Self-Regulated Learning: An Overview of Theory and Data

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The Oxford Handbook of Metamemory
Edited by John Dunlosky and Sarah (Uma) K. Tauber

Online Publication Date: Feb 2016
Subject: Psychology, Clinical Psychology, Cognitive Psychology
DOI: 10.1093/oxfordhb/9780199336746.013.23

Abstract and Keywords

Effective self-regulated studying can influence students' learning in school and beyond. This chapter reviews research on two key decisions: when to study and how to study. It first reviews the decisions people make about when to start and stop studying—that is, when to study—and the metacognitive judgments that underlie those decisions. It distinguishes between small-scale and large-scale decisions, such as which problem to work on next and whether to study today at all, respectively. It then discusses decisions about how to study, for example, whether or not to take notes, underline, test oneself, or reread. It then discusses key areas for future research, with an emphasis on student-centric research and research in digital learning environments. It offers practical recommendations for studiers about how to avoid overconfidence and procrastination and how to choose study strategies that increase short-term difficulty and long term success.

Keywords: learning, metacognition, self-regulated, studying, education, students

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If you have been meaning to read this chapter for a while and are now finally getting around to it, join the club. The first author meant to write it for a long time and was already past his submission deadline when he wrote the first sentence (through no fault of the second author). Everyone procrastinates, though some do more than others (Steel, 2007). Students are no exception (Solomon & Rothblum, 1984); for example, one report estimated that up to 95% of college students engage in procrastination (Ellis & Knaus, 1977). Furthermore, correlational research shows that procrastinators get worse grades and withdraw from courses more often than nonprocrastinators (Semb, Glick, & Spencer, 1979). Experimental research shows that students who are given well-planned deadlines get better grades and earn more money than peers who are allowed to set deadlines for themselves (Ariely & Wertenbroch, 2002).

When deciding whether to study, the procrastinator’s question is simple: Do I need to start right now if I want to finish my assignment on time? Studying usually commences only when the answer is yes. This approach would be less problematic if it were not for the planning fallacy: people have a strong bias to underestimate how long it will take to complete almost any task (Kahneman & Tversky, 1979; Kruger & Evans, 2004). If you think it will take two days to write a good paper and you therefore start writing two days before it is due, you are in trouble, because it will almost certainly take more than two days. In one study (Buehler, Griffin, & Ross, 1995), students were asked to predict the time by which they were 50% certain they would finish an academic assignment. Only 13% finished by the time they had predicted. Even more alarming, when students were asked the same question, but this time targeting a 99% certainty level—that is, when they were very careful to give themselves plenty of time—only 48% finished by the predicted time.

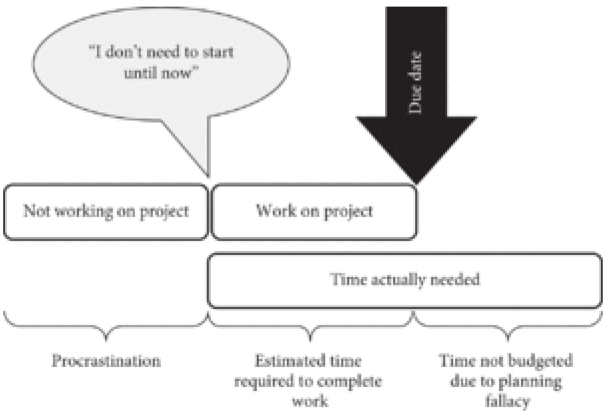

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Figure 1: The relationship between procrastination, planning fallacy, and due dates.

As Figure 1 shows, the combination of procrastination and planning fallacy is a “double whammy.” Accurately estimating the time required to complete an undertaking, or starting sooner than seems necessary, or both, are necessary to be on time; otherwise the assignment is likely to come due before there has been sufficient time to complete it.

What and When to Study

Procrastination and the planning fallacy affect when people decide to start and stop studying—that is, when to study. In this section we address decisions about when to study and then turn to decisions about what to study. Because procrastination and the planning fallacy affect hours (or days) of a student’s time, we consider them influences on large-scale decisions. Although large-scale decisions can have a major impact on student learning, the majority of research on self-regulated study has focused on small-scale decisions.

Large-scale Decisions

There are three categories of large-scale decisions: When to start studying, what to study, and when to stop studying. Prioritization is a central feature of large-scale decisions. There are always alternatives to studying and they are often more enjoyable in the short term (e.g., going out with friends at night, or hitting the snooze button in the morning). In addition to prioritizing studying over not studying, students have to prioritize which topic they most need to study among the multiple topics they could study. Due dates obviously have a large impact on whether, what, and when students start studying, and most students say they study whatever is due soonest or most overdue (Kornell & Bjork, 2007).

When students crack the books, they get to decide how much time they spend studying. One might study for one hour a day while another studies for six. In most of the experimental research on self-paced study, however, the duration of the study session is held constant. For example, a participant in an experiment may get to decide which items (such as vocabulary words, concepts, or definitions) to study within a 10 minute time period, but he or she usually cannot decide to study for more than 10 minutes. This is unfortunate because the total amount of time a student dedicates to schoolwork is probably among the most consequential decisions a student can make (assuming that the efficiency of their study is nonzero).

