The Metacognitive Foundations of Effective Remembering

Joshua L. Fiechter, Aaron S. Benjamin, and Nash Unsworth

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

Print Publication Date: Jun 2016
Subject: Psychology, Clinical Psychology, Cognitive Psychology
Online Publication Date: Jul 2015 DOI: 10.1093/oxfordhb/9780199336746.013.24

Abstract and Keywords

Learners' success in remembering reflects their strategic approach to the demands that their memory places on them. Differences in success on memory tasks are usually taken to reveal memory ability; but things are more complicated. Memory performance is determined by the interplay of learners' goals and motivations and the sophistication of the approaches they bring to a particular learning context. Thus, rememberers are burdened with choosing strategies that most efficiently meet their goals, given conditions at encoding or retrieval. Learners must navigate the costs and benefits of engaging select strategies, beginning with simple decisions such as how to distribute study time and ending with complex scenarios where they must infer superior learning strategies following exposure to an alternative strategy. Learners may modulate their use of beneficial strategies in accord with their goals but are much less successful at bringing completely new strategies to bear when the situation calls for them.

Keywords: metamemory, metacognition, learning, strategies, remembering, decision making

When someone is described as having good memory, there is often an implication that he or she has been endowed with superior mental hardware relative to individuals with average memory. The oftentimes analogous treatment of cognition and computers further reinforces the view of differences in memory having provenance in differences in "hardware." One computer may have more storage, or more RAM, and thus display better performance; why not treat differences in human performance similarly? One goal of this chapter is to suggest an alternative notion: that a person with good memory may have better software for dealing with the limitations of capacity and access that we all face.

The relatively recent interest in metamemory (Nelson & Narens, 1990; 1994)—how learners assess their learning and make decisions about memory use—has brought attention to this "software" side of memory research. Learners do more than store and retrieve information—they possess a higher level of processing that monitors the efficacy of encoding and retrieval and makes adjustments based on desired outcomes and competing demands. One result that is quite clear is that learners are sensitized to how well materials are learned. Thus, you may have a student who begins an exam with a sense of confidence because she believes she has learned the necessary information well, while another student feels anxious as a result of poor learning or retention. Monitoring may not always be accurate, as will be discussed later in this chapter, but it often is, and there are conditions under which accuracy can be enhanced. Learners are also able to control their processing in a multitude of ways. They may, for example, elect to stop searching for an item in memory if a certain amount of time has passed or they feel that additional effort would be in vain.

Critically, monitoring and control appear to influence one another. That is, students attempting to recall an item on a test may realize that their current search strategy is ineffective, and therefore they (p. 308) decide to revise their strategy to something that they hope is more effective. The implication of this interactivity is that learners are able to *strategically* work with memory in order to achieve their mnemonic goals. That is, without communication between monitoring and control processes, learners would be unable to evaluate the efficacy of their processing and thus be unable to update to something more useful, if necessary.

Learners also possess goals and motivations extraneous to their performance, such as how much time they wish to dedicate to a task. These factors are part of the landscape in human memory research, tempting as it may be to treat learners simply as encoders and retrievers. For instance, a student may study longer for a test that she expects will be challenging, and this lengthier study session may be at the expense of studying for another class. A student may focus on one class more than others because that class is more challenging, more interesting, or of more practical importance than other classes, among other reasons. A student also may choose to forego further study because she feels she needs a break or time with friends. Decisions such as how to allocate study time and how long to persist at a task are very common to students. Making such decisions requires an assessment of both performance goals and personal goals, and some possible solutions may be more optimal than others.

Following an earlier chapter by Benjamin (2008), we will adopt a perspective here in which differences in human memory performance are seen to at least partly reflect variance in the effectiveness with which one interacts with memory. This view does not deny differences in memory capacity or even the existence of different memory systems, but it does allow us to consider variance in performance under very simplifying assumptions about the hardware of memory. Under this view, considerable differences in mnemonic performance will still exist even when storage capacity and processing systems are held constant. To illustrate, consider a common task that many engage in several times every day: the act of saving and finding files on a computer. Two individuals with identical computers might still exhibit great differences in their ability to recover information simply because one has developed more efficient strategies for saving and retrieving information. A user can choose to give more precise names to folders and files so that they serve as better cues when they must retrieve a document later. They can also choose to organize information into folders containing similar information rather than have one folder with numerous, unrelated files. Both decisions will make it easier to retrieve a stored file at a later time. Yet this greater ease reflects nothing about the innate capacity of the storage device, nor of its potential.

Just as individuals might approach the storage and retrieval of computer files more efficiently, so can individuals interact more efficiently with memory. For instance, they can allocate superior but more resource-intensive processing (e.g., deep processing) to materials they deem to be more important, they can organize information in memory so that important information can be assimilated with ease, and they can decide exactly what information should be encoded and what can be left to external memory devices, like the Internet. Differences in memory performance can therefore be attributed in part to learners' interaction with memory, rather than to qualities of the memory system itself.

Furthermore, what constitutes a quality interaction with memory may change depending on the learning context and the learner's goals. A student studying two hours before an exam should not necessarily adopt the same strategy for covering the material as a student who is studying two weeks before an exam. Likewise, it would be inefficient for a student desiring only a C on an exam to study the same way, or the same amount, as a student wanting an A on that exam. Because the ideal approach is dependent on constraints of the learning situation and learner goals, learners will assess their situation and make strategic decisions that will help them maximize performance within the constraints of their situation. That is, they will consider the costs and benefits of implementing a mnemonic strategy before implementing it.

We suggest that strategy implementation involves two components: (1) the processing of materials and (2) the amount of processing necessary to reach a goal. The first component relates to the *tactical* properties of a strategy—for example, focusing on associations between targets on a cued recall task versus focusing on associations between targets and cues. The second relates to the *temporal* properties of a strategy, for example, spending more time making associations between certain difficult word pairs over easy pairs. The benefits of temporal decisions in strategy use are likely to be more intuitive. For instance, it is obvious to most students that spending more time studying will usually result in superior memory for class materials. The benefits of tactical decisions, however, may be less apparent. College students often do not appreciate the mnemonic (p. 309) benefits afforded to them by scientifically proven strategies (e.g., Bjork, Dunlosky, & Kornell, 2013; Karpicke, Butler, & Roediger, 2009; Kornell & Bjork, 2007; cf. Tullis, Finley, & Benjamin, 2013; Tullis, Benjamin, & Fiechter, 2015). If the benefits of a strategy are not understood, they probably will not be implemented spontaneously. That is, if we assume that learners are attempting to conserve their cognitive resources, it would be of little value to them to engage in strategies that have unknown outcomes, particularly strategies that are more cognitively demanding to implement. We will emphasize the distinction between temporal and tactical adjustments in strategy adaptation and present the evidence that suggests learners are more likely to spontaneously make temporal but not tactical shifts in their strategies. For tactical adaptations, it appears that exposure to alternative strategies, or exposure to the mnemonic consequences of those strategies, is crucial to a learner's decision making process.

We begin with a discussion of what learners have been shown to do spontaneously, that is, without instruction to study by any particular method or by exposing them to any alternative methods. We then examine instances where learners' spontaneous strategies can be improved by instruction. Finally, we end by examining cases where learners are required to make sophisticated inferences and decisions to adjust their encoding via experience with a task but not direct instruction. Such "learning to learn" (Postman, 1964, 1969) is valuable tool in a learner's skill set.

Learners' Spontaneous Use of Strategies

All learners have a repertoire of tools that they bring to encoding tasks; these tools allow them to enhance learning or remembering, but often at the expense of expending greater cognitive resources. In this section, we review six ways (see Table 16.1) in which learners can exert control over their memory, with an eye toward the tradeoffs considered in the decisions to engage (or not) a superior strategy.

Table 16.1 An overview of the six topics covered in the first section.

Topic	**Highlights**
Allocation of study time	• When unconstrained, learners focus on the most difficult items. • When constraints are in place (such as performance goals or time limitations), learners often study the easiest of unmastered items.
Allocation of memory search time	• Learners’ perceptions of item and task difficulty influence how long they are willing to search memory. • Learners are influenced by the amount to be remembered and confidence in their output when deciding when to terminate search. • Learners are quick to terminate search for items that do not appear plausible or familiar.
Terminating encoding session	• Learners tend to terminate their encoding before materials are sufficiently committed to memory. • Insufficient study has been demonstrated with learning word lists, flash cards, and retrieval practice.
Scheduling	• Learners tend to space more difficult items and mass easier items. • Scheduling is modulated by perceptual processing of items.

Incentives and mnemonic scheduling	• Learners' mnemonic performance is enhanced when incentives are present. • Learners appear to search longer for incentivized items. • Social comparisons appear to incentivize learners to re-search memory.
Spontaneous use of tactical strategies at encoding and retrieval	• Learners can tactically guide their retrieval of category exemplars. • Individual differences in working memory capacity influence the extent to which learners implement tactical strategies at encoding and retrieval.

