Research on the Allocation of Study Time:

Key Studies From 1890 to the Present (and Beyond)

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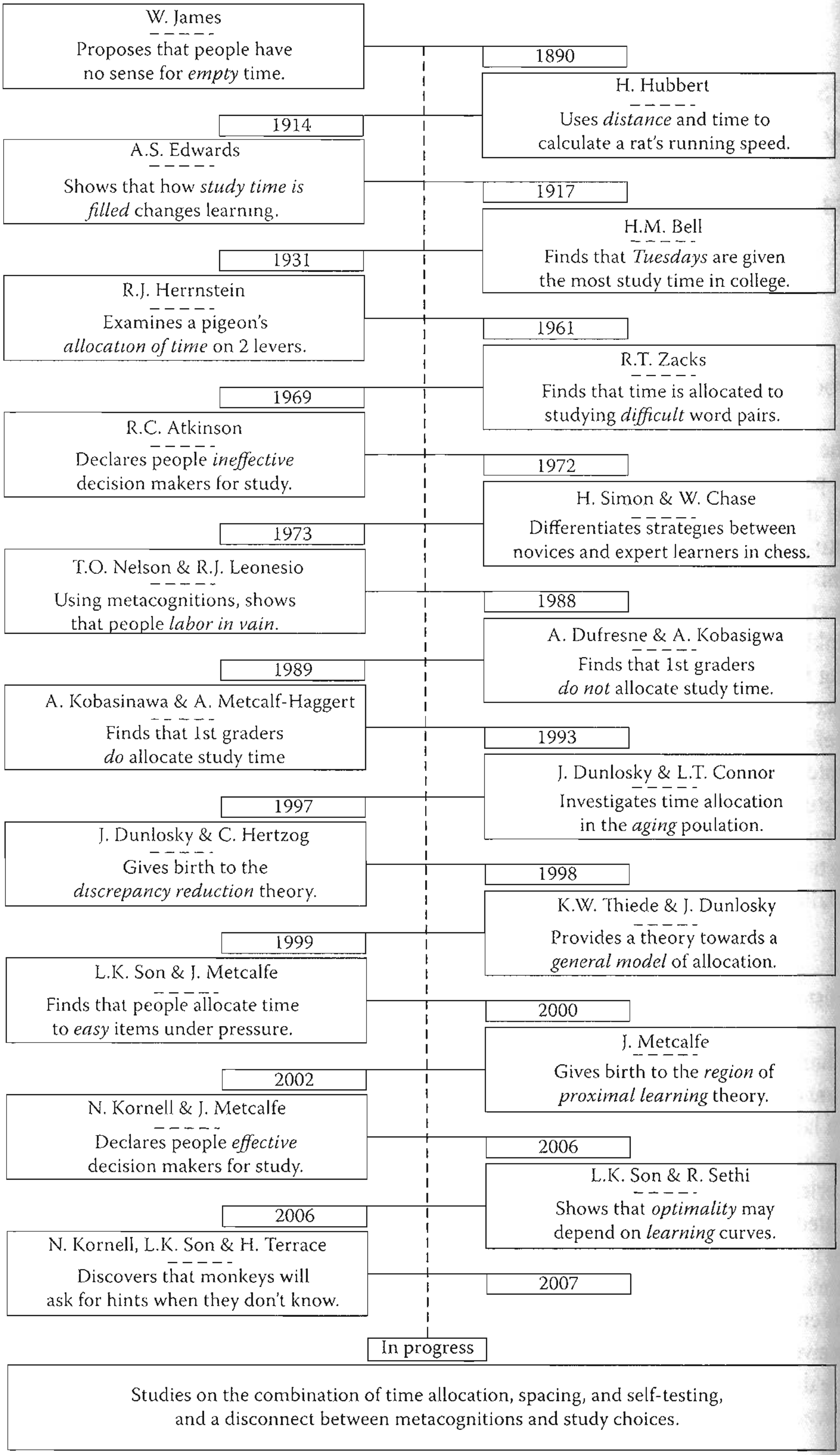
Introduction

Time has always been a fascinating concept. Many great philosophers, physicists, and psychologists have pondered the definition, and the very existence, of time. Is time inside the mind or external to it? Is time a fourth dimension on a space–time continuum? Is time real or just an illusion? The answers to each of these questions, themselves, are worthy of a book (or stack of books). It is easier to agree with other aspects of time, however, for instance, "Lost time is never found again" (Benjamin Franklin, who also said "Time is money"); and "Time is God's way of keeping everything from happening at once" (anonymous). Time cannot be repeated, skipped, or replaced, and no commodity is more valuable. How time is allocated may determine the effectiveness of our behaviors; thus, time is a central element of life itself. In this chapter, we present a history of research on the topic of how people allocate time during study, beginning with its roots prior to the cognitive revolution and stopping at key points throughout the psychological literature. In doing so, we aim to answer the question of whether people achieve optimality when allocating the limited time that is available.