The decisions that determine how much time students spend studying in a given day or week—decisions about when to start studying and when to stop—are large-scale decisions. The National Survey of Student Engagement recently reported that the amount of time students spend studying for class is much less than their instructors expect (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Professors expect full-time university students to study around 25 hours per week for class, but only about 11% of freshmen do so (Kuh et al., 2008). More research attention on these large-scale decisions, and on factors that induce students to spend more time studying, would advance our collective understanding of self-regulated learning.

Small-scale Decisions

Large-scale decisions are often made by making basic judgments about one’s own knowledge, such as “have I learned enough that I’m ready to take the test?” and “which topic do I need to spend the most time on?” Small-scale decisions are also made based on judgments about one’s own knowledge, but they typically concern a single fact or concept and involve the investment of minutes or seconds of study. For more on the effects of metamemory judgments in education, see Bjork, Soderstrom, and Yue (this volume).

Most of the research that has been conducted on self-regulated study has involved the small-scale decisions that affect seconds or minutes of a student’s time. These decisions occur when a student has already begun studying a topic. In most cases, the duration of the study session itself is held constant and students decide what to do with their time.

Students can go for extended periods of time without making small (or large) scale decisions. For example, there is little decision making involved in completing a reading assignment, other than deciding to start reading. The same is true when working on a problem set if the student works on the problems in order, one at a time. More generally, few decisions are necessary when the materials dictate what and how much the student should study. However, even when no decisions are being made, students do try to monitor their comprehension of the materials they are learning. The high frequency of mind-wandering while reading suggests that their monitoring efforts fall short at times (Schooler et al., 2011). When comprehension monitoring is successful, though, there is an underlying readiness to take action if necessary. In this sense, reading a textbook is akin to driving: like a driver who monitors an open highway, but does not have occasion to apply the brakes, a student might monitor her comprehension while reading a textbook even if she does not ever need to stop (e.g., to reread a complicated passage).

Reading and doing a problem set are two examples of situations where there is not necessarily a need to prioritize. If the goal is to cover all of the material, it is often sensible to just cover all of it, in the order it is presented. Study decisions become more common, and possibly more important, when there is a need for prioritization. It is common for students to find that they do not have enough time to study everything, especially when studying for an exam. In such situations they must focus on some items at the expense of others.

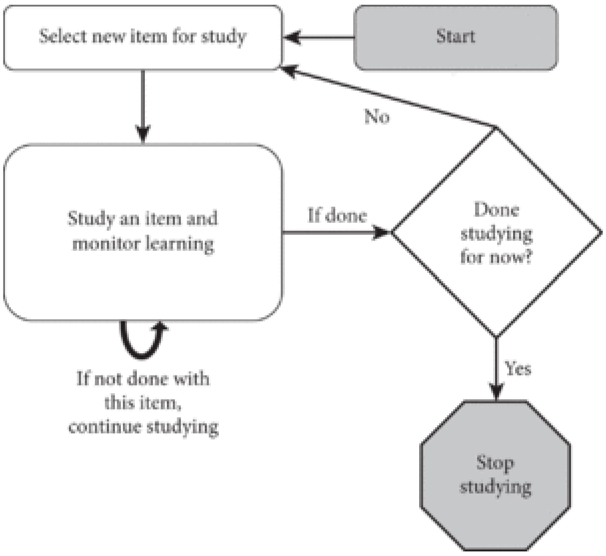

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Figure 2: Sequence of events when studying an item.

There are two main kinds of small-scale decisions: Which item to study next and when to stop studying that item. As Figure 2 shows, these decisions are cyclical: An item is selected and studied, and then it is time select the next item to study, and so on.

Three Models of Study-time Allocation

Models of Study Time Allocation		
Model	Prioritized Info	Learning Goal
Discrepancy reduction (DR)	Most difficult items	Mastery of all items
Region of proximal learning (RPL)	Easiest unknown items	Mastery of learnable items
Agenda based regulation (ABR)	Depends on learning goal	Depends on task or situation

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Figure 3: Models of study time allocation.

Three models of study time allocation make predictions about how students make small-scale decisions about which items to prioritize while studying: discrepancy reduction (DR), region of proximal learning (RPL), and agenda-based regulation (ABR). These models are summarized in Figure 3. Although there are differences, these models also have important points in common. They all assume that learners try to maximize learning by prioritizing among items, usually by studying information that they do not know very well. In all of the models, prioritizing among items to decide what and how long to study requires making a judgment of learning (JOL)—that is, a judgment of how well an item has been learned (see Rhodes, this volume). Here we describe differences between the models but also highlight ways in which they are compatible.

In the first model, DR, the highest priority is given to items for which the current state of learning is most discrepant from the desired state of learning—that is, to the items that are farthest from being learned (Dunlosky & Hertzog, 1998). These are items that a student might give the lowest JOLs to, indicating that they consider these items to be the least learned. In this way, JOLs are thought to drive study decisions. When the goal is mastery—that is, to learn everything—adhering to DR makes sense. But as students prepare for an upcoming exam, the goal is not always mastery.

Students often end up with too little time to prepare for exams and write papers. The limited availability of study time sometimes causes students to set goals that fall short of mastery. For example, a student with three exams to prepare for in the coming week might think of mastery as an ideal but may decide that gaps in her knowledge are inevitable and set a goal short of mastery.

