$, $d=0.86$, $t(52)=2.19$, $p=0.03$, $d=0.60$, respectively, and a similar pattern was observed for keywords highlighted.

To see if opinions about the importance of highlighting were related to retention, we conducted a 2(highlighting vs. no-highlighting)×2(spaced vs. massed)×3(pro-highlighters vs. unsure vs. anti-highlighters) between-subjects ANOVA on the final test scores. Spacing did not interact significantly with any variable, so we collapsed across the massed and spaced conditions. Interestingly, a significant effect of group emerged, such that anti-highlighters (M=0.45; SE=0.03) outperformed unsure participants (M=0.37; SE=0.03), who outperformed pro-highlighters (M=0.30; SE=0.02), $F(2, 172)=9.60$, MSE=0.34, $p<0.001$, with individual t-tests confirming each of the between-group differences to be statistically significant, average d=0.38.

Although anti-highlighters outperformed pro-highlighters, we nonetheless expected pro-highlighters to benefit most from being allowed to use a highlighter. As shown in Table 2, however, the opposite was observed. Anti-highlighters benefited marginally from use of a highlighter (M=10 % benefit), $t(53)=1.69$, $p=0.09$, $d=0.50$, and unsure participants benefited significantly (M=17 % benefit), $t(53)=3.92$, $p<0.001$, $d=1.00$), but pro-highlighters did not benefit at all (M=0 % benefit), $t(72)<1$. The interaction between highlighting group and highlighting condition was statistically significant, $F(2, 172)=3.90$, MSE=0.14, $p=0.02$.

Table 2 Highlighting activity and final test performance by highlighting efficacy and belief classification

Experimental condition and belief classification	Total words highlighted (SE)	Keywords highlighted (SE)	Final test performance (SE)
Highlighters			
Pro-highlighters	219.9 (20.3)	8.9 (.4)	0.30 (0.03)
Unsure highlighters	212.2 (24.1)	7.6 (.6)	0.45 (0.03)
Anti-highlighters	132.1 (24.1)	9.6 (.3)	0.50 (0.04)
Non-highlighters			
Pro-highlighters	–	–	0.30 (0.03)
Unsure highlighters	–	–	0.28 (0.03)
Anti-highlighters	–	–	0.40 (0.04)

General Discussion

The goal of the present research was to explore potential benefits of highlighting in relation to distributed study and students' metacognitive beliefs about highlighting as a study tool. We found that highlighting improved later cued recall of highlighted information without impairing recall of non-highlighted information from a text passage, a finding that is inconsistent with a von Restorff-based explanation. That is, highlighting did not seem to enjoy its benefit merely by making highlighted text stand out upon re-study. Furthermore, we found that the benefit of highlighting was numerically greater when participants read the passage twice without delay, suggesting that highlighting may be particularly beneficial when students re-read text passages immediately.

The results of the present research suggest that highlighting, far from being an ineffective study technique (Dunlosky et al. 2013), can facilitate long-term retention—particularly when students, possibly owing to limited available study time, engage in massed re-readings or study sessions. In such situations, students could probably improve the effectiveness of their study via selective highlighting because such a practice would lead them to think about why they initially selected certain words or phrases to highlight, resulting in deeper processing during subsequent readings.

If initial highlighting does encourage learners to engage in such considerations about previously highlighted material, then highlighting might have some of its beneficial effects—as suggested earlier—by serving to dispel the misleading effect of fluency arising during a subsequent re-reading. Indeed, the sense of fluency typically felt during an immediate re-reading has been suggested as a major factor in why two back-to-back readings of a chapter result in no better learning than just one reading (Callender and McDaniel 2009). Accordingly, times when a sense of fluency is high and most likely to discourage deep processing on a second reading should also be the times when having previously highlighted the passage would be most beneficial—a pattern consistent with our finding of a greater benefit for highlighting when text readings were massed versus spaced.

A surprising finding of the present study is that participants who valued highlighters the most profited least from their use. One possible reason for this finding is that participants who were unaccustomed to highlighting put more effort into the act of highlighting, with the ultimate result of better retention. From this perspective, highlighting could be characterized as a desirable difficulty, at least for some students, because it forces them to think about and process text differently than they typically would and in a way that ultimately leads to better memory for that text. These results also suggest that even if participants were prevented from engaging in the type of study processes they normally employ, the costs of such prevention did not outweigh the benefits of using a highlighter.

Our results also indicate that training students how to highlight effectively could help promote useful study strategies. Students often re-read text passages as a study activity, and indeed, many rate it as their no. 1 study activity (Dunlosky et al. 2013; Karpicke et al. 2009; Kornell and Bjork 2007, 2009). Presumably, then, students are highly likely to persist in this activity. Accordingly, instructing them how to do so optimally would seem not just warranted, but obligatory. Highlighting training such as that proposed by Leutner et al. (2007), for example, could well be helpful in furthering this goal, even—or perhaps especially—for those who already believe that highlighting is a beneficial study technique. Such training should involve encouraging students to think carefully about which sections of the text should be highlighted and to justify their choices, as well as asking those questions again when re-reading a previously highlighted section. Such questioning during highlighting and re-reading should evoke two beneficial activities for improved retention: deeper processing and retrieval practice, both of which have been repeatedly shown to improve retention (e.g., Craik and Lockhart 1972; Roediger and Karpicke 2006).

More generally, the present work provides another example of what Bjork (1999) and others (e.g., Koriat and Bjork 2005) have referred to as an illusion of competence. Specifically, learners can be fooled by objective and subjective indices of performance into thinking that a given manipulation is useful for learning even when it is not. In this context, individuals who become reliant on highlighters for studying—such as the pro-highlighters or heavy highlighters in the present study—may think that the act of highlighting is helpful in and of itself. As the present results confirm, however, simply the act of highlighting text is not sufficient to promote its retention. Indeed, despite the fact that highlighting a relevant portion of a text was clearly beneficial, more overall highlighting activity tended to lead to worse—not better—performance at final test. Clearly, it is not highlighting per se that is beneficial; rather, it is how highlighting changes the way students read and think about text that is beneficial.

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