A History of Time Allocation

William James, the father of modern psychology, was one of the earliest to describe various aspects of time from a psychological perspective (1890). In Figure 1, we begin with James on our "timeline" of time allocation. Pastness, he said, is time on which memory and history builds. He wrote of pastness as "that to which every one of our experiences in turn falls a prey" (p. 605). Immediate, or present, time was more complicated — although present time has a "duration ... we do not first feel one end and then feel the other after it, and from the perception of the succession feel the interval of time in between, but we seem to feel the interval of time as a whole, with its two ends embedded in it" (p. 610). James also sorted out the difference between how we perceive time and space, two concepts that may be analogous to a physicist but are quite different to someone looking at his or her watch. He described the difference between space and time as follows:



1890

W. James
Proposes that people have no sense for *empty* time.

1914

H. Hubbert
Uses *distance* and time to calculate a rat's running speed.

1917

A.S. Edwards
Shows that how *study time is filled* changes learning.

1931

H.M. Bell
Finds that *Tuesdays* are given the most study time in college.

1961

R.J. Herrnstein
Examines a pigeon's *allocation of time* on 2 levers.

1969

R.T. Zacks
Finds that time is allocated to studying *difficult* word pairs.

1972

R.C. Atkinson
Declares people *ineffective* decision makers for study.

1973

H. Simon & W. Chase
Differentiates strategies between novices and expert learners in chess.

1988

T.O. Nelson & R.J. Leonesio
Using metacognitions, shows that people *labor in vain.*

1989

A. Dufresne & A. Kobasigwa
Finds that 1st graders *do not* allocate study time.

1993

A. Kobasinawa & A. Metcalf-Haggert
Finds that 1st graders *do* allocate study time

1997

J. Dunlosky & L.T. Connor
Investigates time allocation in the *aging* poulation.

1998

J. Dunlosky & C. Hertzog
Gives birth to the *discrepancy reduction* theory.

1999

K.W. Thiede & J. Dunlosky
Provides a theory towards a *general model* of allocation.

2000

L.K. Son & J. Metcalfe
Finds that people allocate time to *easy* items under pressure.

2002

J. Metcalfe
Gives birth to the *region of proximal learning* theory.

2006

N. Kornell & J. Metcalfe
Declares people *effective* decision makers for study.

2006

L.K. Son & R. Sethi
Shows that *optimality* may depend on *learning* curves.

2007

N. Kornell, L.K. Son & H. Terrace
Discovers that monkeys will ask for hints when they don't know.

In progress

Studies on the combination of time allocation, spacing, and self-testing, and a disconnect between metacognitions and study choices.

Figure 1 A timeline of time allocation.

> To realize a quarter of a mile we need only to look out the window and *feel* its length by an act which, though it may in part result from organized associations, yet seems immediately performed. To realize an hour, we must count "now! — now! — now! — now! —" indefinitely. Each "now" is the feeling of a separate *bit* of time, and the exact sum of the bits never makes a very clear impression on the mind." (p. 611)

James went on to propose that people cannot accurately estimate how much time is available: "To be conscious of a time interval at all is one thing; to tell whether it be shorter or longer than another interval is a different thing" (p. 615). Finally, James wisely explained that time that is "filled" is easily approximated — for example, if time is filled with a song, we can estimate how long the time was based on the beat of the song. On the contrary, time that is empty, "We have no sense for" (p. 619).

James's characterization of time perception is accurate — which is unfortunate because decisions about time allocation become critical precisely when time is available, or empty, not filled. And, if one has "no sense for" the amount of time that is available, then how can it be allocated appropriately? In some sense, James foreshadowed doubt that would be cast decades later on the idea that time allocation could ever be optimal.