The second model, RPL, takes limited availability of study time into account when making predictions about students' study decisions. According to RPL, unlearned items are given the highest priority, but only if the learner has deemed them to be learnable (Metcalfe, 2002, 2009). The model predicts that low priority will be given to items that are considered unlearnable or items that are already learned; high priority will be given to items in between. Metcalfe and collaborators refer to this set of high-priority items as the student's RPL (Kornell & Metcalfe, 2006; Metcalfe & Kornell, 2003, 2005). The main difference between DR and RPL is the treatment of very difficult items; in RPL they are given a low priority, whereas in DR they are given a high priority because they are farthest from being learned (i.e., highly discrepant).

The third model, ABR, points out that study decisions are not guided by JOLs alone. JOLs, which are primarily based on perceived item difficulty (see section on monitoring later in the chapter), are integral to study control in both DR and RPL (e.g., Ariel, Dunlosky, & Bailey, 2009; see also Thiede & Dunlosky, 1999). ABR makes the general point that many factors—including but not limited to time pressure, which RPL focuses on—can influence study decisions. In particular, a student's agenda (i.e., plans and goals) plays an important role. For example, study decisions are affected by incentive structures like the number of points an item is worth and, of course, the perennial question: "Excuse me, professor, will that be on the test?" (Ariel et al., 2009). According to ABR, when agendas become important, they can override JOLs as the major factor controlling study decisions.

The two primary types of decisions regarding time—what to study and for how long—seem to be governed by different rules. Decisions about what to study often fit with RPL predictions (Kornell & Metcalfe, 2006; Metcalfe & Kornell, 2003; Price & Murray, 2012; Son & Metcalfe, 2000). Decisions about when to stop tend to follow DR. Laboratory research shows that people spend the longest on the most difficult items—which fits with DR—even when mastery is not the goal because time is limited. For example, Metcalfe and Kornell (2005) found that participants mostly avoided very difficult items when choosing what to study, but when determining how long to spend studying, they spent the most time on the most difficult items (in terms of time spent per trial; total time was greatest on easier items because they were selected more often). RPL predicted that they would study these items very briefly. Thus it seems that although goals influence choices about what to study, once learners have started studying an item, their attention is captured by the item and the decision to stop may be relatively automatic, influenced by how much the learner seems to be learning rather than by a higher-level agenda (Metcalfe & Kornell, 2005). Note, however, that the ABR model maintains that higher-level agendas play a role during all phases of study time regulation (Ariel et al., 2009). Whether this finding—that people seem to ignore agendas once they have committed to studying an item—applies in real life is an open question.

All of the models assume that a student’s goal in making study decisions is to maximize his or her test performance. Under some circumstances this goal can be achieved by studying according DR (Nelson, Dunlosky, Graf, & Narens, 1994), although in other cases spending too much time on difficult items can impair learning (Atkinson, 1972). This impairment is especially apparent when students have been instructed to strive for mastery, which can lead them to “labor in vain” (Nelson & Leonesio, 1988). More recent studies have identified benefits of RPL; in one study, for example, participants who were given limited time to study not only selected the easiest unknown items to study but also benefited from doing so (Kornell & Metcalfe, 2006). Studying according to an agenda can enhance learning with respect to that agenda (Ariel et al., 2009; Ariel, 2013). For example, Ariel et al. (2009) found that the number of points an item was worth had a larger influence than JOLs on study decisions.

There are also potential drawbacks to studying according to ABR, DR, or RPL. Studying according to DR can lead people to burn a lot of time on items that they still will not get right when they take a test. ABR optimizes performance for a specific set of incentives but might be harmful if the incentive structure changes—for example, the learner will be in trouble if something that was not important, and was therefore neglected, suddenly becomes important. Similarly, RPL optimizes performance on a specific test at a specific time, but one consequence of studying items until they are learned and then stopping is that they might be learned just well enough to be remembered for the test but not for very long afterward. In other words, items that are just above a recall threshold and are therefore recalled on the day of the test might drop below threshold soon after (Kornell, Bjork, & Garcia, 2011). Furthermore, items that remain far below threshold—items that are not studied because they are so difficult—remain very difficult to learn because zero learning gains have been made (Storm, Friedman, Murayama, & Bjork, 2014).

In sum, the three models (DR, RPL, and ABR) are not mutually exclusive. All assume that learners try to maximize learning by prioritizing among items and usually studying information that they do not know. Agendas play a role in both ABR and RPL and JOLs are central to all three models. The next section discusses factors that influence JOLs and therefore study decisions.

How to Study

The prior sections were primarily focused on decisions about what, when, and how much to study. Next we turn to decisions about how to go about studying—that is, what activities students choose to engage in while they study.

There is an oft-cited proverb: Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime. The same would seem true of learning. Teach a person to learn, and he'll learn for a lifetime. Unfortunately, most people are not taught much about how to learn, and they do not have a sophisticated understanding of how to study. For example, Kornell and Bjork (2007) asked students at the University of California, Los Angeles, "Would you say that you study the way you do because a teacher (or teachers) taught you to study that way?" Only 20% of respondents said yes. A slightly higher 36% of a sample from Kent State University said yes to the same question (Hartwig & Dunlosky, 2012). Whether these students received well-informed instruction is a separate question.

Two approaches to research on how people study	
Approach	
Cognition-centric	*Student-centric*
Start with an effective study strategy; examine study choices relevant to this strategy.	Start with study choices students make frequently; examine effectiveness of these strategies.
Advantages	
Can identify practices that students should engage in more.	Can inform students about the value of the techniques they are using.
Disadvantages	
Not always relevant to decisions students actually make.	If not grounded in cognitive principles, research does not always generalize.
Examples	
Testing	Testing
Spacing	Highlighting/underlining
Elaborative interrogation	Laptop versus longhand note-taking
Selecting a set of word pairs for study	Procrastination

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Figure 4: Two approaches to research on how people study.

