Self-Regulated Learning: Beliefs, Techniques, and Illusions

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Abstract

Knowing how to manage one's own learning has become increasingly important in recent years, as both the need and the opportunities for individuals to learn on their own outside of formal classroom settings have grown. During that same period, however, research on learning, memory, and metacognitive processes has provided evidence that people often have a faulty mental model of how they learn and remember, making them prone to both misassessing and mismanaging their own learning. After a discussion of what learners need to understand in order to become effective stewards of their own learning, we first review research on what people believe about how they learn and then review research on how people's ongoing assessments of their own learning are influenced by current performance and the subjective sense of fluency. We conclude with a discussion of societal assumptions and attitudes that can be counterproductive in terms of individuals becoming maximally effective learners.

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INTRODUCTION

Increasingly, learning is happening outside of formal educational settings and in unsupervised environments. Our complex and rapidly changing world creates a need for self-initiated and self-managed learning—not only during the years typically associated with formal education, but also across the lifespan—and technological advances provide new opportunities for such learning. Knowing how to manage one's own learning activities has become, in short, an important survival tool. In this review we summarize recent research on what people do and do not understand about the learning activities and processes that promote comprehension, retention, and transfer.

Importantly, recent research has revealed that there is in fact much that we, as learners, do not tend to know about how best to assess and manage our own learning. For reasons that are not entirely clear, our intuitions and introspections appear to be unreliable as a guide to how we should manage our own learning activities. One might expect that our intuitions and practices would be informed by what Bjork (2011) has called the "trials and errors of everyday living and learning," but that appears not to be the case. Nor do customs and standard practices in training and education seem to be informed, at least reliably, by any such understanding.

Certain societal attitudes and assumptions also seem to play a role in our not learning how to become maximally effective learners. One such assumption seems to be that children and adults do not need to be taught how to manage their learning activities. In surveys of college students by Kornell & Bjork (2007) and Hartwig & Dunlosky (2012), for example, about 65% to 80% of students answered "no" to the question "Do you study the way you do because somebody taught you to study that way?" (Whether the 20% to 35% who said "yes" had been taught in a way that is consistent with research findings is, of course, another important question.) Institutions, such as colleges, tend to be concerned about whether incoming students possess background knowledge in certain important domains, such as English or mathematics, and tests are often administered to assess whether such knowledge has been acquired. Only rarely, though, are students tested for whether they have the learning skills and practices in place to take on the upcoming years of learning in an efficient, effective way.

It seems likely that the absence of instruction on how to learn does indeed reflect an assumption that people will gradually acquire learning skills on their own—because their experiences across years of learning in schools, the home, and elsewhere will teach them how to manage their own learning—but the prevailing societal emphasis on innate individual differences in learning ability or style may also play a role. The notion that individuals have their own styles of learning, for example, may lead, implicitly or explicitly, to the idea that it is not possible to come up with training on how to learn that is applicable to all individuals (for a review of the learning-styles concept and evidence, see Pashler et al. 2009). The research we review in this article suggests, in contrast, that there are indeed general principles and practices that can be applied to everybody's learning.

BECOMING SOPHISTICATED AS A LEARNER

Before proceeding to reviews of what learners tend to believe about how to learn and what influences learners' ongoing judgments of whether learning has been achieved, it seems useful to consider what someone would need to know in order to become truly sophisticated as a learner. In our view, as we sketch below, becoming truly effective as a learner entails (*a*) understanding key aspects of the functional architecture that characterizes human learning and memory, (*b*) knowing activities and techniques that enhance the storage and subsequent retrieval of to-be-learned information and procedures, (*c*) knowing how to monitor the state of one's learning and to control one's learning activities in response to such monitoring, and (*d*) understanding certain biases that can impair judgments of whether learning that will support later recall and transfer has been achieved.

Understanding Relevant Peculiarities of Human Memory

To become maximally effective as a learner requires, in part, understanding what Bjork & Bjork (1992) labeled "important peculiarities" of the storage and retrieval processes that characterize human learning and memory. Doing so involves understanding some key ways that humans differ from man-made recording devices. It is important to understand, for example, that we do not store information in our long-term memories by making any kind of literal recording of that information, but, instead, we do so by relating new information to what we already know. We store new information in terms of its meaning to us, as defined by its relationships and semantic associations to information that already exists in our memories. What that means, among other things, is that we have to be an active participant in the learning process—by interpreting, connecting, interrelating, and elaborating, not simply recording. Basically, information will not write itself on our memories. Conscientiously taking verbatim notes or reading to-be-learned content over, if it is done in a passive way, is not an efficient way to learn.

We need to understand, too, that our capacity for storing to-be-learned information or procedures is essentially unlimited. In fact, storing information in human memory appears to create capacity—that is, opportunities for additional linkages and storage—rather than use it up. It is also important to understand that information, once stored by virtue of having been interrelated with existing knowledge in long-term memory, tends to remain stored, if not necessarily accessible. Such knowledge is readily made accessible again and becomes a resource for new learning.

To be sophisticated as a learner also requires understanding that accessing information stored in our memories, given certain cues, does not correspond to the "playback" of a typical recording device. The retrieval of stored information or procedures from human memory is a fallible process that is inferential and reconstructive—not literal. Research dating back to a classic study by Bartlett (1932) has demonstrated repeatedly that what we recall of some prior episode, often confidently, can actually be features of the episode combined with, or replaced by, features that derive from our assumptions, goals, or prior experience, rather than from the episode itself. When we remember the past, we are driven, if not consciously, to make our recollections fit our background knowledge, our expectations, and the current context.

Importantly, retrieval is also cue dependent. The fact that some to-be-learned information is readily recallable during the learning process—owing, perhaps, to recency and/or cues that are present during learning but will not be present later—does not necessarily mean it will be recallable in another time and place, after the learning process has ended.

It is critical, too, for a learner to understand that retrieving information from our memories has consequences. In contrast to the playback of information from some man-made device, such as a compact disk, retrieving information from human memory is a "memory modifier" (Bjork 1975): The retrieved information, rather than being left in the same state, becomes more recallable in the future than it would have been without having been accessed. In fact, as a learning event, the act of retrieving information is considerably more potent than is an additional study opportunity, particularly in terms of facilitating long-term recall (for reviews of research on retrieval as a learning event, see Roediger & Butler 2011, Roediger & Karpicke 2006). Under some circumstances, it may also be important for a learner to understand that such positive effects of retrieval on the later recall of the retrieved information can be accompanied by impaired retrieval of competing information, that is, recall of other information associated to the same cues, an effect labeled retrieval-induced forgetting by Anderson et al. (1994) (see sidebar Retrieval-Induced Learning and Forgetting).

Broadly, then, to be a sophisticated learner requires understanding that creating durable and flexible access to to-be-learned information is partly a matter of achieving a meaningful encoding of that information and partly a matter of exercising the retrieval process. On the encoding side, the goal is to achieve an encoding that is part of a broader framework of interrelated concepts and ideas. On the retrieval side, practicing the retrieval process is crucial. To repeat an example provided by Bjork (1994), one chance to actually put on, fasten, and inflate an inflatable life vest would be of more value—in terms of the likelihood that one could actually perform that procedure correctly in an emergency—than the multitude of times any frequent flier has sat on an airplane and been shown the process by a flight attendant.

Knowing Activities and Techniques that Enhance Storage and Retrieval

Beyond achieving a general understanding of the storage and retrieval processes that characterize human learning and memory, a truly effective learner needs to engage in activities that foster storage of new information and subsequent access to that information. Doing so involves focusing on meaning, making connections between new concepts and concepts that are already understood, organizing to-be-learned knowledge, and so forth. It also involves taking advantage of technologies that have the potential to enhance such activities, as well as taking advantage of the power of collaborative interactions to enrich the encoding of information and concepts and exercise the retrieval of such information and concepts.

Becoming sophisticated as a learner also involves learning to manage the conditions of one's own learning. Aside from acquiring any conceptual understanding of why certain learning activities enhance later recall and transfer of to-be-learned knowledge and procedures, simply knowing that one should incorporate such activities into how one manages one's own learning can be a major asset. Thus, for example, knowing that one should space, rather than mass, one's study sessions on some to-be-learned topic can increase one's effectiveness as a learner, as can knowing that one should interleave, rather than block, successive study or practice sessions on separate to-be-learned tasks or topics (see, e.g., Cepeda et al. 2006). Similarly, knowing that one should vary the conditions of one's own learning, even, perhaps, the environmental context of studying (Smith et al 1978, Smith & Rothkopf 1984), versus keeping those conditions constant and predictable, can make one a more effective learner, as can knowing that one should test one's self and attempt to generate information or procedures rather than looking them up (e.g., Jacoby 1978). Some of the evidence that such manipulations of the conditions of learning enhance later recall is presented later in this review, but for now the point is that becoming sophisticated as a learner requires knowing how to manage one's own learning activities. In that respect, we are both teacher and student.