But, the question of people's optimal allocation of empty time was put on hold for almost 80 years. Instead, behavioral and psychological researchers focused on the contents of filled time. In fact, the time that was required to complete a task, *reaction time*, quickly became one of the key dependent variables in experimental psychology. In 1914, for instance, Helen Hubbert measured how far rats could run in a maze as a function of a range of time durations. Using a stopwatch to keep track of time, Hubbert was able to calculate the running speed of each of her subjects.

A few years later, in 1917 — still decades before the cognitive revolution — in a collection of articles bound together and titled, *Studies in Psychology Contributed by Colleagues and Former Students of Edward Bradford Titchener*, Edwards was the first to show that even equal times (times that are equally filled, that is) could result in vast learning differences when tested later. In his experiment, students were told to study, but during study, one group was given a review period, while the other was not. Edwards's results showed superior learning in the review group over the non-review group. Thus, in the early 1900s it became known that the type of time filler used can significantly change learning and retention in study situations. (But still, it remained to be seen whether people would choose the right strategy on their own, that is, whether people would allocate study time to review, a question that has begun to be answered only recently; Kornell & Bjork, 2006; Kornell & Son, 2006.)

Some years later, Bell (1931) examined the study habits of a population that could be characterized as having difficulty allocating time — college students. By recording the distribution of students' study time over the course of a week, Bell showed that most studying was done on Tuesday, and the least studying was done on Friday. Interestingly, in what was perhaps the first hint of a *labor-in-vain effect* (see Nelson & Leonesio, 1988, described in the next section), time spent studying was not diagnostic of scholastic success. That is, school grades did not increase as study time did. Other explanations were not tested; for instance, students might have chosen to study just enough to achieve a certain level of performance (e.g., a B+ average grade) and devoted just enough time to studying to do so (and a student's goals play an important role in their study decisions; Dunlosky & Thiede, 1998; Thiede & Dunlosky, 1999). More evidence of labor in vain surfaced 2 years later: Eurich (1933) recorded how much time college students spent reading each day, along with the number of pages they read. He found that seniors read more pages than did the sophomores, but no significant difference appeared regarding the issue of test performance (although, again, other factors were not tested; for example, selection effects may have been responsible or perhaps students who read more, especially the seniors, were taking more difficult classes than those who studied less).

In the years between the mid-1930s and the late 1960s, researchers took on a diverse range of topics with respect to time. For instance, studies were conducted on how much time was needed to learn a specific vocation or to become an expert in a specialized field, such as dentistry, medicine, automobile driving, and aviation piloting (e.g., Toops & Kuder, 1935). It would be decades before researchers concluded that it takes approximately 10 years to develop expertise in any area, including chess, painting, piano playing, neuropsychology, and music composition — even Mozart was unable to produce world-class music until the age of 17 (Bloom, 1985; Ericsson, 1996; Ericsson, Krampe, & Tesch-Römer, 1993; Hayes, 1989; H. A. Simon & Chase, 1973). Witnessing the fruits of one's labor can require enormous patience; even in the presence of prodigious talent, the rewards of optimal study time allocation can be very long term, which makes it all the harder for students to learn to make optimal decisions about how to regulate their study time.

The cognitive revolution arrived in the 1960s, with new ideas and uses for time. Following on Broadbent's (1958) introduction of the idea of the human brain as an information processor, Melton (1963) proposed that our short-term processing abilities were limited by time, and the time it took to scan one's own memories was even recorded (Sternberg, 1966). More importantly for the present purposes, researchers began to take interest in how people (and animals) *chose* to allocate their time, spurring a new era of research on learner-controlled time allocation.

Learner-Controlled Time Allocation

How is time allocated? This question, which James foreshadowed in the 19th century, was asked again almost 80 years later, in both pigeons (Herrnstein, 1961) and humans (Zacks, 1969). In the pigeon study, there were two levers, both releasing food on variable-interval schedules, and the amount of time that the pigeon allocated to each of the levers was recorded. The results suggested that the pigeons seemed to have a systematic and virtually optimal allocation strategy. The amount of time that they allocated to each lever matched the lever's reinforcement value. In a study by Zacks asking a similar time allocation question — except with college undergraduates — participants were presented with word pairs on a computer and were told that they could study each pair for as long as they wished. They could also take test trials whenever they chose. The results of this first-of-its-kind experiment showed that (1) there was a controlled method by which researchers could measure time allocation strategies, and (2) when allowed to allocate their time freely, people spent more time on pairs that were objectively more difficult to learn.