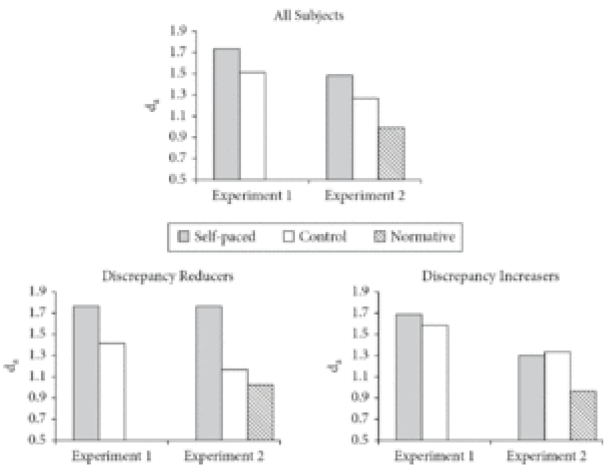
Allocation of Study Time

Perhaps the easiest strategy available to learners is to differentially allocate study time across materials to be learned (see also Kornell & Finn, this volume). Numerous studies have allowed learners to control their study in order to analyze distributions of study time. Of these studies, the most common finding is that learners will allocate more of their study time to difficult items versus easy items (see Son (p. 310) & Metcalfe, 2000, for a review). For example, Le Ny, Denhiere, and Le Taillanter (1972) found that subjects spent more time studying lists composed of highly confusable trigrams than lists containing less confusable trigrams. Research has also shown that subjective assessments of difficulty influence study time, finding that subjects study items longer that had been accorded lower judgments of learning (JOLs; i.e., Cull & Zechmeister, 1994; Mazzoni & Cornoldi, 1993; Nelson, Dunlosky, Graf, & Narens, 1994; Nelson & Leonesio, 1988; Son & Metcalfe, 2000). This finding obtains even when normative difficulty between items is homogenous (Mazzoni, Cornoldi, & Marchitelli, 1990). In fact, Metcalfe and Finn (2008) showed that JOLs influenced what items were selected for restudy even when they were dissociated from difficulty, thus suggesting that perceptions of difficulty influence study time more than actual difficulty does.

Learners gain proficiency at effectively allocating study time as they age. Masur, McIntyre, and Flavell (1973) found that third graders and college students elected to restudy items that they had forgotten on a previous test, while first graders elected to restudy items that they had recalled. Bisanz, Vesonder, and Voss (1978) had subjects repeatedly study and test on the same set of cue-target picture pairings until they reached perfect recall. Subjects also viewed the studied pairs after each testing session and provided postdictions on whether they had successfully recalled the target picture. Relative to younger subjects, college-age subjects showed superior discrimination between items they had successfully or unsuccessfully recalled on previous tests. Furthermore, college-age subjects' discrimination performance correlated more strongly with the number of study-test cycles necessary to reach perfect recall. This finding suggests that older learners are better able to winnow out sufficiently learned items from further study, thereby studying more efficiently than younger learners. These findings, along with others analyzing study habits across age spans (e.g., Dufresne & Kobasigawa, 1989; Kobasigawa & Metcalfe-Haggert, 1993) suggest that even basic tasks, such as monitoring past performance and deciding where to put forth more effort, are not innately present in learners' metacognitive repertoires.

The strategy of spending more time on more difficult materials is one that generally pays off. Mazzoni and Cornoldi (1993) examined the effects of study pacing on free-recall performance. They allowed one group of subjects to self-pace their study and had a second group study at a fixed pace. Recall was superior for subjects in the self-paced condition. These subjects were able to allocate more study time to items they judged to be more difficult. Koriat, Ma'ayan, and Nussinson (2006) also examined self-paced versus other-paced study time. Over four study-test cycles, they found that subjects allowed to self-pace allotted more time to items that they judged as more difficult and showed superior cued-recall performance on average (although this superior performance was not evident after the first study-test cycle). Tullis and Benjamin (2011) examined recognition performance between a self-paced study group and an experimenter-paced group. The self-paced subjects showed superior recognition, but this advantage only appeared for the subset of subjects who allocated more study time to items that were of greater normative difficulty (see Figure 16.1). Taken together, these three studies provide evidence that allocating more study time to more difficult items is beneficial to memory across a range of tasks.

Dunlosky and Hertzog (1998) proposed the *discrepancy reduction hypothesis* to describe learners' tendency to focus more resource-intensive processing on difficult materials. The discrepancy reduction hypothesis states that learners will study material until they reach mastery. Harder items, which are furthest from mastery, will thus receive the most attention during study. The discrepancy reduction hypothesis explains much of the extant literature on study-time allocation. It is important to note, however, that discrepancy reduction is not always the optimal approach to study. Studies in which learners allocate most of their study time to the hardest items typically impose no constraints on study time, nor on what material should be learned. It is ideal in this scenario, with unconstrained time and a goal to learn every item, to reserve the most effort for the most difficult items. However, the ideal approach changes when complete mastery is either impossible or unwarranted. As an example, consider a student who is preparing for an exam mere hours before the exam is to begin. Complete mastery is unlikely in this scenario; our hypothetical student would be better off salvaging what information he or she could easily encode and focusing on the more difficult material only if time warranted. Here the benefits of mastery would no longer hold sway over the time costs necessary to achieve mastery.



Click to view larger

Figure 16.1 Item discriminability between self-paced subjects, experimenter-paced subjects, and subjects given a normative allotment of study time (Experiment 2) *(left panel).* Self-paced subjects were classified as either discrepancy reducers *(upper right panel)* or discrepancy increasers *(lower right panel).* Only discrepancy reducers were statistically better than experimenter-paced subjects (Tullis & Benjamin, 2011).

Evidence shows that learners are sensitive to the altered cost benefit analysis when study time and goals are constrained. Thiede and Dunlosky (1999) found that when subjects were given a (p. 311) low-performance goal for memory of a list, they focused their study time on the easiest items (see also Dunlosky & Thiede, 2004). Subjects in this study were interacting efficiently with memory: by switching their focus to easier materials, they could still reach their goals while sidestepping the greater costs concomitant with focusing on difficult items. Son and Metcalfe (2000) similarly showed that limitations on total study time led subjects to switch their focus to easier items. As is the case with lower goals, imposing time constraints probably makes the costs of mastery too great. Learners are better off targeting easier materials, a strategy that allows them to successfully encode a maximal amount of information in the limited time that they are given.

Given the findings of Thiede and Dunlosky (1999) and Son and Metcalfe (2000), Metcalfe (2002) proposed that learners will engage in discrepancy reduction only if they are attempting to master all of the to-be-learned materials and if they are given unlimited study time. And indeed, nearly all of the experiments on study-time allocation fit those criteria. Metcalfe (2002) proposed that discrepancy reduction is a specific instance of a more general study-time allocation policy, which she called the region of proximal learning (RPL). The RPL framework suggests that learners will focus on the easiest of to-be-mastered items, and as a study session progresses, learners will shift the focus of their studying to increasingly difficult information. Thus, when only a very short amount of time is allowed, learners will only have studied the items closest to mastery. But when a longer amount of time is allowed, learners will be able to shift their efforts toward more difficult items (i.e., engage in discrepancy reduction).

There is a fair bit of evidence supporting predictions made by the RPL framework. Learners who are forced to study medium difficulty items in lieu of easy and difficult items exhibit the best recall performance (Metcalfe & Kornell, 2003). Furthermore, learners will choose to study unmastered items in order of descending JOLs (Metcalfe & Kornell, 2005), and their performance suffers when they are prevented from studying the easiest of the unmastered ones (Kornell & Metcalfe, 2006). Thus, the RPL framework illustrates learners' abilities to make optimal temporal adjustments in study-time allocation. That is, as constraints on the learning situation change, learners are able to adapt their study efforts in order to maximize the efficiency of their encoding. (p. 312)

Most research on study-time allocation examines study time as a function of item difficulty. However, work by Ariel, Dunlosky, and Bailey (2009) suggests that learners are sensitized to more than just item difficulty when deciding where to allocate study time. They found that item reward more strongly influences study decisions than item difficulty. That is, a learner will study higher-value material rather than appropriately difficult material if they must choose between the two. Habitual factors (such as the impulse to read from left to right) also influence study-time allocation. For instance, items that are placed at the leftmost position of an array are studied longer than items in a less salient location (Dunlosky & Ariel, 2011). Habitual biases can be diminished by contextual factors, however, such as time pressure or constrained amounts of item for restudy (Ariel & Dunlosky, 2013). All things considered, allocation of study time appears to involve consideration of several factors, ranging from high-level features such as item worth and difficulty to low-level features such as item location.