What makes acquiring such sophistication difficult is that the short-term consequences of introducing manipulations such as spacing, variation, interleaving, and generating can seem far from beneficial. Such manipulations introduce difficulties and challenges for learners and can appear to slow the rate of learning, as measured by current performance. Because they often enhance long-term retention and transfer of to-be-learned information and procedures, they have been labeled desirable difficulties (Bjork 1994), but they nonetheless can create a sense of difficulty and slow progress for the learner.

RETRIEVAL-INDUCED LEARNING AND FORGETTING

In general, the fact that retrieving information from our memories not only makes the retrieved information more recallable in the future, but also renders competing information—that is, information associated with the same cues—less accessible, is adaptive. Making competing information less accessible, however, can be undesirable under some circumstances, such as when items subjected to such retrieval-induced forgetting are then needed later. Might practice tests, for example, which typically consist of items that differ from those on the later criterion text, actually impair access to information selected against on the practice test, but later needed on the criterion test? It is important to know what conditions and types of testing enhance retrieval-induced forgetting when it is adaptive and eliminate it when it is nonadaptive. Recent findings (see Little et al. 2012), for example, suggest that multiple-choice practice tests may have the virtue that items presented as incorrect alternatives become more, rather than less, accessible when they are later the correct answer to different questions.

Monitoring One's Learning and Controlling One's Learning Activities Effectively

Finally, learning effectively requires not only making accurate assessments of the degree to

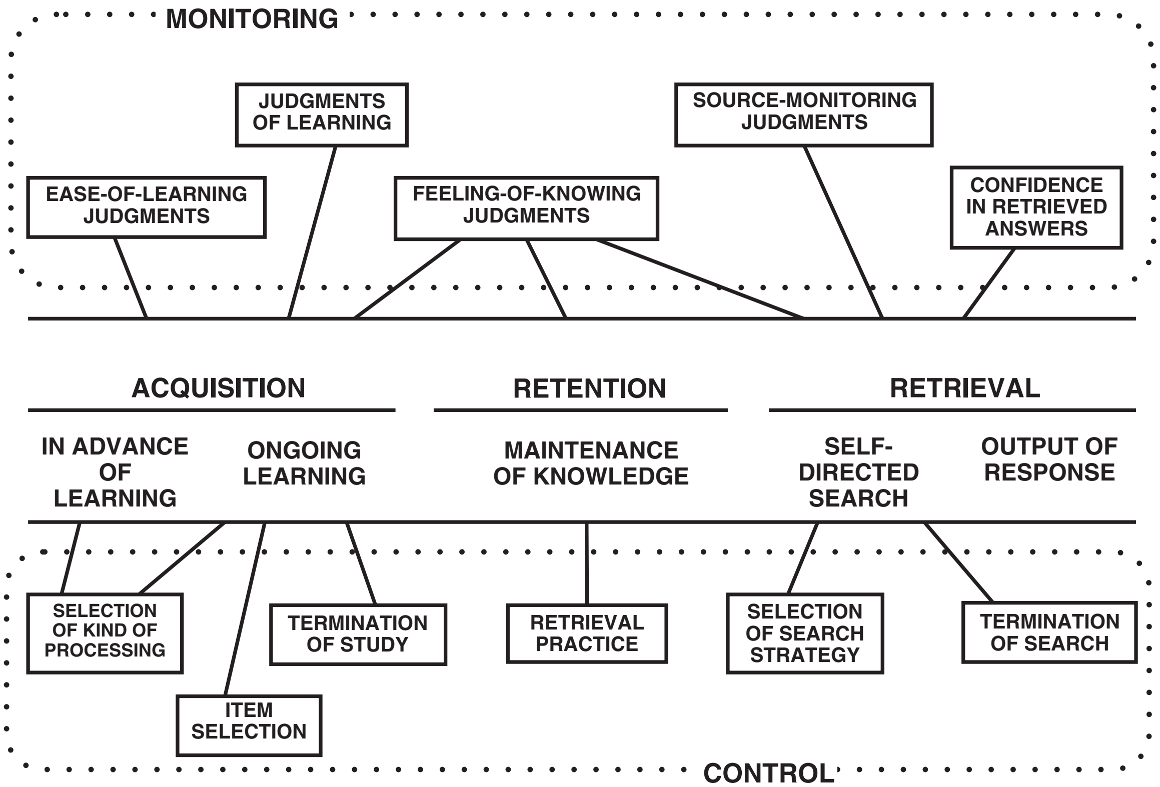

Figure 1

Adapted from Nelson & Narens's (1990) framework for metamemory. From Dunlosky et al. (2007).

which one's learning goals have been achieved, but also responding in effective ways to such assessments. As Nelson & Narens (1990) argued in an influential paper, metacognitive monitoring and metacognitive control play important roles—and interact in important ways—during the acquisition, the retention, and the retrieval of to-be-learned information. Their framework, shown with two additions in **Figure 1**, served as an early guide for research on metacognition and remains a useful framework. Dunlosky et al. (2007) added "source-monitoring judgments" to Nelson & Narens's (1990) framework, and we have added "retrieval practice" during the retention phase in order to reflect that a sophisticated learner may know that information and procedures, to remain accessible until some criterion test, must be reinstated/retrieved prior to that test.

Basically, the learning process involves making continual assessments and decisions, such as what should be studied next and how it should be studied, whether the learning that will support later access to some information, concept, or procedure has been achieved, whether what one has recalled is correct, and on and on. As captured in **Figure 1**, there is an important back and forth between monitoring and control. To become sophisticated and effective as a learner requires not only being able to assess, accurately, the state of one's learning (as illustrated by the monitoring judgments listed in the top of the figure), but also being able to control one's learning processes and activities in response to such monitoring (as illustrated by the control decisions).

Becoming sophisticated in monitoring and controlling one's learning and learning activities turns out to be no small challenge. As demonstrated by the research reviewed below, (*a*) learners can easily be misled as to whether learning has been achieved, typically resulting in overconfidence, and (*b*) what people tend to believe about activities that are and are not effective for learning is often at odds with reality. Assessing the state of one's learning is difficult because the objective and subjective indices on which one might base such assessments, such as current performance or the sense of familiarity or fluency in encoding or retrieving to-be-learned information, can reflect factors unrelated to whether learning has been achieved. Current performance—and the subjective sense of retrieval fluency, that is how readily information and procedures come to mind—can be heavily influenced by factors such as recency, predictability, and cues that are present during learning but will not be present later, and the subjective sense of familiarity or perceptual fluency can reflect factors such as priming rather than being a valid measure of learning.

Finally, to be effective in assessing one's own learning requires being aware that we are subject to both hindsight and foresight biases in judging whether we will be able to produce to-be-learned information at some later time. Hindsight bias (Fischhoff 1975) refers to the tendency we have, once information is made available to us, to think that we knew it all along. Thus, a student preparing for an examination and trying to decide what to study in the time remaining before the exam may try to base such judgments on scanning sections of a textbook chapter, but such judgments will tend to be unreliable because the information is at hand, so to speak. Foresight bias (Koriat & Bjork 2005), on the other hand, rather than reflecting a knew-it-all-along tendency, reflects a will-know-it-in-the-future tendency. It derives from an inherent difference between study and test situations—namely, that the answer is present during study, but will be absent and required at test—and it is most likely to occur when an answer that is solicited during testing is judged to be natural or obvious when presented along with the question, but is less likely to come forward, owing to the elicitation of other possible answers, when the question is presented alone.

WHAT DO STUDENTS BELIEVE ABOUT HOW TO LEARN?

What kinds of strategies do students believe work best? Which ones do they use, and does using them relate to their achievement? To answer such questions, researchers have generally used two methods—administering questionnaires about strategy use and examining how students use strategies to manage their learning in the laboratory. We review evidence from both methods below, and, to foreshadow, the evidence converges on a sobering conclusion: Although individual differences occur in effective strategy use, with some students using effective strategies that contribute to their achievement, many students not only use relatively ineffective strategies (e.g., rereading), but believe that they are relatively effective.