Around the same time, Atkinson (1972) focused on perhaps the most important issue in the examination of study time allocation: Do people allocate their study time *effectively*? He based his research on a Markov model of human learning in which items could be in one of three states: *L* (or permanently learned), *T* (or transitional), and *U* (or unlearned). According to this theory, the learning objective is to bring as many items as possible into the *L* state, which is a "safe" state (i.e., learned items are not in danger of being forgotten). To arrive at the *L* state, an item must pass through first the *U* state and then the *T* state. Using a computer algorithm, Atkinson was able to categorize which of the items — English–German vocabulary pairs — were in each of the three states for each participant. The computer (or the participants themselves, in one condition) then allocated study time to each item based on its current state of learning. There were four time allocation conditions: (1) random order, in which all items, including those that were already in *L*, were presented for an equal amount of time; (2) self-selection, in which the participants were allowed to choose for themselves which items they would study (and they tended to choose the unlearned items); (3) optimal strategy with equal parameters, in which items that were in either *T* or *U* were given equal time; and (4) optimal strategy with unequal parameters, in which those items that were determined to be in the intermediate *T* state were given the most study time. On a delayed test, as expected, the random sequence produced the worst performance. Both the equal parameter and the self-selection conditions produced intermediate and comparable performances. The most impressive finding was that when the computer devoted the most study time to the intermediate *T* items – in the unequal parameters condition — learning was greatly enhanced (there was a 108% performance gain over the random strategy). Interestingly, the self-selection strategy yielded a gain that was much smaller, only 53% over the random strategy. Atkinson concluded that the most effective strategy is to allocate study time to items of intermediate difficulty, not to the items that are the most difficult or to those that are already learned. On a pessimistic note, he also concluded that, "My data, and the data of others, indicate that the learner is not a particularly effective decision maker" (p. 930). This bold claim has been challenged by more recent evidence, which we consider in detail in this chapter.

Still, learners usually have control over their learning, and over the next 15 years or so, cognitive psychologists investigated people's time allocation strategies using paradigms that were similar to the one Zacks used in 1969 (see Son & Metcalfe, 2000, for a review). In general, experimental participants were given items that varied in objective difficulty to study, one at a time, for as long as they wished. The majority of studies showed that people had a systematic strategy, in line with Zacks' and Atkinson's findings: They allocated most of their time to relatively difficult items.

During this time period, primarily throughout the 1980s, research on learner-controlled study time allocation became more and more intertwined with research on *metacognitive* knowledge. Rather than testing people's allocation strategies on items at various levels of *objective* difficulty, experimental participants were asked to make their own *subjective* assessments of difficulty prior to making study time allocation decisions — the same way they would have to in real life, making metacognitive judgments to guide study time allocation. In one important instance, Nelson and Leonesio (1988) tested college students in three distinct stages: (1) a judgment stage, in which they were presented with a series of items and had to assess how difficult it would be to learn each one; (2) a study stage, in which participants spent as much time as they wanted studying each item (as in previous time allocation studies); and (3) a recall stage, in which participants' memories for the items were tested. Consistent with previous research, people allocated more study time to the *judged* difficult items. Furthermore, in one condition participants were encouraged to study until they had mastered every item; in another, they were not. The former condition yielded large increases in study time but almost no improvement in later recall — the first laboratory evidence for what was called the labor-in-vain effect (see also Mazzoni & Cornoldi, 1993; Mazzoni, Cornoldi, & Marchitelli, 1990; Nelson, 1993).

Models of Study Time Allocation

A preponderance of time allocation studies in the 1980s and 1990s showed that people preferred to allocate study time to relatively difficult items (Son & Metcalfe, 2000). The *discrepancy-reduction* hypothesis was proposed as an explanation for those findings (Dunlosky & Hertzog, 1998). The hypothesis stated that the allocation of study time is related to the discrepancy between an item's actual and desired knowledge state, which needs to be reduced if learning is to occur. According to the model, the most study time should be allocated to items that have the largest discrepancy. The discrepancy-reduction hypothesis is both descriptive and prescriptive; it proposes that what people do is the same as what they should do — focus on the hardest items.