Research on the decisions students make about how to study falls into the two general categories that we define and describe in Figure 4. Some would argue that the cognitive psychology literature is largely cognition-centric, and because of that it does not answer the questions students are actually asking themselves (e.g., I copy my notes, is that a good idea?). If the goal is to inform students about how to study, some argue that the field should shift toward student-centric research (Daniel & Poole, 2009; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). That is, what are students actually doing when they study? Perhaps the most promising areas of study involve techniques that are both student- and cognition-centric—decisions students regularly make, about which we also have a firm grounding in research regarding the strategy's effectiveness. Self-testing is a prime example.

The Decision to Test Oneself

Some of the decisions students face came up earlier in this chapter. One is self-testing, which seems effective on two fronts: compared to re-reading, tests produce (a) more learning and (b) more accurate metacognitive judgments. Do students test themselves when they study? It depends on the situation; for example, students are surely more likely to test themselves if they are studying vocabulary and have a set of flashcards at hand than if they are studying a textbook chapter and would need to write their own test questions in order to test themselves. As Figure 5 shows, students avoid tests on information they do not yet know, but their desire to test themselves grows stronger as they learn the material better (Kornell & Bjork, 2007; Kornell & Son, 2009; Son, 2005).

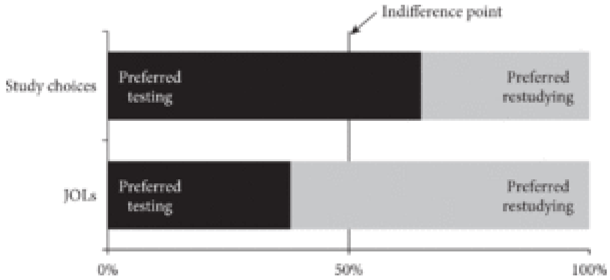

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Figure 5: Proportion of participants who preferred testing versus restudying when making study choices

(adapted from Kornell & Son, 2009, Experiment 2)

and when making JOLs

(adapted from Kornell & Son, 2009, Experiment 1).

These studies also showed, however, that even though the majority of students preferred to test themselves, learning was not always their primary goal. Instead, their goal through testing was to figure out whether or not they knew each item. This strategy seems consistent with the ABR model of study time, in the sense that other goals besides maximizing learning—in this case, the goal of identifying information one does not know—can control study decisions. In fact, one study (Kornell & Son, 2009) showed that JOLs were lower for test trials than presentation trials for the same participants who chose to test themselves (see Figure 5). This finding shows that metacognitive judgments and study decisions can sometimes be disconnected or even opposite of each other.

The Decision to Drop Items from Further Study

When faced with a well-learned item people prefer to test themselves rather than re-read, but in real life there is also another option: stop studying the item altogether. Karpicke (2009) asked participants to learn foreign-language vocabulary words. After correctly recalling a pair they were given three options and asked what they wanted to do with the pair on future trials: restudy it, test themselves on it, or drop the pair from their set of items. Instead of choosing to test themselves on high-JOL items, participants often dropped these items from future study or testing. Though they believed that they had learned these items, they were often wrong, as the final test revealed.

Another study of dropping suggests that people sometimes drop items from further study that they do not think they have learned. Kornell and Bjork (2008b) found that participants often dropped an item from further study after recalling the answer for the first time. The JOLs made clear, however, that the participants were not confident that they would recall the item later. It seems that participants' illusion was not that they had fully learned the item; it was that they would not gain from studying the item further. The data showed clearly that, in fact, continuing to study would have been very beneficial. Thus, the Karpicke (2009) and Kornell and Bjork (2008b) studies both suggest that when people drop items from their list of items to study, they often do so prematurely and would benefit from continuing to test themselves instead (see also Karpicke & Roediger, 2008).

Do People Choose to Space Their Study?

People tend to rate massing practice as more effective than spacing or interleaving, even when the opposite is true (Cohen, Yan, Halamish, & Bjork, 2013; Kornell & Bjork, 2008a; Simon & Bjork, 2001; Zechmeister & Shaughnessy, 1980). Judgments and ratings are one thing; whether people choose to space and/or interleave is a separate question. With respect to the distinction in Figure 4, however, it is reasonable to question whether students make decisions about spacing per se. Instead, the degree to which students employ spacing may be largely determined by decisions that are made irrespective of spacing. In discussing large-scale study decisions, we argued that impending due dates often control when students decide to start on a project. A survey that supported this claim asked students, “How do you decide what to study next?” (Kornell & Bjork, 2007, p. 223). For a student to intentionally implement a spacing strategy they would have to plan a study schedule ahead of time. Yet 81% of respondents said they study either “Whatever I feel I’m doing the worst in” (22%) or “Whatever’s due soonest/overdue” (59%). Only 11% said they plan a study schedule ahead of time. Hartwig and Dunlosky (2012) replicated this finding, with percentages of 80% and 13%, respectively. (The surveys also showed that 4% and 2% of respondents, respectively, said they study whatever they haven’t studied for the longest time—a spaced strategy.) Thus, asking students to space their study may not be pragmatic because for most students, spacing simply is not a factor that has an effect on study decisions.

Given that study schedules seem to determine the degree to which students engage in spaced practice, it is the teachers who have the most potential to make sure that students engage in spaced practice. In other words, teachers, not students, are the group who should heed advice about the benefits of spaced practice.