Surveys of Students' Strategy Use and Beliefs About Studying

One of the most frequently used assessments of student self-regulation is the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich et al. 1993). The MSLQ includes 81 items that measure 15 subscales that pertain to student motivation and strategy use. Of most relevance here, four subscales tap students' use of general learning strategies. These subscales are each measured by multiple items and include elaboration (e.g., pulling information together from multiple sources when studying), rehearsal (e.g., repeating materials over to oneself), organization (e.g., outlining the material to organize it), and critical thinking (e.g., questioning what one reads while studying). In a recent meta-analysis, Credé & Phillips (2011) examined the relationship among these subscales and student grades from 67 independent samples that included responses from over 19,000 college students. The relationships between these subscales and student grades were low and sometimes nonsignificant. As noted by Credé & Phillips (2011), however, these low relationships may arise for multiple reasons. The relationships may not be linear, with some strategies being used largely by average students. For instance, high performers may not need to use repetition and low performers may not be motivated to use repetition. Moreover, these general strategies will not be effective for all kinds of exams; thus, those endorsing the use of critical thinking during study may not outperform others when exams merely tap memory for the materials. Other limitations are that the general wording of the scale items may not be interpreted the same way by all students (Credé & Phillips 2011), that some of these strategies are just not that effective (e.g., rehearsal or repetition), and that others are effective only if used properly.

One way to sidestep some of these limitations—such as differences in scale interpretation—is simply to ask students to identify the specific strategies that they use while studying. For instance, self-testing is an effective strategy that may boost student performance because it can promote both elaboration and organization (e.g., Carpenter 2011; Pyc & Rawson 2010, 2012; Zaromb & Roediger 2010), but the single question about this effective strategy on the MSLQ is treated more generically as a learning strategy that contributes to only one subscale. To assess more directly the use of specific strategies, Kornell & Bjork (2007) had 472 college students at the University of California, Los Angeles fill out a study-habit survey that focused on their use of rereading and testing. Seventy-six percent indicated that they reread either whole chapters or what they had underlined, and around 90% indicated that they used self-testing in some fashion. In a follow-up to this survey study, Hartwig & Dunlosky (2012) reported nearly identical usage for 324 college students at Kent State University, and, importantly, they related frequency of use of these strategies to the students' grade point average (GPA). Both testing and rereading were significantly correlated with GPA (see also Gurung et al. 2010).

These survey results at first seem at odds with outcomes from students' free reports of study strategies. When simply asked, for example, "What kind of strategies do you use when you are studying," only 11% of college students from Washington University reported practicing retrieval (Karpicke et al. 2009). One possible resolution of the discrepancy is that college students may not believe testing is a strategy to enhance learning, so they may not include it in free reports of their strategy use. Consistent with that possibility, when Kornell & Bjork (2007) asked students why they used self-testing, only 18% indicated that they used it because they learn more when they self-test than when they reread; by contrast, about 70% indicated that they used self-testing to figure out how well they have learned the information.

Such beliefs may explain in part why few students reported the use of self-testing when asked about their strategy use on the open-ended survey administered by Karpicke et al. (2009). In fact, when the same students were given a forced-choice question about testing, many more (about 42%) endorsed its use. Thus, many students do use this effective learning strategy, but the prevalent belief is that self-testing is largely for self-evaluation, and most students believe that rereading is a more effective strategy than is self-testing (McCabe 2011). Both of these inaccurate beliefs about self-testing may curtail its use.

Self-testing is intrinsic to the use of flashcards that many students report using (Hartwig & Dunlosky 2012, Karpicke et al. 2009), but do students use them effectively? To address this question, Wissman et al. (2012) had college students complete a survey designed to reveal, among other things, how and when students use self-testing with flashcards. The students surveyed reported using flashcards mainly to learn vocabulary. Moreover, when using flashcards, they reported that they would continue until they had correctly recalled a response three or more times, which does, in fact, yield much better retention of vocabulary compared to recalling a response only once (Pyc & Rawson 2009, Vaughn & Rawson 2011). Almost all the students reported that they would use flashcards more than once to learn materials for an exam, but they also reported that such use was largely limited to just a day or two before the exam. This kind of cramming is popular (Taraban et al. 1999) and certainly does not optimize retention, although students believe it is an effective way to learn (Kornell 2009).

Students' Beliefs as Indexed by Decisions They Make in Managing Their Learning

Another way researchers have investigated students' beliefs about how to learn is to have them complete a task and observe how they approach it. One straightforward method that has provided compelling results is to have students self-pace the study of to-be-learned materials and then examine how they allocate study time to each item (for a historical review, see Son & Kornell 2008). In a typical experiment, the students first study all the items at an experimenter-paced rate (e.g., study 60 paired associates for 3 seconds each), which familiarizes the students with the items; after this familiarity phase, the students then either choose which items they want to restudy (e.g., all items are presented in an array, and the students select which ones to restudy) and/or pace their restudy of each item. Several dependent measures have been widely used, such as how long each item is studied, whether an item is selected for restudy, and in what order items are selected for restudy.

The literature on these aspects of self-regulated study is massive (for a comprehensive overview, see both Dunlosky & Ariel 2011a and Son & Metcalfe 2000), but the evidence is largely consistent with a few basic conclusions. First, if students have a chance to practice retrieval prior to restudying items, they almost exclusively choose to restudy unrecalled items and drop the previously recalled items from restudy (Metcalfe & Kornell 2005). Second, when pacing their study of individual items that have been selected for restudy, students typically spend more time studying items that are more, rather than less, difficult to learn. Such a strategy is consistent with a discrepancy-reduction model of self-paced study (which states that people continue to study an item until they reach mastery), although some key revisions to this model are needed to account for all the data. For instance, students may not continue to study until they reach some static criterion of mastery, but instead, they may continue to study until they perceive that they are no longer making progress (for details, see Dunlosky & Thiede 1998, Metcalfe & Kornell 2005).

Third, students develop agendas—that is, plans—for the allocation of their study time, and sometimes these agendas, in contrast to the discrepancy-reduction model, do not prioritize the most difficult items for study (Ariel et al. 2009). Thiede & Dunlosky (1999), for example, told students that their goal was merely to learn 6 out of the 30 items that were being presented for study. In this case, students presumably developed an agenda to complete the task efficiently and selected to restudy only a few of the easiest items to restudy. Similarly, Metcalfe (2009, Kornell & Metcalfe 2006) reported that under some conditions students choose the easiest items first for study and spend more time studying the easiest items. Focusing on the easier items first (which Metcalfe calls studying within the region of proximal learning) is one of many agendas that students can develop to allocate their study time, and doing so can even boost their learning (Atkinson 1972, Kornell & Metcalfe 2006).

Finally, developing agendas to allocate study time effectively is a mindful way to approach a new learning task, but students do not always mindfully regulate their study. Instead, their study choices are sometimes biased by habitual or prepotent responses. One habitual bias that can disrupt effective allocation of study time arises from reading. When students are given an array of items to study (e.g., a list of vocabulary items in a textbook), native English speakers choose items for study in a left-to-right (or top-down) manner (Dunlosky & Ariel 2011b) instead of first focusing on either the most difficult items (as per discrepancy reduction) or easiest items (as per the region of proximal learning). The idea here is simply that habitual biases can undermine the development of effective agendas for study time allocation. Thus, for example, a student preparing for a test might simply open a textbook and read through the assigned pages versus having any kind of plan of attack that might guide their studying. Such passive reading—and even rereading—is much less effective than active processing, such as self-explanation or self-testing.

Recent studies have used a modified version of the self-paced study method to investigate when and how students allocate their learning. As described above, participants typically receive a familiarity phase with the items (e.g., a brief experimenter-paced presentation of each item) and then make a control decision about what to do next. These studies explore the kinds of practice schedule that students use while studying, such as whether they prefer spacing or massing their study (e.g., Benjamin & Bird 2006; Pyc & Dunlosky 2010; Son 2004, 2010; Toppino & Cohen 2010; Toppino et al. 2009) and whether they prefer to reschedule practice-test trials or restudy trials (Karpicke 2009, Kornell & Son 2009). Researchers are only beginning to investigate these topics, but some intriguing issues have emerged, and we consider three of them next.

The first issue concerns students' decision to use (or not to use) an effective spacing strategy. Consider a commonly reported outcome: When students study an item and are asked either to study it again (i.e., massed study) or to study it later after other items have been studied (i.e., spaced study), they tend to space their study more than they mass it. Even though students prefer to space study in these laboratory experiments, it does not mean that they believe spacing is a more effective strategy. Much evidence suggests otherwise. When students are given the option to space study either after a short lag or after a long lag, they prefer the shorter lag (Cohen et al. 2011, Wissman et al. 2012), which typically yields inferior performance and indicates that students do not understand the power of spacing. Moreover, McCabe (2011) had participants read a scenario where students were either spacing or massing their study of paintings from famous artists, with the goal of later being able to identify which of the studied artists painted each of a series of new paintings. Most participants said that massing would be better than spacing!