Virtually all study time allocation studies conducted in the 20th century shared certain unnatural elements. For example, most experiments presented to-be-learned materials one at a time and allowed people to study for as long as they wanted, *but only once*. Under those conditions, people were able to determine how much time they spent on a given item, but they could not choose which items they wanted to study (and the two types of decisions can lead to different outcomes; see Metcalfe & Kornell, 2005). Furthermore, the items were usually presented sequentially, not simultaneously (which also leads to different outcomes; see Thiede & Dunlosky, 1999). A second constraint was that because participants were given unlimited time to study, they might have believed — perhaps rightly in the laboratory context — that time pressure was not an issue, and that there was ample available time to learn all of the items. In real life, though, time pressure is common during study (just ask anyone who has ever run out of time studying for an exam or turned in a paper late). More important, taking time to study one topic or item often leaves less time to study others. These issues — of simultaneous presentation and of the total time available — were investigated in a series of studies (e.g., Son & Metcalfe, 2000; Thiede & Dunlosky, 1999; also see Dunlosky & Thiede, 2004). Thiede and Dunlosky, for example, found that people's allocations shifted to easier materials when items were presented *simultaneously* instead of sequentially. This shift to studying the easier materials also occurred when time pressure increased (e.g., Metcalfe, 2002; Son & Metcalfe, 2000).

In light of the new procedures and resultant findings, a new theory was put forth, arguing for the importance of a "region" of difficulty in which items are most amenable to learning, which consists of items just beyond the learner's grasp. This region does not necessarily include the most difficult items, but rather items that are *almost* learned — a region of difficulty comparable to Atkinson's (1972) transitory (*T*) state. The items that inhabit this region could also depend on the specific learning situation: For instance, changes in study format or increases in time pressure could shift the region toward easier items, which can be learned in a relatively short amount of time. Thiede and Dunlosky (1999) first reported such a shift, calling this strategy a shift to easier materials (STEM), and soon thereafter Metcalfe (2002) proposed the term *region of proximal learning* to refer to the most learnable items. Metcalfe and Kornell (2003; see also Kornell & Metcalfe, 2006; Metcalfe & Kornell, 2005) tested this new time allocation theory and found that when people were asked to select easy, medium, and difficult items under varying time availabilities (5, 15, and 60 seconds), they tended to study the easy items when very little time was available and moved to the medium and difficult items only as time availability increased. Like discrepancy reduction, the region of proximal learning framework is prescriptive as well as descriptive, and there is evidence suggesting that, by using it, people increase their learning (see "Optimal Time Allocation" below). Although, as described, the region of proximal learning model and the discrepancy reduction model make different predictions in some circumstances, their predictions are the same under other conditions (when there is no time pressure, and there is not a tradeoff in time between studying one item and another), and since it is under those conditions that most study time allocation experiments have been conducted, both theories are consistent with Zacks's (1969) study time allocation findings and most everything that followed (Son & Metcalfe, 2000).

It seems clear today that the allocation decisions people make are driven metacognitively, and that allocations depend on factors like whether items are presented simultaneously or sequentially, how much total study time is available, and the personal goals a student sets. The fact that people use a certain strategy is by no means proof that they *should* use that strategy, however, as every psychology student knows (especially students studying the use of heuristics in judgment and decision making). In the words of Metcalfe and Kornell (2005), "We still do not know whether what [people] do enhances their learning, or is in any way optimal" (p. 476). The issue of which allocation strategies are optimal is the next focus in our timeline.

Optimal Time Allocation

How might one go about testing what is optimal? One way is to pit people against a computer, as Atkinson (1972) did over 30 years ago; as described, he showed that people were better than random but far from optimal. Nelson, Dunlosky, Graf, and Narens (1994) took a similar approach; they asked people to make metacognitive judgments of learning (JOLs) about a set of word pairs and then to choose which of the items they wanted to restudy. Following the study choice, participants were allowed to restudy in one of four conditions: self-control, in which participants studied the items they had selected; high JOL, in which they studied the items they had rated as easiest; low JOL, in which they studied the items they had rated as hardest; and objectively difficult, in which they studied the objectively most difficult items based on norms.

Recall performance on a test that followed restudy showed that the best performance occurred in the self-control and low-JOL conditions, followed by the objectively difficult condition. Performance was worst in the high-JOL condition. Recall in the self-control and low-JOL conditions were the same because participants in the self-control condition chose to study the low-JOL items (so participants studied essentially the same items in both cases). It appears as though the basic strategy participants used was to study the items they did not already know (a seemingly universal strategy). This experiment showed that people can, and do, help themselves when studying by choosing to study items they do not know instead of items they do know.