Allocation of Memory Search Time

Research has also shown that learners' perceptions of item difficulty influence memory search time at retrieval. Costermans, Lories, and Ansay (1992) looked at search time on an item-by-item basis. They found that unretrieved items given higher feelings of knowing (FOKs) were searched for longer than were items given lower FOKs. This finding suggests that a learner will continue to search for an item if they feel they have a relatively high probability of retrieving it (see also Nelson, Gerler, & Narens, 1984). Young (2004) examined recall from categories as a function of the difficulty of accessing those categories. She presented subjects with two semantic categories from which they could retrieve exemplars. Subjects were quicker to switch to a category that was easier than the current one than to one that was harder, and once they switched to an easy category they searched longer. The benefits of searching an easier category outweighed the cost of switching. When the task was constrained such that subjects were allowed only one switch between categories, subjects continued to search easy categories longer than difficult categories, but they were now slower to leave a given category regardless of difficulty. The cost of switching was higher in the constrained version of the task, and subjects took the appropriate measures to offset the higher cost by searching an initial category for longer time.

Evidence also suggests that total memory search time will be shortened if a task is deemed difficult. Dougherty and Harbison (2007) obtained decisiveness ratings for their subjects by having them respond to survey items such as "I usually make important decisions quickly and confidently." They found that subject decisiveness interacted with task difficulty when it came to terminating memory search, with the more decisive subjects being quicker to terminate memory search when the retrieval task was perceived as difficult versus easy. Less decisive subjects did not terminate memory search as quickly, which suggests that learner traits influence search termination.

Other factors also seem to influence the allocation of memory search time. For instance, total search time seems to be influenced by knowledge of the number of items one is searching for, with participants searching longer when they know the number of items to be recalled compared to when they don't know the number of items to be recalled (Unsworth, Brewer, & Spillers, 2011a; Winograd, 1970). Likewise, search termination decisions are related to the confidence participants have in the most recently recalled item, with participants continuing to search longer when they are confident in the last recalled item compared to when they are less confident in the last recalled item (Unsworth, Brewer, & Spillers, 2011a).

Research on memory search time allocation has found similar results as studies on assessing the plausibility of information. For instance, Reder (1982) had subjects read stories and then had them either undergo a recognition test for statements from the stories or assess the plausibility of statements from the stories. When presented with a statement from a previously read story, subjects were quicker to judge the statement as plausible than they were to recognize it. This finding supported a hypothesis by Reder (1982) that learners first check for a match in memory when presented with a question, and only if a match is found do they continue searching for verbatim material that they can retrieve (see also Benjamin, 2001, 2005b; Reder, 1987). These findings support the notion that learners tend to be efficient with their time. That is, by first checking to see if an item matches to memory, they are forestalling a situation where they search for information that cannot be retrieved. Glucksberg and McCloskey (1981) found similar evidence by asking subjects questions that they did not know. In their experiments, subjects were quick to indicate that they did not know the answer to a question (e.g., “How (p. 313) old is Ann Landers?”). Subjects were slower, however, when asked questions that were relevant to their knowledge (e.g., “Does Ann Landers have a degree in journalism?”), which suggests that they had found enough of a match to memory to compel them to continue searching.

Terminating the Encoding Session

Another decision facing learners at encoding is when to cease their study. For instance, a student may plan to hold a study session until they feel that they have successfully encoded a predetermined amount of information, or they may plan to study until they feel they have tapped their cognitive resources. Le Ny et al. (1972) found that learners study stimuli for an insufficient amount of time when directed to completely master the materials. Dufresne and Kobasigawa (1989) showed that learners ranging from first grade to college all study insufficiently when directed to master all materials, though college-age learners are closer to mastery than are younger learners. In a similar vein, Kornell and Bjork (2008b) found that learners choose to drop flashcards from study even though dropped items would benefit from further encoding. Karpicke (2009) likewise found that learners end retrieval practice too soon. Generally, learners appear to study for too short a time. This failure may be due to the sense of fluency that familiar materials engender, thereby inflating assessments of learning (Benjamin, Bjork, & Schwarz, 1998; Benjamin, Bjork, & Hirshman, 1998; Whittlesea & Williams, 1998). Alternatively, learners may be aware that materials are not mastered but cease study out of a sense of depreciating returns on study time (Metcalfe & Kornell, 2005).

Scheduling

In addition to decisions about how to allocate study time or when to terminate an encoding session, learners also must make decisions about how to schedule their practice. Spacing repeated exposures to materials has been shown to improve memory (for review, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). Spacing is advantageous in the sense that study time can be held constant yet yield more effective results. But despite its advantages, rememberers often report a sense of superior learning when practice is massed rather than spaced (Baddeley & Longman, 1978; Kornell, 2009; Kornell & Bjork, 2008a; Simon & Bjork, 2001). This result may be another case of utilizing misleading cues present in the learning context; for instance, learners massing their practice often learn the material quickly—though temporarily—and this rapid acquisition may elicit a higher sense of fluency. Of course, in these studies, learners' assessments of the value of spacing and massing are taken after the learning episode, a fact that may mask what learners think about these options during the course of study. What happens when learners must decide spontaneously which items will be spaced and which will be massed?

Son (2004) had subjects provide JOLs to a list of cue-target pairs and then make a decision to mass the pairs, space the pairs, or be done studying them. She found that subjects chose to mass items that received lower JOLs (that is, items that were perceived as being more difficult) and space items that received higher JOLs. Benjamin and Bird (2006) presented subjects with a list of paired associates that subjects had to either space or mass. Contrary to Son's (2004) methodology, subjects in Benjamin and Bird's (2006) experiment had to space or mass exactly half of the items. There was no option to be done studying. They found that subjects chose to space nominally difficult items but mass easy items—the opposite of Son's (2004) results. These opposing results were reconciled by a study by Toppino, Cohen, Davis, and Moors (2009), who showed that the relationship between item difficulty and decisions about spacing is influenced by presentation time. When items are presented for a very brief period, as was the case in Son's (2004) study, learners elect to mass more difficult items. Likewise, when items are presented for a longer period, as was the case with Benjamin and Bird (2006), learners will elect to space more difficult items. This reversal is probably due to the fact that very brief presentations are insufficient to even fully apprehend the stimulus visually, thus leading to a situation in which two consecutive presentations are more beneficial than the sum of two separate ones (see Ariel, Dunlosky, & Toppino, 2014). In a related finding, Metcalfe and Kornell (2005) showed that the benefit of spacing became a disadvantage when presentation times were very short. Taken together, the evidence suggests that learners will elect to space more difficult items as long as they are given sufficient time to process the items on the first presentation.

If we return to the time allocation models introduced earlier, Dunlosky and Hertzog's (1998) discrepancy reduction model and Metcalfe's (2002) region of proximal learning framework, we can see that learners are essentially electing to discrepancy (p. 314) reduce when they decide to space harder items. That is, they are reserving the more effective schedule for the hardest items. However, as happens when allocating study time, learners will choose to space easier items if constraints are in place that limit the amount of exposure to studied materials. That is, they are now applying the more effective schedule to items within their region of proximal learning. Recall that with study-time allocation, learners were able to make efficient adjustments when facing time constraints. The findings of Toppino et al. (2009) suggest that they appear to make efficient spacing decisions in the face of such constraints as well. Whether learners make similar decisions to space or mass when performance goals are varied (just as they adjust study-time allocation to match performance goals) remains to be seen.

Incentives and Mnemonic Strategies

Another feature of the learning context that may affect learners' use of mnemonic strategies is the presence of incentives. Work with incentives suggests that learners' mnemonic performance is enhanced when incentives are offered. For instance, Heyer and O'Kelly (1949) found that subjects who were under the impression that 10% of their class grade rested on retention performance showed superior long-term retention compared to a group that was not incentivized. Weiner and Walker (1966; see also Loftus and Wickens, 1970) found similar long-term retention differences between high-incentive and low-incentive conditions. Study time in these experiments was fixed, so subjects' abilities to vary encoding were constrained to control they could exert without devoting more or less study time to materials.

To combat the constrained study time, it appears as though subjects were able to make a temporal adjustment in study during other segments of the experimental procedure. Wickens and Simpson (1968) found that subjects operating under higher incentives performed more poorly on an intervening task undertaken between study and test. Thus, subjects were probably putting forth less effort during the intervening task so that they could more thoroughly rehearse the to-be-tested items. Castel, Benjamin, Craik, and Watkins (2002) found a similar pattern for older adults. In their study, older adults tended to focus on high-incentive items that they could easily remember and rehearse these memorable items at the expense of encoding additional information. These findings suggest that learners are able to find a means of differentially allocating rehearsal (a temporal shift in encoding strategy) even when the constraints of the experimental task do not obviously afford the implementation of such strategies.