Given that students do not understand the power of spacing, it may not be surprising that they fail to incorporate spacing into their study routines. Consider results from Tauber et al. (2012, experiment 3), who had college students attempt to learn to categorize birds into their families. During a familiarity phase, six different birds from eight families (e.g., Jay, Grosbeak, Warbler) were presented individually for 6 seconds. Participants had 30 minutes to restudy the same birds, and they could choose the order in which they studied birds from the families. For this self-paced phase, they were first presented a randomly chosen bird from one family (e.g., a Green Jay, from the Jay family), and when they finished studying this bird, the interface depicted in **Figure 2** was presented.

During the self-paced phase, the participants were instructed to study the birds in an order that would best help them to classify new birds on the final test. On average, participants chose to restudy 57 birds, and a sizable majority of participants (75%) preferred to block (or mass) instead of interleave (or space). In fact, when massing their study, the students tended to study most of the birds within a family (about 5 out of 6) before moving to another one. These data are in line with Simon & Bjork's (2001) findings that contrary to the facts, participants predict higher future performance when getting blocked practice than they do when getting interleaved practice, as discussed in the next session. To summarize, despite the fact that students do choose spacing over massing in some contexts, this choice is unlikely a symptom of effective regulation because students appear not, based on other findings, to understand the power of spacing or use it consistently across different tasks.

The second issue concerns students' decision to stop studying. When given the option to drop items from study, they tend to do so prematurely: They drop them once they believe they have learned them (Metcalfe & Kornell 2005), even though another study attempt or retrieval attempt (e.g., practice test) would further enhance their learning (Karpicke 2009, Kornell & Bjork 2008b). Although this latter outcome suggests that students do not make effective control decisions with regard to the use of practice tests, note that outside of the laboratory, students report testing themselves on items many times after those items can already be successfully retrieved (Wissman et al. 2012). One difficulty here is that some laboratory tasks include constraints (e.g., allowing strategy selection only after all items have already been recalled) that may stifle students' natural use of strategies like self-testing.

Third, and finally, when given the choice to restudy a list of words or to be tested on those words, students tend to request practice tests, especially when these tests involve feedback (Kornell & Son 2009). Consistent with the survey data described above, however, most students report wanting to use a practice test to evaluate their learning and not to enhance it (Kornell & Son 2009). Although speculative, students' use of testing as a tool to monitor memory may ultimately lead them to underuse it as a learning tool.

In summary, students do endorse using some effective strategies for learning, such as self-testing, and they sometimes make good decisions about how to manage their time in laboratory experiments. Nevertheless, other outcomes suggest that students do not fully reap the benefits of these effective strategies. With respect to testing, many students believe that rereading is a superior strategy to testing (McCabe 2010), even though the benefits of rereading are modest at best (Dunloskey et al. 2012, Fritz et al. 2000, Rawson & Kintsch 2005). Moreover, most students use testing to evaluate their learning and hence may not use it more broadly as a strategy to enhance their learning. With respect to spaced practice, even though students sometimes prefer to space study in laboratory experiments, such spacing occurs within a single session. Unfortunately, given that students endorse cramming and believe doing so is effective, they will not obtain the long-term benefits that arise when spacing practice occurs across multiple sessions (e.g., Bahrick 1979, Rawson & Dunlosky 2011).

Why might students underuse effective strategies and believe that ineffective ones are actually effective? One reason why they may underuse effective strategies is that many students are not formally trained (or even told) about how to use effective strategies, perhaps because societal attitudes and assumptions indicate that children and adults do not need to be taught them. As noted by McNamara (2010), "there is an overwhelming assumption in our educational system that the most important thing to *deliver* to students is content" (p. 341, italics in original). Indeed, most college students report that how they study is not a consequence of having been taught how to study by teachers or others (Kornell & Bjork 2007).

Perhaps even worse, students' experience in using strategies may sometimes lead them to believe that ineffective techniques are actually the more effective ones (e.g., Kornell & Bjork 2008a, Simon & Bjork 2001). For instance, across multiple experiments, Kornell (2009) reported that 90% of the college student participants had better performance after spacing than massing practice. When the study sessions were over, however, 72% of the participants reported that massing was more effective than spacing. This metacognitive illusion may arise because processing during study is easier (or more fluent) for massing than spacing, and people in general tend to believe that easier processing means better processing (Alter & Oppenheimer 2009). Unfortunately, as the next section explains in more detail, these metacognitive illusions can trick students into believing that a bad strategy is rather good, which itself may lead to poor self-regulation and lower levels of achievement.

WHAT INFLUENCES LEARNERS' JUDGMENTS OF LEARNING AND PREDICTIONS OF FUTURE PERFORMANCE?

Making sound study decisions is a precondition of being a successful learner. These decisions depend on students' judgments of how well they know the material they are studying. Students often study until they have reached what they deem to be an acceptable level of knowledge (Ariel et al. 2009, Kornell & Metcalfe 2006, Thiede & Dunlosky 1999)—for example, they study chapter 3 until they judge that they will remember what it covers on an upcoming test, then turn to chapter 4, and so forth.

The term judgment of learning (JOL) is used to describe such predictions of future memory performance. In a typical JOL task, participants judge the probability that they will remember the information they are studying on an upcoming test. The accuracy of JOLs can play a large role in determining how adaptive (or maladaptive) study decisions end up being (Kornell & Metcalfe 2006, Nelson & Narens 1990).

What factors influence JOLs? Early metacognition researchers (e.g., Hart 1965) assumed that people judged a memory by making a direct, internal measurement of its strength. According to this direct-access view, a metacognitive judgment is similar to a thermometer, which measures temperature directly, without need for inference. The thermometer is a flawed analogy, however. Metacognition is more like a speedometer, which measures the rotation of a car's tires. A "judgment" of speed is inferred based on the rotation rate. Metacognitive judgments are also inferential (Schwartz et al. 1997). Support for this inferential view comes from studies reviewed in the next section, studies that reveal systematic biases and errors in the inferences people draw. These errors, which are not predicted by the direct-access view, are the clues researchers have used to uncover the mechanisms underlying metacognitive judgments. They are also a cause for concern for learners because faulty monitoring can lead to maladaptive study decisions.

Belief-Based Versus Experience-Based Judgments and Predictions

Judgments of learning are inferences based on cues, but what cues? There appear to be two broad categories of cues—beliefs and experiences (Jacoby & Kelley 1987, Koriat 1997). Belief-based cues (which are also known as theory-based or knowledge-based cues) refer to what one consciously believes about memory, such as "I learn by studying." Experience-based cues include anything learners can directly experience, including how familiar an answer seems, how loud a speaker is talking, how pronounceable a word is, and so forth.

Competition and interactions between experience-based and belief-based cues. A deep psychological difference appears to divide beliefs from experience. Although people clearly hold beliefs about their memories, they frequently fail to apply those beliefs when making JOLs—that is, they are insensitive to belief-based cues even (and perhaps especially) when they are, at the same time, highly sensitive to experience-based cues (see, e.g., Kelley & Jacoby 1996). A study by Kornell et al. (2011b) provides compelling evidence of this phenomenon. Participants were asked to study a list of single words. Two variables were manipulated: Items were presented in a font size that was either large or small, and participants were informed that a given word either would or would not be presented a second time. Font size is an experience-based cue, whereas a future study opportunity cannot be experienced, at least not in the present. Participants' JOLs were consistently affected by font size but were largely unaffected by the number of future study trials. Ironically, the number of study trials had a large effect on learning, whereas font size had no effect.

In addition to providing evidence for the inferential view of metacognition—in which judgments do not necessarily correspond to memory strength—Kornell et al.'s (2011b) findings highlight the fact that people can be sensitive to experience-based cues and not belief-based cues, even in a situation where the opposite should be true.

Evidence of a stability bias. Failing to predict that future studying will affect one's knowledge is an example of what Kornell & Bjork (2009) labeled a stability bias in memory—that is, a bias to act as though one's memory will not change in the future (see also Kornell 2011, 2012). Kornell and Bjork found that participants, when asked to study a list of word pairs once and then to predict their final test performance after 0–3 additional study trials, were underconfident in their ability to learn in the future, demonstrating a stability bias, but were also, at the same time, overconfident in their current level of knowledge. This pattern is troubling because it appears to provide dual reasons not to study as much as would be optimal.

Similarly, a study by Koriat et al. (2004) demonstrated a surprising stability bias with respect to forgetting: Participants' predictions of their later test performance were not affected by whether the participants were told they would be tested immediately, after a week, or even after a year (but see Rawson et al. 2002). The participants did, in fact, have a theory of forgetting at the belief level, and when the idea of forgetting was made salient, the participants became sensitive to retention interval—but without such prompting their judgments were insensitive to forgetting and highly inaccurate.