Kornell and Metcalfe (2006) further investigated the potential benefits of self-regulated study time allocation. After replicating Nelson et al.'s (1994) findings, Kornell and Metcalfe presented participants with a more difficult problem: What would people do if they had to decide which items to study when they could not simply reject items they already knew, that is, when all of the items were unknown? Participants were asked to study and make JOLs on Spanish–English pairs, and then they were tested on all of the pairs; any pair they answered correctly was dropped from the rest of the experiment. Participants were then asked to select half of the remaining items for further study. After making their choices, participants were divided into four independent conditions: high JOL, in which they studied the subjectively easiest items; low JOL, in which they studied the subjectively hardest items; honor, in which they studied the items that they had selected; and dishonor, in which they studied the items that they had not selected. The results showed that people chose to study the *easiest* items when selecting among items they did not know. Moreover, test performance was the highest when people's choices were honored. Thus, in contrast to what Atkinson (1972) found but similar to what Nelson et al. (1994) found, people seemed to use strategies that were effective and, in this procedure, optimal for learning (see also Son, under revision).

Another way to investigate optimal strategies is to derive theoretical predictions about which study strategies should work best by numerically simulating the types of allocations that would result in the highest levels of learning. One of the challenges in doing this is to include all of the major factors that might influence the learning of any particular item. Based on the existing data on time allocation strategies, the following seem to be important: (1) the learning curve, or how incremental increases in learning change over time; (2) where on the learning curve a particular item currently is, or how much prior allocation has already been invested; and (3) the total time that is available for study. Son and Sethi (2006) compared concave and S-shaped learning curves, two potential learning functions (see Figure 2), and defined as a possible goal of the learner to maximize the learning "score," or extent of learning, summed across all items that are to be learned, for all time availabilities. Optimality depended on the item's learning curve: When the items followed the path of a concave function, then regardless of time availability, optimality entailed that people allocate more time to the less-well-learned items (with learning gains that will be greater than those that are more fully learned and at a plateau). When the learning curves were S shaped, however, optimality looked more complicated. With little time availability, one should allocate time to the items closer to a learned state, but as time availability increased, items at a lower state of learning should receive more

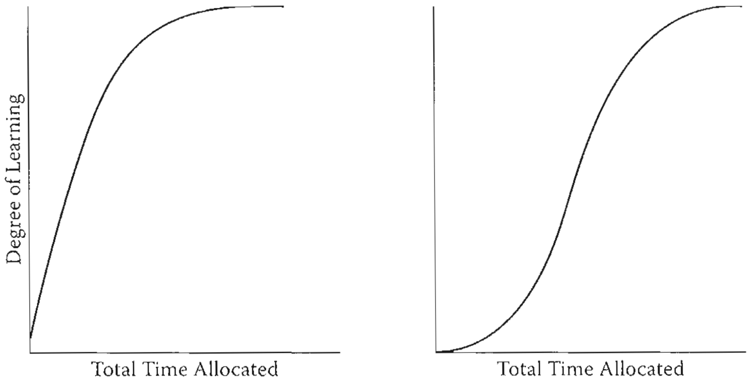


Figure 2 Two learning functions: concave and S shaped.

study. These findings suggested that optimal time allocations will depend highly on the structure of the learning function: With one type of curve, a discrepancy-reduction strategy is favored; with another learning curve, the region of proximal learning strategy seems beneficial.

Under this framework, whether people can achieve optimality is still unanswered. To be optimal, the learner would need to know two things: (1) the shape of the learning curves for the items that need to be learned and (2) how much time was available for study. How realistic is it to assume that these factors are known during study? There is evidence to suggest that, as a rule, people wholly misunderstand the shape of the learning curve (Kornell & Bjork, 2006). One might, however, have a fairly realistic sense of how much learning would be gained during a *short* and *present* time. If people did not consider the entire learning curve and instead based their decisions on knowledge of this "limited region" learning gain, might optimality still be attained? Sethi and Son (data collected in 2007, manuscript under revision) tested this idea and calculated when optimality would occur if time were allocated preferentially for the item with the highest current gain in learning. What they found was that, using these adaptive strategies based on limited knowledge, again it would depend on the shape of the item's entire learning curves: When learning was concave, people would always be optimal; when learning was S shaped, there would be regions of time availability where optimality would not be attained.