There is also evidence that presenting incentives at recall alters learners' mnemonic strategies and, as a result, their mnemonic performance. Loftus and Wickens (1970) found that by offering incentives at recall, subjects searched memory for a longer time and ultimately recalled more correct items. Davelaar, Yu, Harbison, Hussey, and Dougherty (2013) found that manipulating incentives at recall affected subjects' memory search times asymmetrically. In their study, subjects won or lost points for each word they could correctly or incorrectly recall. Subjects were predictably quicker to end memory search when an incorrect response would lose them more points than a correct response would gain them. However, when the number of points awarded was larger than the amount detracted, subjects searched memory no longer than they did in a baseline condition where the awarded and detracted values were equal. One possible interpretation of these findings is that learners are more responsive to increased costs than increased benefits. Returning to the literature on incentives at encoding, Wickens and Simpson (1968) showed that learners who would receive a shock for each incorrectly recalled item performed significantly more poorly on an intervening task than a group that would receive monetary rewards for each correctly recalled item. That is, subjects in the shock group were probably engaging in more rehearsal for the upcoming recall test. This finding suggests that the shock group (facing increased costs) was more motivated than the money group (facing increased benefits) to perform well on the recall test (though it is impossible to evaluate whether the money and shock served as a reward and punishment, respectively, of equal magnitude).

Social comparisons can also incentivize learners at recall. Fraundorf and Benjamin (2015) led subjects to believe that they were competing with a previous participant's cued recall scores. Furthermore, they manipulated word pair difficulty by including some pairs made up of related words (easy pairs) and unrelated words (difficult pairs). When subjects were tested on a cue-target pairing, they were told whether their fictive competitor had gotten that pair correct, incorrect, or had not seen the pair. Subjects were then given the opportunity to change their initial response following presentation of their (p. 315) competitor's performance. When the competitor's performance mismatched what would be expected (i.e., the competitor was successful on a difficult pair or was unsuccessful on an easy pair), subjects were more likely to reconsider their response. Moreover, subjects' reconsideration of their responses resulted in better cued recall performance than matched responses. These findings suggest that learners are sensitive to how their experience with materials compares with others'. When they sense a mismatch, they are incentivized to re-search their memory in a qualitatively different way, and response accuracy is enhanced as a result.

Spontaneous Use of Tactical Strategies at Encoding and Retrieval

Many spontaneous strategies used by learners involve temporal strategies. However, studies using categorical free recall have shown that learners also engage in tactical strategies without prior instruction or experience with a task. In two separate experiments, Unsworth, Brewer, and Spillers (2014) had subjects recall either animals or friends in a designated recall period. In each free recall task, the strategy most frequently reported by subjects was visualization (e.g., imagining walking through a zoo when trying to recall animals). In ensuing experiments, Unsworth and colleagues (2014) instructed subjects to adopt a visualization strategy, no strategy at all, or one of an assortment of various other strategies. Subjects who were instructed to use the visualization strategy performed the same as subjects not instructed to use any strategy, and the two groups recalled the most exemplars during the recall period. This finding suggests that learners are adept at picking an effective strategy for a free recall task, with uninstructed learners performing just as well as optimally instructed learners. However, individual differences in working memory capacity (WMC) influence the type of spontaneous strategies that participants use in these types of tasks. Specifically, although both high- and low-WMC individuals tend to use optimal visualization strategies, important individual differences arise when examining other strategies. In particular, high-WMC individuals were more likely to use a general to specific strategy (e.g., using the general category “dog” to guide recall of various types of dogs) and low-WMC individuals were more likely to claim that they did not use a strategy, but rather relied on more random associations to recall items (Schelble et al., 2012; Unsworth, Brewer, & Spillers, 2013).

Evidence also suggests that learners engage in spontaneous tactical adaptations at encoding, although individual differences in WMC again appear to influence the likelihood of doing so. Unsworth and Spillers (2010) found that the difference in free recall performance between high-WMC and low-WMC subjects was larger under intentional encoding versus incidental encoding. Furthermore, high-WMC subjects were more likely to output primacy items when encoding was intentional, suggesting that they were tactically updating their encoding strategy when they anticipated a free recall session. In addition, prior research has shown that high-WMC individuals are more likely to use effective encoding strategies (e.g., grouping, imagery) than low-WMC individuals and these differences in spontaneous encoding strategies partially mediate the strong relation between WMC and recall performance (Bailey, Dunlosky, & Kane, 2008; Unsworth & Spillers, 2010).

In a related study, Unsworth, Brewer, and Spillers (2011b) had subjects make either a rhyme or semantic association judgment between cue-target pairs at encoding; at recall they provided information about the target word corresponding to either its rhyme (e.g., “Rhymes with dog”) or its semantic association (e.g., “Associated with dog”) with the cue word. Thus, the encoding and retrieval conditions could be matched or mismatched in terms of their focus on the rhyming or semantic association between the cue-target pairs. They found that high-WMC subjects experienced a larger diminution in performance on a cued recall task when encoding and retrieval conditions were mismatched versus matched, which suggests that high-WMC learners are more likely to use context cues at encoding than low-WMC learners and are more sensitive to changes in context as a result.

Exposing Learners to Novel Strategies

Finding the right strategy to apply to a given memory task is key to ensuring acceptable performance without compromising attention to other ongoing cognitive demands. Although there are certainly some individuals who are better at handling these complex tradeoffs than others (and some situations, such as dual-task scenarios, that are generally difficult; Finley, Benjamin, & McCarley, 2014), everyone can learn new strategies. In this section, we review learners’ abilities to adopt new strategies following explicit instruction and, more impressively, experience with a new strategy in the absence of instruction.

(p. 316) Exposure via Instruction

The *generation effect* (Jacoby, 1978) refers to the superior learning that results from learners providing information themselves rather than simply reading it. For instance, learners will show superior later memory for having studied the word “cabinet” if they originally had to fill in the blanks for “c_b_n_t” than if they had simply read the word “cabinet.” This advantage suggests that readers do not spontaneously engage whatever processing strategies result in the memory advantage for generated words. Consistent with this interpretation, the benefits of generation can be nullified by instructing learners to adopt more elaborate, qualitatively different strategies than what they spontaneously use when reading text. Begg, Vinski, Frankovich, and Holgate (1991) assigned subjects to a read condition or to a generate condition, but instructed subjects in the read condition to use imagery. That is, they were asked to imagine words as they studied them and hold onto images for as long as words were presented. On an ensuing recognition test, memory performance was equivalent between conditions, suggesting that subjects in the read condition applied the more effective encoding strategy after being instructed to do so. DeWinstanley and Bjork (1997) found that cued recall and free recall performance between readers and generators were similar after instructing readers to focus on cue-target relations or target-target relations, respectively. That is, readers expecting a cued recall test were told to make associations between the cue and target words of each studied word pair, and readers expecting a free recall test were told to make associations across pairings, between the targets of each studied pair. As with Begg et al. (1991), readers in their study demonstrated an ability to tactically update their strategy in response to instruction (see also Bjork, deWinstanley, & Storm, 2007).

The benefits of effective strategies for learning are especially important for older adults, who exhibit widespread difficulties in remembering (Kester, Benjamin, Castel, & Craik, 2002; Craik & Salthouse, 2008). Older adults can also make tactically adaptive changes to their mnemonic strategies upon instruction. Dunlosky, Kubat-Silman, and Hertzog (2003) found that older adults' cued recall performance was enhanced after teaching them relevant strategies (interactive imagery and sentence generation). A group that learned study regulation techniques in addition to strategies showed even better cued recall performance than the group that learned only strategies. Troyer, Hafliger, Cadieux, and Craik (2006) investigated older adults' ability to adopt new strategies for face-name pairings. By having the subjects generate associations between the names and faces, memory for the paired items was superior relative to a control group that was not instructed to make associations between the pairs.

Learners have also demonstrated an ability to adopt new strategies at the time of retrieval. Postma (1999) instructed subjects to adopt either a conservative or a liberal old-new criterion for a recognition memory test. Subjects were also instructed to make remember/know judgments, wherein subjects report "remembering" a stimulus they feel generally familiar with and report "knowing" a stimulus when they can remember specific details of their previous encounter with the stimulus. Subjects adopting a liberal criterion showed increased sensitivity for remember judgments but decreased sensitivity for know judgments relative to the group adopting a conservative criterion (Benjamin, 2005a). Because performance for the two groups was different, these findings suggest that learners were able to update their recall strategies in response to instruction. Unsworth, Brewer, and Spillers (2013; see also Unsworth 2007; 2009b; Unsworth, Spillers, & Brewer, 2012a) found recall performance differences between subjects with high WMC and those with low WMC, thus suggesting that accurate online monitoring of one's strategies and progress during recall can yield benefits in the total amount recalled. However, this difference in recall was eliminated after they instructed subjects to use experimenter-provided category cues, indicating a mediating role for the utility of such cues. Interestingly, both groups improved when cues were provided (though the high-WMC group improved to a lesser extent; see also Unsworth, 2009a; Unsworth, Spillers, & Brewer, 2012b), suggesting that neither group spontaneously generated retrieval cues with maximum effectiveness.