The stability bias has troubling implications. One reason students do not give up on studying, even in the face of difficulty, is the knowledge that eventually they will improve. Students who underestimate how much they can improve by studying may give up hope when they should not. Ignoring forgetting is also dangerous. Students may unconsciously assume that if they know something today, they will know it next week or next month—which is not necessarily true—and stop studying prematurely. (Teachers are vulnerable to the same error when judging their students' knowledge.) Indeed, failing to account for forgetting can produce extreme amounts of long-term overconfidence (Kornell 2011). The effects of the stability bias on over- and underconfidence are illustrated in **Figure 3**.

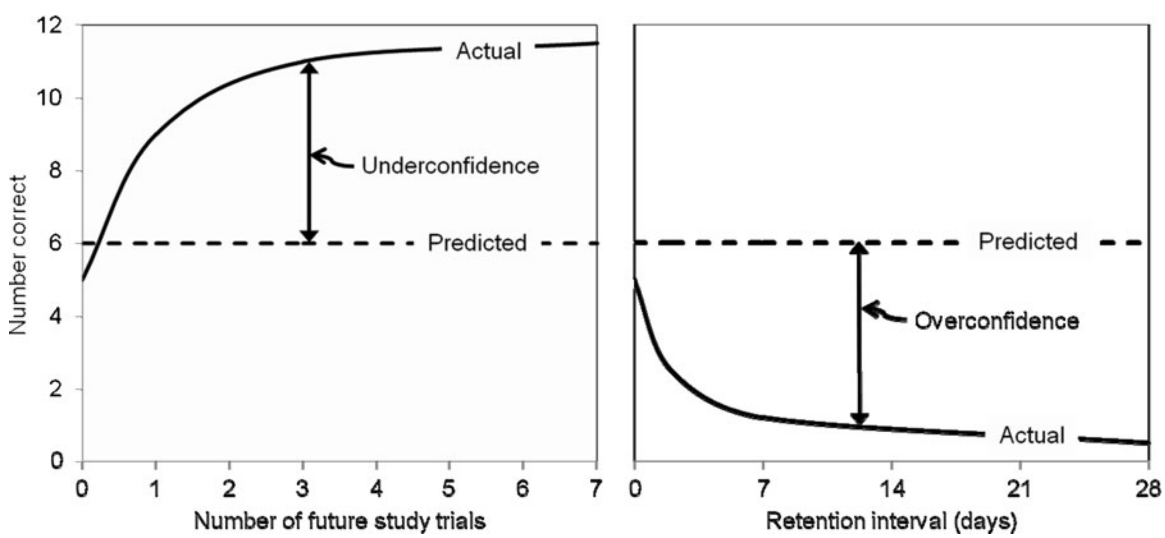

Figure 3

Hypothetical curves depicting changes in predicted and actual learning over time. Predicted recall remains constant due to the stability bias, whereas actual recall increases due to future study trials (*left panel*) or decreases due to forgetting (*right panel*). These dynamics produce an increasing gap between predicted and actual knowledge.

Thus, it appears that people can ignore even the most obvious of metacognitive beliefs, such as the beliefs that studying produces learning and forgetting happens over time. The reason belief-based cues are ignored appears to be that, in general, they fall into the category of cues that do not impact one's current experience. The foresight bias—that is, the failure to take into account how one's memory will be tested, which was discussed previously—falls into this category as well. The form taken by a future test does not affect current experience.

Interpreting Objective Indices of Current Performance: Heuristics and Illusions

It is experience-based cues that guide metacognitive judgments and, by extension, study decisions. One of the most important, salient, and reliable experience-based cues is whether one can presently recall some information or procedure.

Response accuracy. A pair of influential studies by Nelson & Dunlosky (1991) and Dunlosky & Nelson (1992) demonstrated the metacognitive value of testing long-term memory. In these studies, participants were asked to make JOLs about a series of word pairs and later took a test on the pairs. Metacognitive accuracy was operationalized as the gamma correlation—a nonparametric measure of association—between JOLs and subsequent recall. The JOLs were made either immediately after studying or after a delay; they were also made either based on both words in the pair or based on the cue only. Only the delayed cue-only condition allowed participants to make a meaningful test of their memories. This condition produced levels of metacognitive accuracy that were very high (gamma >0.9) and also much higher than in the other three conditions (gamma <0.6), a finding dubbed the delayed JOL effect.

These findings suggest that the best way to distinguish between what one does and does not know may be to test oneself. Doing so appears to benefit learning in two ways. First, accurate monitoring can lead to study choices that enhance learning (Dunlosky & Rawson 2012, Kornell & Metcalfe 2006, Metcalfe & Finn 2008, Thiede 1999). Second, as mentioned previously, tests produce more learning than does similar time spent studying without being tested (e.g., Roediger & Butler 2011). [As Spellman & Bjork (1992) have argued (also see Kimball & Metcalfe 2003, Rhodes & Tauber 2011), it may be that the memory benefits of testing act to make participants' judgments of learning appear more accurate than they really are, but this is an issue that the authors of this article, much less the field, have not settled.]

It is clear that whether one can recall an answer has a powerful influence on JOLs. It seems possible, given the evidence presented thus far, that current experience has exclusive control over JOLs. That is, past events can influence current experience, but only current experience influences JOLs. As Finn & Metcalfe (2007, 2008) have shown (also see King et al. 1980), however, people tend to base their JOLs on their most recent test, even if the test occurred in the past and additional study trials have occurred in the meantime. This judgment strategy is referred to as the memory for past test heuristic. Thus, it appears that experiences, not necessarily current experiences, control JOLs.

Response time. Like the ability to answer a question, the speed with which an answer comes to mind has an important experience-based influence on JOLs. Benjamin et al. (1998) uncovered striking evidence for this claim. They asked participants to answer trivia questions. The participants were told that they would be tested later, and the nature of the test was made very clear: They would be given a blank sheet of paper and, without being asked the questions again, they would be asked to free-recall the answers. During the question-answering phase, after each correct answer, the participants were asked to predict the probability that they would be able to recall the answer again on the final test. The results were surprising: The more confident participants were that they would recall an answer, the less likely they were to recall it. This outcome occurred because participants gave higher JOLs to questions that they answered quickly, but they were most likely to free-recall answers that they had thought about for a long time (see **Figure 4**).

These findings can be interpreted as suggesting that participants have incomplete mental models of their own memories. In particular, answering trivia questions involves semantic memory but free-recalling answers provided earlier involves episodic memory, and one interpretation of the findings is that people do not understand the difference between semantic and episodic memory. Another interpretation of the findings, however, based on the foresight bias, is that the participants' mental models may have been irrelevant. That is, perhaps the participants never took the nature of the final test into account (in which case an accurate mental model would not have affected their judgments). In any event, what is clear is that these participants relied on current experience to make their judgments.

The speed with which an answer comes to mind is often a sensible basis for study decisions—stronger memories do tend to come to mind quickly (Benjamin et al. 1998). For instance, when the final criterion test is cued recall of paired associates, students' use of retrieval speed during prior cued recall is a diagnostic cue that improves the accuracy of students' judgments (Serra & Dunlosky 2005). Nevertheless, studies that dissociate knowledge and response speed are valuable because they make it clear that response time is a more powerful metacognitive cue than is memory strength.

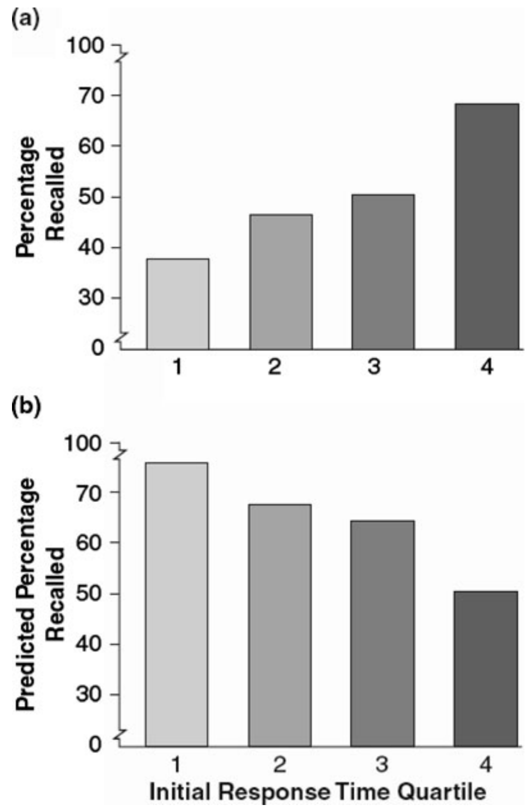

Figure 4

Percentage recalled (*a*) and mean judgment of learning (*b*) as a function of the latency of cued recall. Latency (response time in quartiles) is presented from fastest (*1*) to slowest (*4*). From Benjamin et al. (1998).