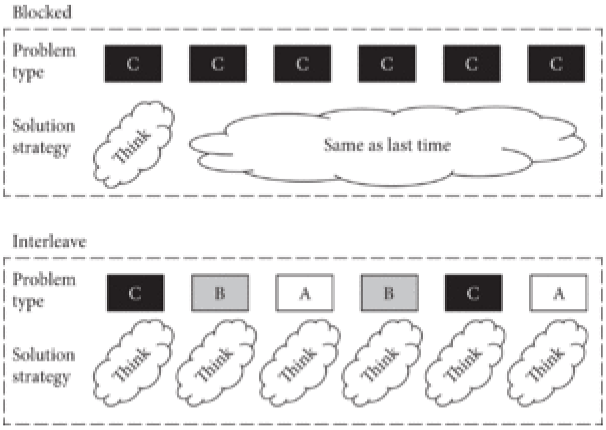

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Figure 6: Thought processes involved in solving problems presented in blocked or interleaved orders.

The same is true with small-scale decisions in the domain of problem solving: It is probably teachers, not students, who have the most potential to implement interleaving and spacing. In high school and college textbooks, problem sets tend to be blocked by chapter—that is, the questions at the end of a given chapter are about the problems from that chapter. The same is true for students at younger ages on worksheets, for example, where students have to solve the same type of problem 10 or 20 times in a row. As Figure 6 shows, blocked practice can be ineffective because after the first problem, students can stop thinking and just use a strategy of doing the same thing as they did last time. Interleaved practice, which forces students to decide on the appropriate strategy for each question, requires more thinking. It also produces far more learning (Rohrer, Dedrick, & Burgess, 2014; Rohrer, 2009).

We have argued that teachers are in a better position than students to implement spacing (using assignment schedules) and interleaving (using mixtures of problem types) than students are. Along with teachers, digital learning tools can also implement spacing, and they can do so in sophisticated ways that try to optimize both the amount of time spent studying a given item and how repetitions are distributed in time (Atkinson, 1972; Lindsey, Shroyer, Pashler, & Mozer, 2014; Pavlik & Anderson, 2005).

Students can, however, make decisions about spacing and interleaving in some domains. For example, students often study with flashcards (or similar techniques), which allows them to cycle through a set of to-be-learned items (Wissman, Rawson, & Pyc, 2012). When doing this, it is exceedingly rare for students to mass practice on exactly the same item; no one studies a flashcard and then studies exactly the same one again immediately (massing is more common in problem solving because even if the underlying concept is the same, the specific problems always change from one problem to the next). There can be differences in the amount of lag (i.e., the temporal gap) between two interleaved study trials (e.g., Kornell, 2009), and these differences in lag during interleaved learning are the topic of the majority of research on study choices with respect to spacing.

Research on whether people mass or space when studying a list of similar items has produced mixed (no pun intended) results. When participants were forced to mass some items and interleave others, some studies have shown that people tend to space relatively difficult items (Benjamin & Bird, 2006; Toppino, Cohen, Davis, & Moors, 2009) but others have shown the opposite (Cohen et al., 2013). As far as whether to space or mass at all, there have been only a few studies in which participants were given the freedom to mass or space as much as they wanted. Participants in one study were asked to learn word pairs and were allowed to freely mass or space. They did not choose to mass their studying, but they did not choose maximal spacing either; instead they choose a degree of spacing that is somewhere in between (Son & Kornell, 2009). In a perceptual concept learning study, participants were shown 6 pictures of bird species from each of 12 families of birds (e.g. 6 wren species from the Passeriformes bird family). A distinct picture of a bird was presented for study on each trial. Participants in the study tended to mass presentation of birds from the same family rather than space them out with birds from other families (Tauber, Dunlosky, Rawson, Wahlheim, & Jacoby, 2013). These findings suggest that studiers do the same thing that textbook designers do: they may not repeat exactly the same information on consecutive trials, but they are happy to repeat the same concept if the surface features have changed.

The Decision to Engage in Explanatory Questioning

Roediger and Pyc (2012) have suggested that "explanatory questioning" techniques, such as elaborative interrogation and self-explanation, are economical ways that students can improve their learning. Elaborative interrogation involves techniques like asking oneself "why" questions (e.g., Why don't plants need to eat?). Self-explanation involves explaining ideas to oneself while learning. These techniques produce large benefits (Pressley et al., 1992; Pressley, McDaniel, Turnure, & Wood, 1987). For example, one study found that when students were intermittently prompted to answer "why" questions as they read a biology text, they learned more than a separate group of students who read the text twice (Smith, Holliday, & Austin, 2010). Moreover, their knowledge was superior for information that was questioned and for other parts of the passages as well.

Explanatory questioning is a cousin of testing in the sense that both involve active learning strategies centered on retrieving information from memory. Like any technique, though, the fact that it is effective is no guarantee that students will take advantage of it. This technique is different from the techniques covered thus far in this section (testing, dropping items from study, and spacing/interleaving) because it is recommended that students do it the first time they encounter new information (e.g., the first time they are reading a textbook). More research is needed on the degree to which students choose to engage in explanatory questioning, but asking students to engage in these techniques as they read slows them down and increases the effort involved, which makes it an unattractive option for most studiers. Again, it might be unrealistic to expect students to engage in explanatory questioning voluntarily without prompting; the best way to implement it might be based on assignments from teachers.