Exposure via Experience

While it is encouraging that learners can adjust their strategic interaction with memory after a simple instructional manipulation, the downside of this result is the implication that learners apparently do not use fairly simple and effective strategies on their own. In those experiments, learners not instructed to do anything strategically different at encoding performed worse than their instructed counterparts, at least as a group. However, there is evidence to suggest that learners are able to adopt superior strategies without direct instruction—but only after (p. 317) gaining some experience with the specific task and their options for encoding.

DeWinstanley and Bjork (2004) had subjects read passages from paragraphs that contained critical terms emphasized in red font color. On a given trial, subjects either read the critical terms or generated them by filling in missing letters. A first test revealed the usual generation effect: Words that were filled in were better remembered than were words that were read. However, after a second study-test cycle, memory for read words increased to the level for generated words. This increase in performance suggests that learners saw the benefit of generation after the first test, and they adjusted their encoding strategy to something closer to generation when studying for the second test. Thus, learners showed that they could adapt their encoding strategy after experiencing a superior strategy.

In a related experiment, Kornell and Son (2009) investigated whether subjects could learn to appreciate the benefits of self-testing. They gave subjects the option to either restudy or self-test on word pairs over four study cycles. Subjects increasingly chose to self-test with each study cycle, suggesting that they were learning to appreciate the mnemonic benefits afforded by self-testing. However, subjects paradoxically rated restudy as the more effective method, and they reported that their decision to self-test was more to diagnose learning rather than to enhance it. While it is tempting to conclude that subjects did not appreciate the benefits of self-testing, they may have had too much of a metacognitive burden to accurately assess which strategy was better. Tullis, Finley, and Benjamin (2013) found that subjects could be guided to appreciate self-testing, but only if they were provided the necessary information (i.e., telling subjects at test which stimuli had been studied and which had been self-tested). Thus, facilitating the detection of critical learning factors helped subjects appreciate the benefits of self-testing.

Although the preceding evidence suggests that learners are completely naïve regarding the effects of testing, it should be noted that they are in fact sensitive to conditions where testing will *not* be beneficial to them even though the benefits of testing elude them. Tullis, Benjamin, and Fiechter (2015) either honored or dishonored subjects' requests to restudy or test on to-be-remembered word pairs. Subjects tended to prefer testing for easy items and restudying for difficult items—an effective strategy given that retrieval practice is less valuable for items that are unlikely to be recalled. Furthermore, memory performance was superior when learners' study choices were honored than when they were dishonored. Honoring their choices even led to superior performance compared to a condition in which every item was tested, regardless of the learner's choices. These results lend credence to the idea that subjects have a limited appreciation of the value of testing—or more specifically, an appreciation for the conditions under which testing is ineffective.

Learners can also adopt new retrieval strategies with experience. Rabinowitz, Freeman, and Cohen (1992) had subjects study a list of words that could be grouped into four categories. They informed some subjects about the categorized nature of the stimuli prior to an initial test. These subjects exhibited more clustering in their free recall output relative to a group not informed about the categorized words. However, on a second study-test cycle, subjects' clustering was equal between both groups. This finding suggests that the naïve group was able to observe the benefits of retrieving by category after the first test and successfully used the strategy with experience. Similarly, Reder (1987) had subjects read stories and later verify events that either were in the story or were plausible given the story. She found that by manipulating the number of plausible versus actual events requiring verification, subjects were able to adopt a retrieval strategy that either emphasized plausibility (when more plausible statements were included on the test) or emphasized memory search (when more actual events were included).

Adjusting Strategies after Exposure to a Memory Test

Learners are able to strategically use information gleaned from experience with various mnemonic strategies. Tests can also be a rich source of information that influences learners' strategic approaches to memory tasks. In this section, we review findings from the test expectancy literature that document both successes and failures of learners to update their strategy after testing. We then review research that demonstrates learners' growing more attuned to both properties of memory and appropriate strategic adaptations after being tested.

Test Expectancy Literature

Several studies have investigated learners' abilities to change encoding strategy based on expected qualities of an upcoming test. These studies use the *test expectancy paradigm*, an experimental design that leads subjects to expect features of an upcoming test, and then provides a critical test that either (p. 318) conforms to the subjects' expectations or violates the subjects' expectations. Effective preparation for a test is revealed by an advantage for subjects in the condition in which the delivered test was the expected one.

Recall versus Recognition.

Tversky (1973) had subjects study labeled pictures of familiar objects for an upcoming recognition test or recall test (subjects were told which test format to expect). The recognition test involved the studied pictures; the recall test involved producing the picture labels. Following study of the stimuli, subjects received two tests, one of the unexpected format and one of the expected format. Subjects performed better when the test format was expected versus unexpected, thus suggesting that they were utilizing strategies during encoding that would promote performance for their anticipated test format. Von Wright and Meretoja (1975) obtained similar findings by using labeled pictures as stimuli for an anticipated test of recall versus recognition. Later evidence showed that children were not able to individualize their study to meet test demands as well as adult learners (von Wright, 1977).

The findings reported so far suggest that learners can effectively adopt strategies to meet anticipated retrieval demands. However, later results obtained using verbal stimuli suggest that learners may not be as savvy at encoding as first thought. Balota and Neely (1980) had subjects go through a series of study-test cycles to induce expectation of either a free recall or recognition test. Subjects studied word lists. Subjects expecting a free recall test performed better on both test formats, regardless of expectation. These results were discordant with the findings of Tversky (1973), who found that expected test formats resulted in better performance for subjects expecting either test format.

Several additional studies have found that when learners expect a recall versus a recognition test, those who expect recall perform better on a critical test regardless of test format. Why might this be the case? The most intuitive explanation is that recall tests are more subjectively difficult than recognition tests. Learners expecting a recall test therefore encode materials with a level of effort commensurate with the expected level of challenge for the upcoming test. Such a change would be what we described earlier as a temporal adjustment, where strategies themselves are not changed but the amount of time implementing the strategies varies. There is evidence to support the notion that learners merely try harder, rather than try something different, when expecting a recall versus recognition test. Subjects in a study by Hall, Grossman, and Elwood (1976) reported similar strategies regardless of what test they were expecting, although the subjects expecting a recall test performed best on a final test regardless of format. These subjects may have been applying strategies similar to those of subjects expecting recognition, but to a greater degree.

Cued Recall versus Free Recall.

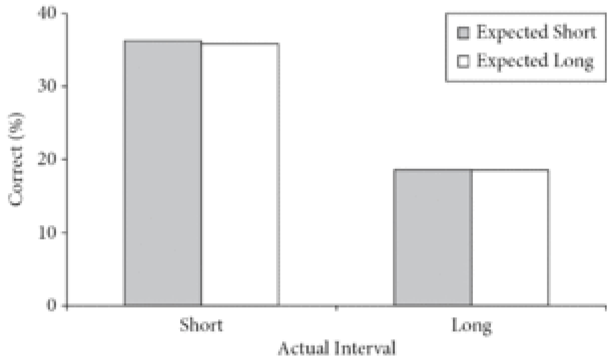
Finley and Benjamin (2012) used the test expectancy paradigm to investigate learners' strategies when they expect a test of cued recall versus free recall. On both tests, subjects had to recall the second (target) word, but they were only presented with the first (cue) word in the cued recall task. An advantage to these two test formats is that strategies positively affecting one are likely to negatively affect the other. For instance, learners expecting cued recall are likely to focus on making associations between cue words and target words. In addition, they are also more likely to devote effort to weakly associated word pairs than to more strongly associated pairs. Likewise, a learner expecting free recall would benefit from attending to associations between the target items, and thus should not attend more to weakly than strongly associated pairs. Subjects in their study completed four study-test cycles before completing a fifth critical cycle. The final test either conformed to subjects' induced expectations or violated their expectations. Unlike other test expectancy studies that also used strictly verbal materials, they found that subjects expecting a cued recall test performed better if given a cued recall test, and that subjects expecting a free recall test performed better if given a free recall test. These results suggest that learners are able to adjust their encoding strategies to accommodate specific recall demands.

Finley and Benjamin (2012, Experiment 3) also measured study time in a self-paced learning paradigm to more directly demonstrate changes in strategy over the course of the initial study-test cycles. Subjects practicing on cued recall devoted more time to low-association word pairs than to high-association word pairs throughout the four practice cycles. On the contrary, subjects practicing on target free recall devoted increasingly similar amounts of study time to high-association and low-association word pairs throughout the practice cycles. For these subjects, association between word pairs was of little value, and they adjusted their (p. 319) study time in a manner that deemphasized intra item associations as the practice cycles progressed.

Expected Retention Intervals.