Interpreting Subjective Indices of Performance: Heuristics and Illusions

Response time and retrieval success are objectively measurable cues, but they are closely related to a more subjective basis for judgments: fluency. Fluency during the perceptual processing of information is the sense of ease or speed of processing; fluency during the retrieval of information is the sense of how readily information "comes to mind." Because the subjective sense of fluency, either in processing information or in retrieving information, falls squarely in the category of experience-based cues, fluency has powerful effects on metacognitive judgments (e.g., Koriat 1993), as we describe next. (Fluency also influences a wide variety of other types of judgment; see Alter & Oppenheimer 2009, Kelley & Jacoby 1996, Kelley & Rhodes 2002, Oppenheimer 2008, Schwarz 2004.)

Retrieval fluency. Retrieval fluency, as mentioned above, is the ease and speed with which information is retrieved from memory (e.g., Benjamin & Bjork 1996, Matvey et al. 2001, Reder 1996). In general, retrieval fluency is a useful heuristic in terms of judging how well something is known, but it can be misleading and create illusions of knowing when it is the product of factors unrelated to degree of learning, such as priming. Kelley & Lindsay (1993), for example, demonstrated that participants' confidence in their answers to general-knowledge questions (e.g., "What was Buffalo Bill's last name?"), whether correct or incorrect, was increased when those answers (e.g., "Cody" or "Hickok") had been pre-exposed in an earlier phase of the experiment. It appears that people are susceptible to using (i.e., misattributing) the sense of familiarity or ease of perception as an index of knowing, even when such fluency does not reflect actual understanding or learning (see also Jacoby et al. 1989).

Confidence judgments like those manipulated by Kelley & Lindsay (1993) are retrospective judgments about an answer that has just been given. Troublingly, it is possible to manipulate confidence in eyewitness testimony by artificially boosting fluency (Shaw 1996). But confidence judgments probably influence study decisions less than JOLs do. The more fluently information comes to mind, the more likely students are to decide they know it, and therefore put it aside and stop studying.

Encoding fluency. Encoding fluency—that is, the subjective feeling that it is easy or difficult to learn a piece of information—is another important influence on decisions about studying (e.g., Miele et al. 2011). For example, Hertzog et al. (2003) asked participants to study unrelated pairs of concrete words. They were also asked to form a mental image of each pair and then make a JOL. Faster encoding (i.e., higher fluency) was associated with higher JOLs. Yet, encoding fluency was misleading (see also Castel et al. 2007) because recall was not correlated with fluency. Thus, like retrieval fluency, encoding fluency can be misleading, but high encoding fluency may decrease the chance that a student will restudy the item.

Perceptual fluency. Metacognitive judgments tend to be higher for items with greater perceptual fluency—that is, items that are subjectively easier to process at a perceptual level. Reder (1987), for example, found that simply pre-exposing key words in a question (such as the words "golf" and "par" in the question "What is the term in golf for scoring one under par?") increased subjects' confidence that they would be able to produce the answer to a given question. Also, as mentioned previously, words presented in larger fonts have been incorrectly judged to be more memorable (Kornell et al. 2011, Rhodes & Castel 2008). Words presented at a louder volume were also incorrectly rated as more memorable (Rhodes & Castel 2009). A recent study even suggested that perceptual fluency can decrease learning: Students learned more when in-class PowerPoint presentations and handouts were converted to fonts that decreased fluency (Diemand-Yauman et al. 2011). This is a worrying outcome given that students judge that they have learned more when information seems more fluent. Such misperceptions may lead to undesirable study decisions. Teachers are affected by fluency as well: The teachers involved in the Diemand-Yauman studies initially objected to using the disfluent fonts that ended up enhancing learning.

Fluency of induction. Self-regulated learning is not limited to one type of learning. Most of the research on the topic involves materials that can be memorized, but such materials do not capture inductive learning—learning a concept or category by observing examples. For example, learning to differentiate elm trees from oaks and maples requires seeing examples of each kind of tree.

Judging the progress of inductive learning is similar to judgments based on encoding fluency. In many cases it relates to perceptual fluency as well. For example, Kornell & Bjork (2008a) investigated inductive learning by presenting paintings by 12 different artists (also see Kornell et al. 2010). Some artists' paintings were presented on consecutive trials while other artists' paintings were presented interleaved with other paintings. As a test, participants were asked which artist painted each of a set of previously unpresented paintings. They were more accurate following interleaved (i.e., spaced) learning than following blocked (i.e., massed) learning.

Blocking may have made it easier to notice similarities within a given artist's paintings, whereas the value of interleaving appears to lie, at least in part, in highlighting differences between categories (Kang & Pashler 2012, Wahlheim et al. 2011). The benefit of interleaving is consistent with a large literature on the benefits of spaced practice in noninductive learning (e.g., Cepeda et al. 2006, Dempster 1996) (see sidebar Why Does Interleaving Enhance Learning?).

As **Figure 5** shows, the majority of Kornell & Bjork's (2008a) participants incorrectly believed that blocking had been more effective than interleaving (for similar results, see Kornell et al. 2010, Wahlheim et al. 2011, Zulkiply et al. 2012). Massing appears to increase the fluency of induction by increasing the retrieval fluency of prior exemplars of a category (also see Wahlheim et al. 2012). In a blocked schedule, the previous example of a category, which was just presented, is highly fluent, whereas it is not in an interleaved schedule. Thus blocked studying is rated as more effective than interleaving. This metacognitive error occurs in noninductive learning as well (Dunlosky & Nelson 1994, Kornell 2009, Simon & Bjork 2001, Zechmeister & Shaughnessy 1980), although, as mentioned previously, students do tend to space their studying at least to some degree (see Son & Kornell 2009 and section What Do Students Believe About How to Learn?).

WHY DOES INTERLEAVING ENHANCE LEARNING?

Interleaving study sessions on separate to-be-learned topics or procedures introduces spacing of the study or practice sessions on a given topic or procedure, but do the benefits of interleaving go beyond the benefits of spacing? Interleaving introduces contextual interference, that is, interference among the separate topics or procedures to be learned (for a review, see Lee 2012), and in the domain of motor skills there is substantial support for the idea that interleaving practice on separate skills to be learned, such as the several strokes in tennis, requires that motor programs corresponding to those skills be repeatedly reloaded, rather than executed over and over again, which has learning benefits. Other findings, though, especially in the domain of learning concepts and categories, suggest that contextual interference introduced by interleaving triggers comparisons and contrasts that result in a higher-order mental representation of how different concepts or categories relate to each other, which then fosters retention and transfer. In that view, the benefits of interleaving indeed go beyond the benefits of spacing per se, but the issue remains a matter of current interest and research (see, e.g., Kang & Pashler 2012, Taylor & Rohrer 2010).

When subjective experience is the best basis for predictions. We have stressed those instances when subjective experience can be misleading, but it is important to emphasize that there are situations in which subjective experience can be the best basis for judgments and predictions. Related to hindsight biases, for example, being exposed to answers and solutions can deny us the type of subjective experience that might otherwise provide a valuable basis for judging our competence, and our subjective experience can be an especially valuable guide in situations where we lack other bases for making judgments and predictions. Jacoby & Kelley (1987), for example, demonstrated that subjects' judgments of the relative difficulty of anagrams (such as "FSCAR-?????"), as measured by the solution performance of other subjects, were much less accurate if made with the solution present (e.g., "FSCAR-SCARF") than if made after having the subjective experience of solving the anagram. Basically, when subjective experience is denied in situations where we do not have another valid basis for judgments and predictions—such as in solving anagrams, where people do not, apparently, have an adequate theory as to what makes anagrams difficult—judgments and predictions can be impaired.