Deciding What Text to Highlight or Underline

We have just reviewed two strategies—spacing/interleaving and explanatory questioning —that are squarely in the cognition-centric tradition, meaning that they receive research attention because they are effective ways to study, not because they are strategies that students consider using with any regularity. Previously we discussed two strategies—testing and dropping items from further study—that students do implement on a somewhat regular basis. Next we consider two more student-centric strategies—note-taking and highlighting/underlining text—that are among the most common learning strategies that students use.

Marking text by highlighting or underlining is a ubiquitous strategy (Dunlosky et al., 2013; Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007). It is not necessary to do scientific research to know that students commonly do take advantage of highlighting (or underlining) while reading. A more interesting issue is the choices students make about what to highlight—and the degree to which these choices enhance learning. The literature on highlighting suggests that the efficacy of highlighting depends greatly on these fine-grained decisions: Students who are good at highlighting seem to benefit from doing so, but for many students, highlighting does not seem to enhance learning, perhaps because these students do not always select the most important information (for a review see Dunlosky et al., 2013).

Deciding What to Write Down While Taking Notes

Taking notes is another ubiquitous study technique. Note taking has two primary impacts on learning. First, notes are a source of information. Most students, especially in college, rely on two sources of information when studying for a test: readings and their notes. There is clear evidence that note-taking enhances learning if the students are later allowed to review their notes (Kiewra, 1989). Second, even if students do not return to their notes later, taking notes can enhance learning because it engenders beneficial processes during encoding (Bretzing & Kulhavy, 1979, 1981; Peverly, Brobst, Graham, &

Shaw, 2003). However, as with highlighting/underlining, there may not be a single answer as to whether taking notes is beneficial; the answer depends on the quality of the notes (Kiewra, 1985; Kobayashi, 2005).

Ironically, as a recent study showed, making note taking faster and easier can actually impair learning. Mueller and Oppenheimer (2014) assigned participants to take notes longhand or on a laptop while watching a series of video lectures. The laptop group could take notes more quickly, so they took more notes and their notes were closer to being verbatim transcripts of the lecture. The longhand group, who could not write as quickly, wrote less but their notes were summaries. The longhand group did better on the final test in two experiments, and this was true when participants were allowed to study their notes before taking the test and when they were not. These results suggest that note taking may be least beneficial when it involves verbatim transcription of what is being said in class. Summarization is more beneficial, presumably because it requires students to think about the meaning of the material, decide what is important, and come up with a summary in their own words. Thus, the decisions students make while they take notes about what and how much to write down can affect them in important ways. One way for students to get more out of note taking may be to write less and summarize more.

Learning in Digital Environments

In the classroom, students are not usually burdened with the task of self-regulating their learning because teachers do it for them. Teachers monitor student learning, create deadlines, and provide incentives (in the form of grades) for good study habits (for more on strategy use in the classroom see Winne, this volume).

The increasing importance of learning outside of formal education may be ushering in a shift in the type and amount of self-regulation expected of learners. Teacher-controlled learning is common in class, but a do-it-yourself type of self-regulation is common outside of school—not only in doing homework, but also in many digital learning environments, which play an ever-growing role in delivering educational content.

Computer-based training systems, game-based learning, Massive Open Online Courses (MOOCs), Intelligent Tutoring Systems, and flipped/blended classrooms are examples of environments that deliver or augment instruction via a digital learning platform. In these contexts, the classic conception of a classroom teacher guiding instruction is not necessarily eliminated, but it is modified. For example, in game-based learning or computer-based training systems, animated agents or tutors may guide learning or model study skills. In MOOCs, students may have assignments or problem sets to complete, but how much time they spend listening to each lecture, for example, is entirely up to the student.

It can take time for students in a new educational system to adjust and learn to make the most of their learning opportunities. Digital learning environments have been changing quickly in recent years and show no signs of slowing down. Next we review research on the nature of such systems and the challenges they pose for students with respect to self-regulated learning.

Most technology-based learning and training programs aim to make the learner construct knowledge rather than absorb it passively (Graesser, Conley, & Olney, 2012). For example, blended classrooms use both electronic media and face-to-face learning methods. Computer-based training systems present instruction in a multimedia format, and tests and feedback are given online. A number of these systems have shown benefits compared to standard classroom instruction (Dodds & Fletcher, 2004; Graesser et al., 2012). Traditionally, these methods have not left it to the student to regulate their learning strategies. In many ways, the computer does it for them by scaffolding key learning processes.

Intelligent Tutoring Systems (ITS) are computerized learning environments that draw from psychology, cognitive science, and learning sciences. ITS are designed with the intent of providing a more flexible and tailored approach to learning by being sensitive to the student's knowledge and ability level, by proceeding adaptively through a schedule of instruction, and by promoting deep content and skill learning (Aleven & Koedinger, 2002). ITS are currently in use in school systems; for example, Carnegie Learning (Anderson, Corbett, Koedinger, & Pelletier, 1995) developed the Cognitive Tutor™ which is based on the cognitive model ACT-R (e.g., Anderson, 1996) and is used by over 2,000 school systems (see Graesser et al., 2012, for a comprehensive review of intelligent tutoring systems). Again, ITS guide student learning rather than having the student self-regulate the entire process.