The studies addressed to this point have all focused on changes in strategy based on anticipated test format. In addition to test format, another element of upcoming test demands that may affect strategy use at encoding is anticipated retention interval. For instance, students preparing for an exam to be held tomorrow may hold a cram study session to account for the limited amount of preparation time at their disposal. Furthermore, massing of materials is beneficial to memory if learners take a test soon after study (Bjork, 1999). However, a student studying for a test to be held in one week may decide to space their rehearsal of test materials. This student would have more available study time and would be better served by spacing materials, since memory for temporally distant information is better served by spacing. Do learners account for retention interval at encoding? Fiechter and Benjamin (2015) addressed this question in a series of experiments in which subjects were asked to remember word pairs for either a long or a short retention interval. The word pairs consisted of a low-frequency Graduate Record Examination word as a cue and a higher-frequency synonym as a target. At study, subjects were presented a word pair along with a cue indicating either a short or long retention interval. In three experiments they used retention intervals of 1 minute versus 4 minutes, 30 seconds versus 3 minutes, and 30 seconds versus 10 minutes. These words were tested at the expected retention interval most of the time (i.e., a word pair cued for testing 1 minute was actually tested in 1 minute) but sometimes at the unexpected retention interval (i.e., a word pair cued for testing in 1 minute was actually tested in 4 minutes). Subjects in all three experiments showed no differential performance at either actual interval based on the expected retention intervals. This finding obtained even in the most extreme case of one interval at 30 seconds and the other interval at 10 minutes.

The three preceding experiments all restricted study time to 5 seconds for each word pair. To see whether subjects might adjust their study time as a function of expected retention interval, Fiechter and Benjamin (2015) included a fourth experiment in which study was self-paced. The results of this fourth experiment were similar to the findings of the first three experiments: performance did not seem to differ at each actual interval regardless of expected retention interval. Furthermore, study times between expected retention intervals did not differ. Subjects studied word pairs for the same amount of time, regardless of whether a test trial was expected in 30 seconds or in 10 minutes.



Click to view larger

Figure 16.2 Mean cued-recall performance as a function of actual retention interval (short vs. long) and expected retention interval (short vs. long) collapsed across four experiments (Fiechter & Benjamin, 2015).

When collapsed across all four experiments, subjects' cued recall performance did not differ as a function of expectation at either the short interval or the long interval (see Figure 16.2). Thus, these four experiments suggest that learners do not make an attempt to account for an expected retention interval.

Why might learners not adjust encoding strategies in response to retention intervals? A study by Koriat, Bjork, Sheffer, and Bar (2004) may provide clues. Across a series of experiments, Koriat et al. had subjects predict forgetting over a range of retention intervals. When retention interval was manipulated within subjects, participants correctly (p. 320) predicted that they would be less likely to remember information over time. However, when the length of the retention interval was manipulated between subjects, subjects predicted the same amount of forgetting between intervals ranging from 10 minutes to 1 year. It may be the case that learners are generally poor monitors of their forgetting, and that they see no need to adjust encoding strategies for a test parameter (incorrectly) deemed to be inconsequential. However, this conclusion is tempered by findings that show subjects' predictions are in fact influenced by anticipated retention intervals when those intervals are manipulated within subjects (Rawson, Dunlosky, & McDonald, 2002; Tauber & Rhodes, 2012).

Learning from Tests

Experience with a test has been shown to be beneficial at encoding in research outside the test expectancy paradigm. For instance, learners will correctly predict the higher recognition probability of low-frequency words versus high-frequency words once given the chance to take a recognition test and make postdictions about whether they would be able to recognize a given word if they were to be tested on it again (Benjamin, 2003). Older adults have also demonstrated this ability to learn to appreciate the recognition advantages for low-frequency words (Tullis & Benjamin, 2012). Learners have also shown the ability to discriminate between an effective and ineffective mnemonic strategy after being able to take a test following the utilization of the strategies. Brigham and Pressley (1988) had subjects learn words using two strategies, one that was very effective (generating mnemonic keywords) and one that was moderately effective (generating sentences including the studied word). Subjects reported that neither strategy seemed to be superior to the other. After testing on the studied words, however, young adults were able to tell that the mnemonic keyword strategy was better than the sentence strategy. Older adults failed to show this enhanced discrimination.

Experience with a recall task has also been shown to affect metacognitive approaches to the task. For instance, on a free recall task, learners have been shown to increasingly output recently presented items first over a series of study-test trials (Conover & Brown, 1977; Huang, 1986; Huang, Tomasini, & Nikl, 1977; see Healey and Kahana, 2014, for a discussion on whether shifts in recall initiation reflect changes in strategy versus tuning of the memory system). Castel (2008) found that learners more accurately predicted primacy and recency effects in free recall performance after experience with utilizing serial position information over a series of study-test cycles. Subjects' predictions grew more accurate even when they relied on serial position cues alone, independent of the words to be studied. Rhodes and Castel (2008) provided subjects with part-list cuing (i.e., a subset of the items from the to-be-recalled list) prior to free recall. The cuing interfered with subjects' performance, and their predictions reflected this interference over a series of study-test trials (though see Finley, Liu, and Benjamin, 2015, for a different account of learners' perceptions of part-list cuing). On a recognition memory task, Benjamin and Bawa (2004; see also Brown, Stevyers, & Hemmer, 2007) found that subjects raised their response criterion over a series of study-test cycles as distractor items became more plausible (making the tests more difficult). The effect was asymmetrical, however; subjects did not lower their criterion as tests became easier. If we interpret subjects' criterion shifts as an update in strategy, these findings suggest that learners are sensitive to the greater match to memory necessary to discriminate between similar materials. Furthermore, strategic approaches to more difficult recognition tests are likely to generalize to easier tests, while going from easy tests to more difficult tests requires an update in strategy.

Summary

Quality use of memory is heavily dependent on making smart decisions regarding how to interact with it. Easy decisions, such as deciding to spend more time encoding in order to have a better chance of remembering something later, are often made spontaneously. Such temporal adaptations have benefits that are transparent to infer and are learned early in development. Furthermore, learners are able to make efficient decisions regarding which items they will study more and those they will study less. In contrast to temporal adaptations, tactical adaptations are more difficult to implement. Most learners are unaware of properties of memory or of the variety of mnemonic strategies available, and they are unable to make smart tactical decisions spontaneously. Instead, experience with a strategy or task needs to inform a learner's decision-making process. Once given experience, learners are fairly successful at implementing effective strategies. For instance, they can guide their own learning by performing study-test cycles, with no additional cues to update their metacognitive control. Thus, it appears that learners are able to learn from their past (p. 321) learning, provided that the context provides them with enough information to make inferences from past memory performance.

Once learners have used their learning experiences to augment their strategic repertoire, they are better equipped to navigate the complex trade-offs between strategy efficacy and performance goals. That is, they will be better able to assess the appropriateness of implementing a strategy based on the resources it demands and the performance levels they are hoping to achieve. Consequently, differences between learners can be explained in part by efficient interaction with memory, rather than differences in memory capacity. This view of memory has trade-offs in itself, placing more burden on the learner while leaving room for improvement as experience with memory accumulates.

References

Ariel, R., & Dunlosky, J. (2013). When do learners shift from habitual to agenda-based processes when selecting items for study? *Memory & Cognition*, *41*, 416–428.

Ariel, R., Dunlosky, J., & Bailey, H. (2009). Agenda-based regulation of study-time allocation: When agendas override item-based monitoring. *Journal of Experimental Psychology: General*, *138*, 432–447.

Ariel, R., Dunlosky, J., & Toppino, T. C. (2014). Contribution of degraded perception and insufficient encoding to decisions to space or mass study. *Experimental Psychology*, *61*, 110–117.

Baddeley, A. D., & Longman, D. J. A. (1978). The influence of length and frequency of training session on the rate of learning to type. *Ergonomics*, *21*, 627–635.

Bailey, H., Dunlosky, J., & Kane, M. J. (2008). Why does working memory span predict complex cognition? Testing the strategy affordance hypothesis. *Memory & Cognition*, *36*, 1383–1390.

Balota, D. A., & Neely, J. H. (1980). Test-expectancy and word-frequency effects in recall and recognition. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 576–587.

Begg, I., Vinski, E., Frankovich, L., & Holgate, B. (1991). Generating makes words memorable, but so does effective reading. *Memory & Cognition*, *19*, 487–497.

Benjamin, A. S. (2001). On the dual effects of repetition on false recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 941–947.

Benjamin, A. S. (2003). Predicting and postdicting the effects of word frequency on memory. *Memory & Cognition*, *31*, 297–305.

Benjamin, A. S. (2005a). Recognition memory and introspective remember/know judgments: Evidence for the influence of distractor plausibility on "remembering" and a caution about purportedly nonparametric measures. *Memory & Cognition*, *33*, 261–269.

Benjamin, A. S. (2005b). Response speeding mediates the contributions of cue familiarity and target retrievability to metamnemonic judgments. *Psychonomic Bulletin & Review*, *12*, 874–879.

Benjamin, A. S. (2008). Memory is more than just remembering: Strategic control of encoding, accessing memory, and making decisions. In A. S. Benjamin & B. H. Ross (Eds.), *The psychology of learning and motivation: skill and strategy in memory use* (Vol. *48*, pp. 175–223). London, England: Academic Press.