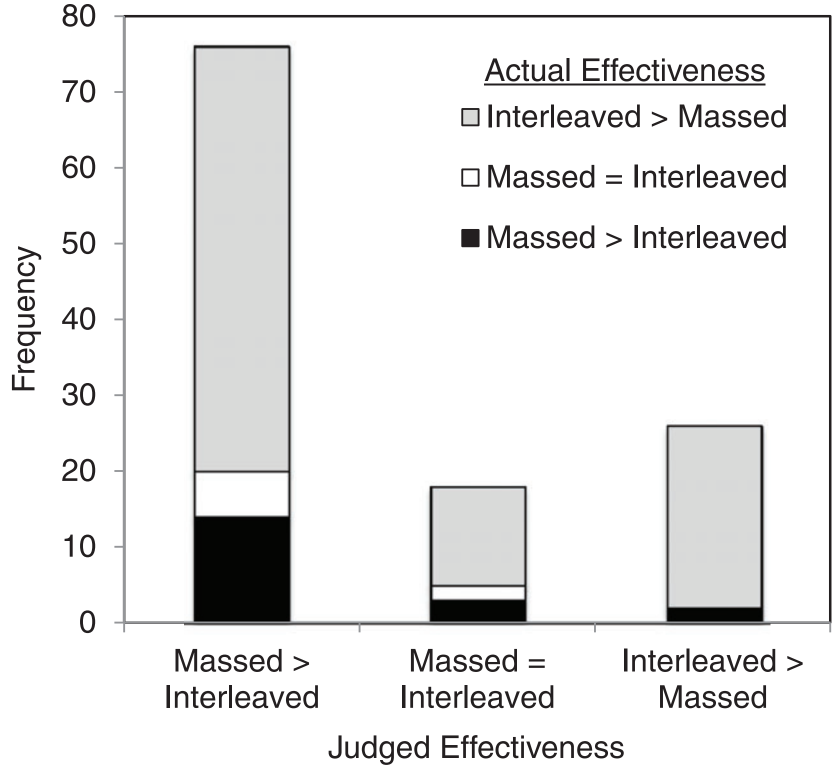

Figure 5

Number of participants (out of 120) who judged massing as more effective than, equally effective as, or less effective than interleaving in Kornell & Bjork (2008a). For each judgment, participants are divided into groups on the basis of their actual performance.

Learning Versus Performance and the Unintuitive Benefits of Desirable Difficulties

Because people make study decisions while they are studying, they tend to be drawn to techniques that lead to the best performance during study. Making study activities easier—by, for example, massing practice—tends to increase judgments of learning, which is problematic because conditions that make learning seem easier can actually decrease long-term learning. Activities such as spacing and interleaving, generating answers, testing oneself, and varying the conditions of learning are known as desirable difficulties (Bjork 1994, Bjork & Bjork 2011). They impair performance—and, hence, apparent learning—during acquisition, but enhance long-term learning. The fundamental problem with using fluency as a basis for study decisions is that learners often interpret high fluency as signaling a high rate of improvement when it can actually, under some circumstances, signal just the opposite. Educators fall victim to this error when they design textbooks that mass studying on one topic at a time instead of periodically returning to prior topics in an effort to promote spaced learning (e.g., Rohrer & Taylor 2006, 2007). Students are prone to the same illusions when regulating their own study activities.

ATTITUDES AND ASSUMPTIONS THAT CAN IMPAIR SELF-REGULATED LEARNING

As we stated in the beginning of this review, it has become increasingly important that one be able to manage one's own learning effectively. We also stressed, though, that becoming truly effective in managing one's own learning is not easy: Doing so requires not only gaining a general understanding of the unique storage and retrieval processes that characterize human memory, but also overcoming certain intuitions, knowing what activities are and are not productive for learning, and avoiding being fooled by current performance and feelings of fluency that reflect factors other than the kind of encoding and understanding that supports long-term retention and transfer. Becoming sophisticated as a learner is also difficult, in our opinion, because doing so requires overcoming societal attitudes and assumptions that are often counterproductive for learning, which we discuss below.

Misunderstanding the Meaning and Role of Errors and Mistakes

Errors and mistakes are typically viewed as something to avoid during the learning process, in part out of fear that they will be interpreted—by ourselves or others—as documenting our inadequacies as a learner, but also out of a concern that such errors or mistakes, by virtue of being produced, will be learned. A variety of research findings suggest, by contrast, that making errors is often an essential component of efficient learning. Introducing desirable difficulties into learning procedures, for example, such as variation or interleaving, tends to result in more errors being made during the acquisition process, but it also tends to enhance long-term retention and transfer (e.g., Lee 2012, Simon & Bjork 2001, Taylor & Rohrer 2010). Conversely, manipulations that eliminate errors can often eliminate learning. Thus, for example, when retrieval of to-be-learned information is made so easy as to insure success, by virtue of recency, strong cue support, or some other factor, the benefits of such retrieval as a learning event tend to be mostly or entirely eliminated (e.g., Landauer & Bjork 1978, Rawson & Kintsch 2005, Whitten & Bjork 1977).

Kornell et al. (2009; also see Grimaldi & Karpicke 2012, Hays et al. 2012, Huelser & Metcalfe 2012, Knight et al. 2012, Vaughn & Rawson 2012) have also demonstrated that anticipating, unsuccessfully, a to-be-learned response can enhance learning. If participants are asked to predict what associate of a given cue word (e.g., Whale) is to be learned before they are shown the actual to-be-learned target (e.g., Mammal), their later cued recall (e.g., Whale: __?__) of the target word is enhanced, versus a pure study condition (e.g., Whale: Mammal), even when the predicted associate differs from the target associate and the total time is equated in the test and the study conditions. More specifically, using 8 seconds to generate a response that turns out to be wrong ("Dolphin," say, in response to the cue Whale), followed by 5 seconds studying the correct response, produces better recall than does studying the correct response for 13 seconds. Significantly, when Huelser & Metcalfe (2012) asked participants, after the final test, which condition, the study or test condition, helped them most to learn the pairs, they said the study condition, even after their own recall performance went in the other direction. Using a somewhat different procedure, Richland et al. (2009) found that long-term learning benefited when participants were asked questions that they could not answer prior to studying text materials.

Making errors appears to create opportunities for learning and, surprisingly, that seems particularly true when errors are made with high confidence. Butterfield & Metcalfe (2001) found that feedback was especially effective when it followed errors made with high confidence versus errors made with low confidence, a finding they labeled a hypercorrection effect. It is an effect that has now been replicated many times (e.g., Butler et al. 2011, Metcalfe & Finn 2011), including at retention intervals long enough to be educationally realistic.

From the standpoint of becoming sophisticated as a learner, the basic message is that making errors and struggling, rather than being simply discouraging, should also be viewed as important opportunities for learning.

Overattributing Differences in Performance to Innate Differences in Ability

There is, in our view, an overappreciation in our society of the role played by innate differences among individuals in determining what can be learned and how much can be learned, and that overappreciation is coupled with an underappreciation of the power of training, practice, and experience. This combination of overappreciating innate differences and underappreciating the roles of effort and practice can lead individuals to assume that there are certain limits on what they can learn, resulting in an underestimation of their own capacity to learn. Basically, to use Dweck's (2006) terms, learners need to have a growth mindset, not a fixed mindset. Differences between individuals do matter, but mostly because new learning builds on old learning, so the level of old learning an individual brings to new learning really matters, and because our personal family and cultural histories have a profound effect on our aspirations and expectations with respect to learning.

Assuming That Learning Should Be Easy

Finally, another common assumption that can be counterproductive is that learning can be, and should be, easy. Such an assumption is fueled by various "made-easy" self-help books, by the common assumption that it important to increase performance in classrooms (when doing so can actually damage long-term learning), and by the idea that we each have our own style of learning. The very influential styles-of-learning idea involves what Pashler et al. (2009) labeled a meshing hypothesis—namely, that learning will be effective and easy if material is presented to the learner in a way that meshes with his or her learning style. In their review of the existing evidence, Pashler et al. could find no support for the meshing hypothesis and even found some evidence that suggests the opposite—that, for example, someone with high visual/spatial ability scores may profit most from verbal instruction, whereas the converse may be true for individuals testing high for verbal abilities.

Our review suggests that effective learning can be fun, it can be rewarding, and it can save time, but it is seldom easy. The most effective cognitive processes involve some effort by the learner—to notice connections and linkages, to come up with examples and counterexamples, to generate and retrieve, and so forth. In short, effective learning requires the active participation of the learner.

CONCLUDING COMMENTS ON SOME FREQUENTLY ASKED HOW-TO-STUDY QUESTIONS

As teachers and researchers interested in improving student learning, we have compiled a list of frequently asked questions. We have tried to select questions that are on students' minds, which means the questions do not mesh perfectly with the principles discussed in this article. To conclude this review, we consider some of these questions and how we might answer them given current research on students' metacognitive and self-regulated learning.

"What Is the Format of the Upcoming Test?"

This may be the most common question students ask. It can annoy teachers because it is not about content, similar to the question "Will that be on the test?" It is, however, an insightful question from the standpoint of self-regulated learning because it implies that the student wants to regulate his or her own learning—and will presumably study differently depending on whether the test will have, say, a multiple-choice versus an essay format. For the former, they may decide to simply skim the relevant materials, whereas for the latter, they may attempt practice testing because doing so reflects essay writing. Unfortunately, the question posed in this manner further highlights misconceptions students have about learning, because regardless of whether the test is multiple choice or essay, the students will retain the sought-after information better if they actively participate in learning, such as by elaborating on the to-be-learned material and by using self-testing (although knowing what type of test to expect can increase students' grades; Lundeberg & Fox 1991). Thus, the answer we often give is that you will do best if you assume the exam will require that you truly understand, and can produce from memory, the sought-after information, whether doing so involves recalling facts, answering comprehension questions, or solving problems.