Recently, however, there has been interest in understanding the dynamic of students' regulatory processes in computer-based learning environments (Azevedo, 2005a, 2005b). For example, Azevedo and collaborators have targeted questions of how computer and human scaffolds facilitate subsequent self-regulatory processes such as planning and monitoring during the learning of challenging science topics (Azevedo & Cromley, 2004; Azevedo, Cromley, & Seibert, 2004; and see Azevedo, 2005b for a review). Other research has focused on how computer-based learning environments allow the capture of data about how students are regulating their learning, for example by measuring quality and quantity of highlighted text or click stream information (Schraw, 2010; Winne, 2010), and how these behaviors map on to performance outcomes (Sansone, Fraughton, Zachary, Butner, & Heiner, 2011).

In recent years there has been growing interest and investment in serious video games designed to enhance learning and promote student engagement. While some are skeptical about the use of games to enhance deep learning (Prensky, 2000), there is a growing sentiment that studying games as a way to engage and encourage learning might be fruitful, in at least some domains. Recently the United States Department of Education put forward an appeal for research “that explores how embedded assessment technologies, such as simulations, collaboration environments, virtual worlds, games, and cognitive tutors, can be used to engage and motivate learners while assessing complex skills” (U.S. Department of Education Office of Educational Technology, 2010, p. 15).

MOOCs, and online courses in general, are playing a growing role in education. Two of the largest MOOC providers, Coursera and edX, claimed that nearly 4.5 million students enrolled in their MOOC courses combined (Breslow et al., 2013). The format of most MOOCs is fairly similar to lecture classes that are given on campus. For example, the first MITx course, Circuits and Electronics (6.002x), is required for undergrads in the Department of Electrical Engineering and Computer Science. The class consisted of a set of video lectures that lasted about 10 minutes each and had illustrations, texts, and equations drawn out on a white board. There were also online exercises and tutorials, an electronic textbook, a discussion forum, and a wiki (Breslow et al., 2013; Seaton, Bergner, Chuang, Mitros, & Pritchard, 2014). Students were graded on 12 homework assignments, 12 lab assignments, a midterm, and a final.

There are a number of major differences between MOOCs and on-campus classes, however. One is that the MOOC completion rate is much lower, with some reports showing only 5% of students completing the average course (Ho et al., 2014). It is possible that at least some students do not finish because of the heightened difficulty of successful self-regulated learning—in particular, they may find it difficult to stay motivated when they are not receiving grades and course credit from a university. Some argue, however, that course efficacy should not be measured solely by completion or certification rates (e.g., DeBoer, Ho, Stump, & Breslow, 2014; Ho et al., 2014). They argue that the difference in numbers reflects a difference in how students approach taking the course—instead of completing it, they may take just as much as they want or need from it. For these students, MOOCs serve a different purpose than most colleges and university courses, which are built on the proposition that taking bits and pieces of a course is not enough. In addition, although the percentages are very low, the actual numbers can be substantial. If 20,000 students enroll in a MOOC, and only 5% finish, that still means that 1,000 completed the course. MOOCs are clearly a new model of student learning and will provide a new context for understanding how students regulate their learning.

Gaming is at the opposite end of the spectrum from MOOCs with respect to motivation: Whereas students in MOOCs sometimes seem to have too little motivation, games create high levels of motivation by spurring curiosity, interest, competition, feedback, and challenge (Graesser et al., 2012), all which promote engagement and motivation, which are strongly related to student achievement (Shute, Ventura, Bauer, & Zapata-Rivera, 2009). Games can also provide immediate feedback and continued practice and can be tailored to the player. It is clear that practice with the game will enhance the specialized skills needed for that particular game. However, it is less clear whether such learning will transfer to novel contexts (Curtis & Lawson, 2002; Egenfeldt-Nielsen, 2006). Graesser and colleagues (e.g., Graesser, Chipman, Leeming, & Biedenbach, 2009) note that the challenge to using games as an instructional tool is ensuring that they are designed to facilitate deep conceptual learning, such as understanding of causal mechanisms and critical reasoning skills, as compared to shallow learning of motor skills or word definitions. Another challenge is that, while players do show gains in skills over the course of some games, there is a shortage of research that has tested a particular educational game against another instructional format (McClarty et al., 2012).

Struggling *While* Thinking or Struggling *to* Think

Learning happens when one is thinking hard and struggling with the material (Bjork & Bjork, 2011; Hiebert & Grouws, 2007). But there are many kinds of struggle. It is especially important to understand the difference between two types of struggle: struggling *while* thinking and struggle *to* think.

Struggling *while* thinking, which means thinking hard about the information one is trying to learn, is productive and desirable. For example, testing oneself and spacing one's study are effective because they increase the chance a learner will struggle with his or her knowledge. Reducing struggle while thinking is like using an unnecessary crutch or a cheat; it robs the learner of an opportunity to process information in a meaningful and elaborate way.

Struggling *to* think, which means struggling to dedicate one's mental resources to thinking hard, is neither productive nor desirable. For example, studying in a place full of distractions can prevent learners from engaging with the material they are trying to learn. Reducing struggle to think makes it easier for students to struggle while thinking.

When studying is done right, struggling while thinking is hard enough. Struggling to think only makes things worse.

When students decide how to study, they should be careful about how to engage in productive struggle. The question to ask is, "What am I making easy for myself?" For example, when studying physics, checking the answer in the back of the book during a problem set, or getting a friend's help solving the problem without actually understanding it, can make homework easier in a way that impairs learning. Making it easier in this way—using crutches and shortcuts—can be a mistake. But making it easier in the sense that one does the reading, takes time to think about the relevant concepts, and works on the problem without being distracted involves no shortcuts, and this kind of "making it easier" can be very effective.