Benjamin, A. S., & Bawa, S. (2004). Distractor plausibility and criterion placement in recognition. *Journal of Memory and Language*, *51*, 159–172.

Benjamin, A. S., & Bird, R. D. (2006). Metacognitive control of the spacing of study repetitions. *Journal of Memory and Language*, *55*, 126–137.

Benjamin, A. S., Bjork, R. A., & Hirshman, E. (1998). Predicting the future and reconstructing the past: A Bayesian characterization of the utility of subjective fluency. *Acta Psychologica*, *98*, 267–290.

Benjamin, A. S., Bjork, R. A., & Schwartz, B. L. (1998). The mismeasure of memory: When retrieval fluency is misleading as a metamnemonic index. *Journal of Experimental Psychology: General*, *127*, 55–68.

Bisanz, G. L., Vesonder, G. T., & Voss, J. F. (1978). Knowledge of one's own responding and the relation of such knowledge to learning. A developmental study. *Journal of Experimental Child Psychology*, *25*, 116–128.

Bjork, E. L., deWinstanley, P. A., & Storm, B. C. (2007). Learning how to learn: Can experiencing the outcome of different encoding strategies enhance subsequent encoding? *Psychonomic Bulletin & Review*, *14*, 207–211.

Bjork, R. A. (1999). Assessing our own competence: Heuristics and illusions. In D. Gopher and A. Koriat (Eds.), *Attention and performance XVII. Cognitive regulation of performance: Interaction of theory and application* (pp. 435–459). Cambridge, MA: MIT Press.

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, *64*, 417–444.

Brigham, M. C., & Pressley, M. (1988). Cognitive monitoring and strategy choice in younger and older adults. *Psychology and Aging*, *3*, 249–257.

Brown, S., Steyvers, M., & Hemmer, P. (2007). Modeling experimentally induced strategy shifts. *Psychological Science*, *18*, 40–45.

Castel, A. D. (2008). Metacognition and learning about primacy and recency effects in free recall: The utilization of intrinsic and extrinsic cues when making judgments of learning. *Memory & Cognition*, *36*, 429–437.

Castel, A. D., Benjamin, A. S., Craik, F. I. M., & Watkins, M. J. (2002). The effects of aging on selectivity and control in short-term recall. *Memory & Cognition*, *30*, 1078–1085.

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin*, *132*, 354–380.

Conover, J. N., & Brown, S. C. (1977). Item strength and input location in free-recall learning. *Journal of Experimental Psychology: Human Learning and Memory*, *3*, 109–118.

Costermans, J., Lories, G., & Ansay, C. (1992). Confidence level and feeling of knowing in question answering: The weight of inferential processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*, 142–150.

Craik, F. I. M., & Salthouse, T. A. (Eds.). (2008). *The handbook of aging and cognition,* 3rd ed. New York, NY: Psychology Press.

Cull, W. L., & Zechmeister, E. B. (1994). The learning ability paradox in adult metamemory research: Where are the metamemory differences between good and poor learners? *Memory & Cognition*, *22*, 249–257.

Davelaar, E. J., Yu, E. C., Harbison, J. I., Hussey, E. K., & Dougherty, M. R. (2013). A rational approach to memory search termination. *Cognitive Systems Research*, *24*, 96–103.

deWinstanley, P. A., & Bjork, E. L. (1997). Processing instructions and the generation effect: A test of the multifactor transfer-appropriate processing theory. *Memory*, *5*, 401–421.

deWinstanley, P. A., & Bjork, E. L. (2004). Processing strategies and the generation effect: Implications for making a better reader. *Memory & Cognition*, *32*, 945–955.

Dougherty, M. R., & Harbison, J. I. (2007). Motivated to retrieve: How often are you willing to go back to the well when the well is dry? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 1108–1117.

Dufresne, A., & Kobasigawa, A. (1989). Children's spontaneous allocation of study time: Differential and sufficient aspects. *Journal of Experimental Child Psychology*, *47*, 274–296.

Dunlosky, J., & Ariel, R. (2011). The influence of agenda-based and habitual processes on item selection during study. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*, 899–912.

Dunlosky, J., & Hertzog, C. (1998). Training programs to improve learning in later adulthood: Helping older adults educate themselves. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 249–276). Mahwah, NJ: Erlbaum.

Dunlosky, J., Kubat-Silman, A. K., & Hertzog, C. (2003). Training monitoring skills improves older adults' self-paced associative learning. *Psychology and Aging*, *18*, 340–345.

Dunlosky, J., & Thiede, K. W. (2004). Causes and constraints of the shift-to-easier-materials effect in the control of study. *Memory & Cognition*, *32*, 779–788.

Fiechter, J. L., & Benjamin, A. S. (2015). Adaptive changes in metacognitive control in response to expected retention intervals. Manuscript in progress.

Finley, J. R., & Benjamin, A. S. (2012). Adaptive and qualitative changes in encoding strategy with experience: Evidence from the test-expectancy paradigm. *Journal of Experimental Psychology: Learning Memory & Cognition*, *38*, 632–652.

Finley, J. R., Benjamin, A. S., & McCarley, J. S. (2014). Metacognition of multitasking: How well do we predict the costs of divided attention? *Journal of Experimental Psychology: Applied*, *20*, 158–165.

Finley, J. R., Liu, X., & Benjamin, A. S. (2015). Metacognitive control: Learning to avoid part-list cues? Manuscript in progress.

Fraundorf, S. H., & Benjamin, A. S. (2015). Conflict and metacognitive control: The mismatch monitoring hypothesis of how others' knowledge states affect recall. Manuscript in progress.

Glucksberg, S., & McCloskey, M. (1981). Decisions about ignorance: Knowing that you don't know. *Journal of Experimental Psychology: Human Learning and Memory*, *7*, 311–325.

Hall, J. W., Grossman, L. R., & Elwood, K. D. (1976). Differences in encoding for free recall vs. recognition. *Memory & Cognition*, *4*, 507–513.

Healey, M. K., & Kahana, M. J. (2014). Is memory search governed by universal principles or idiosyncratic strategies? *Journal of Experimental Psychology: General*, *143*, 575–596.

Heyer, A. W., & O'Kelly, L. I. (1949). Studies in motivation and retention: II. Retention of nonsense syllables learned under different degrees of motivation. *The Journal of Psychology*, *27*, 143–152.

Huang, I. (1986). Transitory changes of primacy and recency in successive single-trial recall. *The Journal of General Psychology*, *113*, 5–21.

Huang, I., Tomasini, J., & Nikl, L. (1977). The primacy and recency effects in successive single-trial immediate free recall. *The Journal of General Psychology*, *97*, 157–165.

Jacoby, L. L. (1978). On interpreting the effects of repetition: Solving a problem versus remembering a solution. *Journal of Verbal Learning and Verbal Behavior*, *17*, 649–667.

Karpicke, J. D. (2009). Metacognitive control and strategy selection: Deciding to practice retrieval during learning. *Journal of Experimental Psychology: General*, *138*(4), 469–486.

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

Kester, J. D., Benjamin, A. S., Castel, A. D., & Craik, F. I. M. (2002). Memory in elderly people. In A. Baddeley, B. Wilson, & M. Kopelman (Eds.), *Handbook of memory disorders* (2nd ed.) (pp. 543–568). London, England: Wiley.

Kobasigawa, A., & Metcalf-Haggert, A. (1993). Spontaneous allocation of study time by first-and third-grade children in a simple memory task. *Journal of Genetic Psychology*, *154*, 223–235.

Koriat, A., Bjork, R. A., Sheffer, L., & Bar, S. K. (2004). Predicting one’s own forgetting: The role of experience-based and theory-based processes. *Journal of Experimental Psychology: General*, *133*, 643–656.

Koriat, A., Ma’ayan, H., & Nussinson, R. (2006). The intricate relationships between monitoring and control in metacognition: Lessons for the cause-and-effect relation between subjective experience and behavior. *Journal of Experimental Psychology: General*, *135*, 36–69.

Kornell, N. (2009). Optimising learning using flashcards: Spacing is more effective than cramming. *Applied Cognitive Psychology*, *23*, 1297–1317.

Kornell, N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin & Review*, *14*, 219–224.

Kornell, N., & Bjork, R. A. (2008a). Learning concepts and categories: Is spacing the “enemy of induction”? *Psychological Science*, *19*, 585–592.

Kornell, N., & Bjork, R. A. (2008b). Optimising self-regulated study: The benefits—and costs—of dropping flashcards. *Memory*, *16*, 125–136.

Kornell, N., & Metcalfe, J. (2006). Study efficacy and the region of proximal learning framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 609–622.

Kornell, N., & Son, L. K. (2009). Learners’ choices and beliefs about self-testing. *Memory*, *17*, 493–501.

Le Ny, J., Denhiere, G., & Le Taillanter, D. (1972). Regulation of study-time and interstimulus similarity in self-paced learning conditions. *Acta Psychologica*, *36*, 280–289.