"I Study by Copying My Notes. Is That a Good Idea?"

The answer to this question depends on what is meant by copying. Because verbatim copying is a passive process, it is also not very effective. Rewriting one's notes, however, or reorganizing them, exercises active organizational and elaborative processing, which all introductory psychology students should know from their textbook is valuable (e.g., Schacter et al. 2011). Studying one's notes and then trying to reproduce them without the notes being visible is another active process and takes advantage of the learning benefits of retrieval practice. The answer to this question, therefore, requires finding out exactly what the students in question do when they copy their notes.

"Does Cramming Work?"

A reflexive "no" seems the right answer to this question, but even in this case the answer is not so straightforward. For one thing, if the student doesn't know the material the day before the exam, cramming will produce a better outcome than will not cramming. The best answer to this question is probably "Work for what?" If the student's goal is merely to obtain enough information to pass (or even do well on) an upcoming test, then cramming may work fine. There is even a subset of students who do well in school who frequently cram for tests (e.g., Hartwig & Dunlosky 2012). Massing study sessions, though bad in the long-term, can yield good recall at a short retention interval, even better than spacing study sessions under some circumstances (e.g., Rawson & Kintsch 2005). If, however, a student's goal is to retain what they learn for a longer period of time (e.g., until they take a more advanced course on the same topic), cramming is very ineffective compared to other techniques. If good performance on an upcoming test and good long-term retention is the goal, then students should study ahead of time and space their learning sessions across days, and then study the night before the exam (e.g., Kornell 2009, Rawson & Dunlosky 2011). Teachers, of course, can use homework assignments, weekly exams, and comprehensive finals to encourage such spaced studying.

"I Did So Much Worse Than I Expected. What Happened?"

As summarized in our review, there are many ways to overestimate one's learning, and some of us consistently overestimate our preparedness for exams. Two routes to such overestimation, as discussed previously in this review, are hindsight bias, looking at to-be-tested material and thinking that it was known all along, and foresight bias, not being aware that when the answer is not present and required on the test other possible answers will come to mind. Perhaps the best answer to this question is a simple one: Take a meaningful self-test without checking the answers until you are done. Only then can you be confident that you know the information (and even then, forgetting can still occur).

"How Much Time Should I Spend Studying?"

This is actually a question students never ask, but perhaps should. Simply spending a lot of time studying is not enough, because that time can be spent very unproductively, but students cannot excel without both (*a*) studying effectively and (*b*) spending enough time doing so. Compounding the problem, it is difficult to monitor one's own study time—because study sessions, even attending class, can include email, online shopping, social networks, YouTube, and so on.

"How Should I Study To Get Good Grades and Succeed in School?"

This question is truly basic and there is much to say in response, though not any single answer. Some strategies, such as self-testing and spacing of practice, do seem generally effective across a broad set of materials and contexts, but many strategies are not so broadly effective and will not always be useful. It makes sense to summarize what one is reading, for example, yet writing summaries does not always benefit learning and comprehension and is less effective for students who have difficulty writing summaries (Dunlosky et al. 2012). Moreover, summarizing a physics problem set may not be appropriate. Studying with other students may be effective if done well (e.g., if students take turns testing one another and providing feedback), but certainly will not work well if such a session turns into a social event or one group member takes the lead and everyone else becomes a passive observer.

As we hope this final section emphasizes, the answers to the questions students tend to ask are seldom simple, and for a good reason: There is much to learn about learning.

SUMMARY POINTS

1. Our complex and rapidly changing world increasingly requires self-initiated and self-managed learning, not simply during the years associated with formal schooling, but across the lifespan.
2. Learning how to learn is, therefore, a critical survival tool, but research on learning, memory, and metacognitive processes has demonstrated that learners are prone to intuitions and beliefs about learning that can impair, rather than enhance, their effectiveness as learners.
3. Becoming sophisticated as a learner requires not only acquiring a basic understanding of the encoding and retrieval processes that characterize the storage and subsequent access to the to-be-learned knowledge and procedures, but also knowing what learning activities and techniques support long-term retention and transfer.
4. Managing one's ongoing learning effectively requires accurate monitoring of the degree to which learning has been achieved, coupled with appropriate selection and control of one's learning activities in response to that monitoring.
5. Assessing whether learning has been achieved is difficult because conditions that enhance performance during learning can fail to support long-term retention and transfer, whereas other conditions that appear to create difficulties and slow the acquisition process can enhance long-term retention and transfer.
6. Learners' judgments of their own degree of learning are also influenced by subjective indices, such as the sense of fluency in perceiving or recalling to-be-learned information, but such fluency can be a product of low-level priming and other factors that are unrelated to whether learning has been achieved.
7. Becoming maximally effective as a learner requires interpreting errors and mistakes as an essential component of effective learning rather than as a reflection of one's inadequacies as a learner.
8. To be maximally effective also requires an appreciation of the incredible capacity humans have to learn and avoiding the mindset that one's learning abilities are fixed.

FUTURE ISSUES

With respect to how learners should optimize the self-regulation of their learning, there remain key issues, both theoretical and applied. We touched on some theoretical issues in sidebars, and we list some applied issues below.

1. What mixture of formal instruction and educational experiences is maximally effective in getting learners to understand how to learn? (For starters, see Morisano et al. 2010.)
2. Why does the retrieval practice triggered by testing have such significant effects on learning and how might those effects be maximized by teachers in classrooms and by learners on their own? (For starters, see Halamish & Bjork 2011, Kornell et al. 2011a, Pyc & Rawson 2010.)
3. How can teachers become better at monitoring their students' long-term learning or lack thereof? (For starters, see Duffy et al. 2009.)
4. Does the act of making metacognitive judgments, such as predicting future performance, enhance later test performance and, possibly, the effectiveness of subsequent study opportunities? If so, what judgments should students make to maximize such effects? (For starters, see McCabe & Soderstrom 2011.)
5. Accurate monitoring of learning is a crucial component of effective self-regulation of learning, but students have difficulties in monitoring their learning and comprehension of complex materials. What scaffolds can students use to ensure high levels of monitoring accuracy for complex materials? (For starters, see Dunlosky & Lipko 2007, Thiede et al. 2009.)
6. Why and when does making errors potentiate subsequent learning? Recent findings suggest that errors can facilitate the effectiveness of subsequent learning opportunities, but other findings suggest that there are circumstances in which producing errors propagates those errors. (For starters, see Grimaldi & Karpicke 2012, Kornell et al. 2009.)

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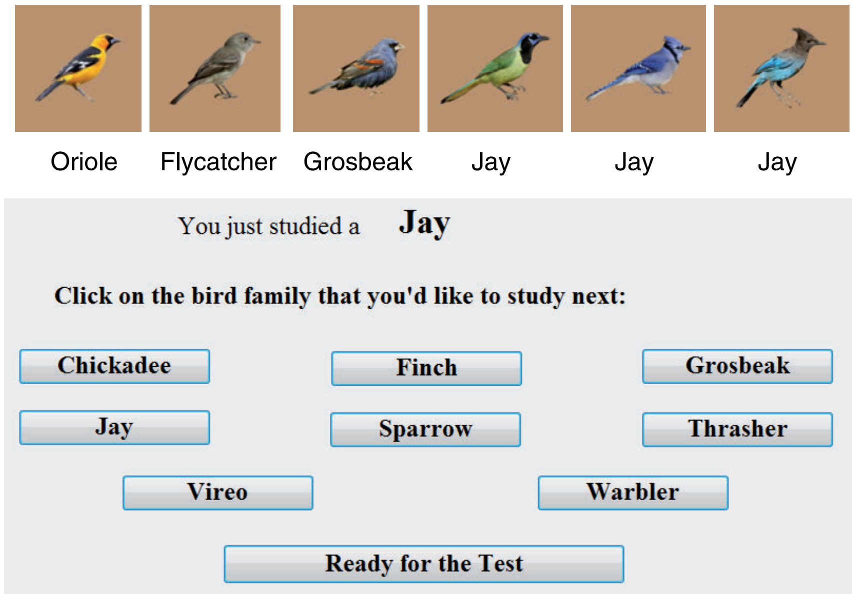

Figure 2

(*Top panel*) Exemplars from four bird families (materials from Wahlheim et al. 2011), with three exemplars (out of six studied) from the Jay family (from left to right: Green Jay, Blue Jay, Stellar Jay). (*Bottom panel*) Interface for choosing the next family. When a button for a given family is pressed, a bird (from the six presented in the familiarity phase) from the chosen family is presented for study along with the family name.