Do not take shortcuts along the path to knowledge. Do not get diverted to an easier path that does not lead to the goal. The easy path will not get you there. But if you are traveling the true path, do not make the path more difficult than it needs to be. Stay focused on the goal. It is not always as fun while you study (shortcuts can save time, after all), but you will be happy when you know the answers on the test.

Future Directions

Decisions about prioritization (e.g., "What should I study and for how long?") have received a great deal of research attention. Most of this research has focused on decisions at the level of items within a topic, such as, "Should I stop studying this item?" (Metcalfe, 2002; Nelson & Leonesio, 1988; Price & Murray, 2012; for a review see Son & Metcalfe, 2000). Choosing an item from within a topic is a fine-grained decision. Research is needed on larger-scale prioritization decisions, such as deciding which topic to study (i.e., deciding between topics) and deciding whether to study or not in the first place. Decisions about which topic to study next are largely driven by assignment due dates (Kornell & Bjork, 2007), at least for students in school. Decisions about whether or not to study, which probably have large effects on student learning, are influenced by the planning fallacy and procrastination, two biases that influence all humans, not just students, but that deserve further attention with respect to study decisions.

The majority of research on self-regulated study, at least in cognitive psychology, takes a cognition-centric approach. More student-centric research should be conducted on questions that students want answers to, such as the strategies students use when they engage in common study activities, such as when they take notes, highlight/underline, copy their notes, make flashcards, and so on.

One student-centric issue that has received relatively little research attention is how people study various types of material and for various courses. What students do, and what works, almost certainly depends on whether a student is taking literature, math, or Spanish (and so forth). Research on the strategies used with different learning materials would be productive. On a related note, research on learning in digital environments (see earlier section) would involve examining study strategies in various learning environments and incentive systems.

There are multiple differences between learning word pairs, which is frequently the task in lab studies, and learning something more complex like American history. One difference is that word pairs are not complex or difficult to understand and they mainly require memorization. American history, and most high school and college courses, require conceptual understanding. For example, as students prepare to study for an upcoming American history exam, they need to evaluate how much they know about the Progressive Era and the Vietnam War, and how much time they should dedicate to reviewing each of those topics. A few recent studies have investigated JOLs with respect to category learning, which involves learning perceptual concepts (Jacoby, Wahlheim, & Coane, 2010; Wahlheim, Dunlosky, & Jacoby, 2011; Wahlheim, Finn, & Jacoby, 2012), and research on metacomprehension was reviewed earlier. However, there is little research on self-regulated study with respect to learning concepts. It seems likely to be a topic of future investigation, since understanding how people evaluate their conceptual knowledge and make study decisions about it has obvious implications for education.

Practical Recommendations to Learners

With respect to how to study, our most general advice is this: It is crucial that you struggle while thinking, because easy studying is often ineffective. Do not try to take shortcuts on the path to knowledge. Instead, make it as easy as possible to think hard by avoiding pitfalls such as trying to study in a situation that leads to too much distraction. We have already alluded to multiple productive ways to make things difficult. For example, if you want to do well on a test, do not make the mistake of going over the answers and deciding that you know them—which is easy when they are right in front of you. Instead simulate test conditions by quizzing yourself and see if you really know the answers. Other examples include summarizing rather than transcribing notes during a lecture, spacing repeated study sessions apart in time to allow forgetting, asking oneself questions while studying, and returning to restudy information that seemed well-learned at one point but might have been forgotten. These strategies have dual benefits: They enhance learning and make self-monitoring more accurate.

One reason to make things difficult while studying is that making things too easy leads to overconfidence, which in turn leads students to stop studying too soon. Students should actively avoid overconfidence, especially students who have a pattern of doing worse on exams than they expected. One way to avoid overconfidence is to test oneself; another is to consider what could go wrong on a test and think about what one does not know. Ironically, students also tend to be underconfident in their ability to learn and improve, and so a student who is discouraged by how difficult the material is might benefit from remembering that she is prone to underestimating her capacity for learning.

Procrastination is huge hurdle to effective studying. Advice that one should avoid procrastination is easy to find (e.g., Benjamin Franklin: "Don't put off until tomorrow what you can do today,") but advice on how to do so is difficult to come by. Research suggests that there are ways of decreasing procrastination: Increase expectancy of success, set appropriate and achievable subgoals, and form predictable work habits that essentially make the decision that it is time to work *for* you (Steel, 2007). There are also ways to overcome another huge problem for studiers, the planning fallacy: One way is to break the task down into elements and consider how long each subtask will take (Kruger & Evans, 2004); another is to consciously estimate that everything will take twice as long as you think it will take.

Studying more is not effective unless one is smart about how to study. We have tried to explain how students can become smarter studiers. Making bad choices about *how* to study can be akin to pedaling a stationary bike: You put in effort but you go nowhere. Making bad choices about *what and when* to study can be like riding in the wrong direction (*what*) or starting a race at the wrong time (*when*). Our goal in this chapter is to point studiers in the right direction and give them a faster bike. There is one last piece of advice, and it is the most obvious of all: The more time you spend riding, the farther you get—and the same is true of studying. First learn to study efficiently and then study a lot. Distance = rate × time, and learning = efficiency × time. If you end up accomplishing your goals and have free time afterward, study some more.

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