Loftus, G. R., & Wickens, T. D. (1970). Effect of incentive on storage and retrieval processes. *Journal of Experimental Psychology*, *85*, 141–147.

Masur, E. F., McIntyre, C. W., & Flavell, J. H. (1973). Developmental changes in apportionment of study time among items in a multitrial free recall task. *Journal of Experimental Child Psychology*, *15*, 237–246.

Mazzoni, G., & Cornoldi, C. (1993). Strategies in study time allocation: Why is study time sometimes not effective? *Journal of Experimental Psychology: General*, *122*, 47–60.

Mazzoni, G., Cornoldi, C., & Marchitelli, G. (1990). Do memorability ratings affect study-time allocation? *Memory & Cognition*, *18*, 196–204.

Metcalfe, J. (2002). Is study time allocated selectively to a region of proximal learning? *Journal of Experimental Psychology: General*, *131*, 349–363.

Metcalfe, J., & Finn, B. (2008). Evidence that judgments of learning are causally related to study choice. *Psychonomic Bulletin & Review*, *15*, 174–179.

Metcalfe, J., & Kornell, N. (2003). The dynamics of learning and allocation of study time to a region of proximal learning. *Journal of Experimental Psychology: General*, *132*, 530–542.

Metcalfe, J., & Kornell, N. (2005). A region of proximal learning model of study time allocation. *Journal of Memory and Language*, *52*, 463–477.

Nelson, T. O., Dunlosky, J., Graf, A., & Narens, L. (1994). Utilization of metacognitive judgments in the allocation of study during multitrial learning. *Psychological Science*, *5*, 207–213.

Nelson, T. O., Gerler, D., & Narens, L. (1984). Accuracy of feeling-of-knowing judgments for predicting perceptual identification and relearning. *Journal of Experimental Psychology: General*, *113*, 282–300.

Nelson, T. O., & Leonesio, R. J. (1988). Allocation of self-paced study time and the “labor-in-vain effect.” *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 676–686.

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 125–141). New York, NY: Academic Press.

Nelson, T. O., & Narens, L. (1994). Why investigate metacognition? In J. Metcalfe & A. P. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 1–25). Cambridge, MA: MIT Press.

Postma, A. (1999). The influence of decision criteria upon remembering and knowing in recognition memory. *Acta Psychologica*, *103*, 65–76.

Postman, L. (1964). Studies of learning to learn: II. Changes in transfer as a function of practice. *Journal of Verbal Learning and Verbal Behavior*, *3*, 437–447.

Postman, L. (1969). Experimental analysis of learning to learn. In J. T. Spence & G. H. Bower (Eds.), *The psychology of learning and motivation: Volume 3. Advances in research and theory*. New York, NY: Academic Press.

Rabinowitz, M., Freeman, K., & Cohen, S. (1992). Use and maintenance of strategies: The influence of accessibility to knowledge. *Journal of Educational Psychology*, *84*, 211–218.

Rawson, K. A., Dunlosky, J., & McDonald, S. L. (2002). Influences of metamemory on performance predictions for text. *The Quarterly Journal of Experimental Psychology*, *55A*, 505–524.

Reder, L. M. (1982). Plausibility judgments versus fact retrieval: Alternative strategies for sentence verification. *Psychological Review*, *89*(3), 250–280.

Reder, L. M. (1987). Strategy selection in question answering. *Cognitive Psychology*, *19*, 90–138.

Rhodes, M. G., & Castel, A. D. (2008). Metacognition and part-set cuing: Can interference be predicted at retrieval? *Memory & Cognition*, *36*, 1429–1438.

Schelble, J. L., Therriault, D. J., & Miller, M. D. (2012). Classifying retrieval strategies as a function of working memory. *Memory & Cognition*, *40*, 218–230.

Simon, D. A., & Bjork, R. A. (2001). Metacognition in motor learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 907–912.

Son, L. K. (2004). Spacing one's study: Evidence for a metacognitive control strategy. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 601–604.

Son, L. K., & Metcalfe, J. (2000). Metacognitive and control strategies in study-time allocation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 204–221.

Tauber, S. K., & Rhodes, M. G. (2012). Measuring memory monitoring with judgments of retention (JORs). *The Quarterly Journal of Experimental Psychology*, *65*, 1376–1396.

Thiede, K. W., & Dunlosky, J. (1999). Toward a general model of self-regulated study: An analysis of selection of items for study and self-paced study time. *Journal of Experimental Psychology. Learning, Memory & Cognition*, *25*, 1024–1037.

Toppino, T. C., Cohen, M. S., Davis, M. L., & Moors, A. C. (2009). Metacognitive control over the distribution of practice: When is spacing preferred? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 1352–1358.

Troyer, A. K., Hafliger, A, Cadieux, M. J., & Craik, F. I. M. (2006). Name and face learning in older adults: Effects of level of processing, self-generation, and intention to learn. *Journal of Gerontology: Psychological Sciences*, *61B*, P67–P74.

Tullis, J. G., & Benjamin, A. S. (2011). On the effectiveness of self-paced learning. *Journal of Memory and Language*, *64*, 109–118.

Tullis, J. G., & Benjamin, A. S. (2012). The effectiveness of updating metacognitive knowledge in the elderly: Evidence from metamnemonic judgments of word frequency. *Psychology and Aging*, *27*, 683–690.

Tullis, J. G., Benjamin, A. S., & Fiechter, J. (2015). The efficacy of learners' testing choices. Manuscript submitted for publication.

Tullis, J. G., Finley, J. R., & Benjamin, A. S. (2013). Metacognition of the testing effect: Guiding learners to predict the benefits of retrieval. *Memory & Cognition*, *41*, 429–442.

Tversky, B. (1973). Encoding processes in recognition and recall. *Cognitive Psychology*, *5*, 275–287.

Unsworth, N. (2007). Individual differences in working memory capacity and episodic retrieval: Examining the dynamics of delayed and continuous distractor free recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*, 1020–1034.

Unsworth, N. (2009a). Examining variation in working memory capacity and retrieval in cued recall. *Memory*, *17*, 386–396.

Unsworth, N. (2009b). Variation in working memory capacity, fluid intelligence, and episodic recall: A latent variable examination of differences in the dynamics of free recall. *Memory & Cognition*, *37*, 837–849.

Unsworth, N., Brewer, G. A., & Spillers, G. J. (2011a). Factors that influence search termination decisions in free recall: An examination of response type and confidence. *Acta Psychologica*, *138*, 19–29.

Unsworth, N., Brewer, G. A., & Spillers, G. J. (2011b). Variation in working memory capacity and episodic memory: Examining the importance of encoding specificity. *Psychonomic Bulletin & Review*, *18*, 1113–1118.

Unsworth, N., Brewer, G. A., & Spillers, G. J. (2013). Working memory capacity and retrieval from long-term memory: The role of controlled search. *Memory & Cognition*, *41*, 242–254.

Unsworth, N., Brewer, G. A., & Spillers, G. J. (2014). Strategic search from long-term memory: An examination of semantic and autobiographical recall. *Memory*, *22*, 687–699.

Unsworth, N., & Spillers, G. J. (2010). Variation in working memory capacity and episodic recall: The contributions of strategic encoding and contextual retrieval. *Psychonomic Bulletin & Review*, *17*, 200–205.

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2012a). The role of working memory capacity in autobiographical retrieval: Individual differences in strategic search. *Memory*, *20*, 167–176.

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2012b). Working memory capacity and retrieval limitations from long-term memory: An examination of differences in accessibility. *The Quarterly Journal of Experimental Psychology*, *65*, 2397–2410.

von Wright, J. (1977). On the development of encoding in anticipation of various tests of retention. *Scandinavian Journal of Psychology*, *18*, 116–120.

von Wright, J., & Meretoja, M. (1975). Encoding in anticipation of various tests of retention. *Scandinavian Journal of Psychology*, *16*, 108–112.

Weiner, B., & Walker, E. L. (1966). Motivational factors in short-term retention. *Journal of Experimental Psychology*, *71*, 190–193.

Wickens, D. D., & Simpson, K. C. (1968). Trace cue position, motivation, and short-term memory. *Journal of Experimental Psychology*, *76*, 282–285.

Whittlesea, B. W. A., & Williams, L. D. (1998). Why do strangers feel familiar, but friends don't? A discrepancy-attribution account of feelings of familiarity. *Acta Psychologica*, *98*, 141–165.

Winograd, E. (1970). Effect of knowledge of set size on search termination in long-term memory. *Psychonomic Science*, *20*, 225.

Young, C. J. (2004). Contributions of metaknowledge to retrieval of natural categories in semantic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*, 909–916.

Joshua L. Fiechter

Department of Psychology, University of Illinois at Urbana-Champaign

Aaron S. Benjamin

Department of Psychology, University of Illinois at Urbana-Champaign, Urbana-Champaign, IL

Nash Unsworth

Department of Psychology, University of Oregon