The question of optimal time allocations is obviously a complicated one, which makes modeling it virtually impossible without a number of simplifying assumptions. One such assumption, which may be relaxed in future investigations, is the use of learning score, or extent of learning, summed across all items as a metric of learning. In reality, summed learning level and the number of items that can be retrieved (i.e., the number of items that are above a retrievability threshold) are not necessarily the same; for example, by strengthening a set of weak items, summed learning level increases, but if those items do not become recallable, then recall rates do not increase. This is especially important in the current context because ignoring such weak items is one of the reasons studying according to the region of proximal learning framework is advantageous in terms of rates of recall — even when it might not be advantageous in terms of summed learning level. Of course, how optimal one is will depend on what goal one has in mind. Another assumption that greatly simplifies the predictions, but may be relaxed at some point, is that studying an item does not change the shape of its learning curve but instead simply moves an item along a fixed curve. Son and Sethi (2006) assumed that the processes of forgetting and learning could be represented as items moving up and down a fixed curve. In other models, however, learning is accompanied by two changes; the item moves up a learning curve, but at the same time, the actual shape of the learning curve itself changes (as does the shape of the forgetting curve). Indeed, the strength of a given item in memory can be represented by two indices, corresponding to current retrievability and long-term storage (see Bjork & Bjork, 1992).

In summary, findings from the last dozen years show that people appear to have systematic time allocation strategies and benefit from using them. Two models of study time allocation, discrepancy reduction and region of proximal learning, are able to account for most of the research from the 20th century, and the latter is able to account for some of the more ecological research that has occurred in the 21st century as well. The scope of the research has continued to broaden as new methods of research have been designed, and efforts to increase generality (e.g., Thiede, Anderson, & Therriault, 2003) have raised new questions and answered others.

Beyond the Classroom

In a classroom, the importance of metacognitive monitoring and self-regulated study is limited somewhat by the fact that part of a teacher's job is to help students make study choices (or to tell them outright what and when to study). But, not all study decisions occur in a classroom. Self-regulated study may play its most important role when students are on their own. Students constantly face time allocation choices during homework, for example, what topic to study next, for how long, and when to move on to the next topic. Students also face decisions about *how* to study; there are innumerable study techniques that students use, some of which are very effective (e.g., creating an integrated summary of a textbook chapter) and some probably not very effective at all (e.g., trying to read a chapter for the first time while half asleep the night before an exam). In some cases, a workbook leads students through exercises during homework but is primarily for younger students; older students are largely left to decide on their own.

In our experience, the majority of students have had little or no training in how to study. The second author often reads a children's book (*My Friends*, by Taro Gomi, 2005) containing the line, "I learned to study from my friends the teachers." If only it were true. In a survey of University of California at Los Angeles undergraduates, 80% answered "No" when asked whether a teacher taught them to study the way they do (Kornell & Bjork, 2007). Perhaps this state of affairs was reasonable in William James's time, when the knowledge base about which study techniques work was relatively small — but as this chapter illustrates, that is no longer the case.

Not all study choices occur in an educational context. To take a unique example, Kornell, Son, and Terrace (2007) investigated a completely different type of study choice, one that *never* occurs in a classroom: the study choices of nonhuman primates.

Instead of asking undergraduates to study for an exam, they trained monkeys to make "study" choices that allowed them to earn food rewards. The monkeys were presented with a list-learning task in which they had to touch a set of photographs in a certain order. They could ask for a "hint," representing an "I don't know enough" state, during the task by touching an icon on the right side of a touch-sensitive computer monitor mounted in their testing chambers (see Figure 3). When they requested a hint, blinking lines appeared on the screen surrounding the next correct response in the list of photographs. To constrain hint taking, there was a penalty for taking hints—the monkeys earned only a food pellet when they used a hint to arrive at a correct answer, but they earned a more desirable M&M for correct answers made without hints.

Requesting a hint was similar to a study choice in the sense that, like a choice to restudy versus not restudy, a monkey had to decide whether to complete the list by asking for a hint (i.e., by studying) or whether to complete the list without a hint (i.e., by not studying). Making that decision required that the monkey monitor whether it knew the answer — that is, it required metacognition. The result was that the monkeys learned to take hints at high rates when a list was new (and they had not yet learned the sequence of photographs well) and to decrease their hint taking as they gained more experience with the list. This finding demonstrated that monkeys, by using their metacognitive abilities to control their behavior, engage in self-regulated learning.

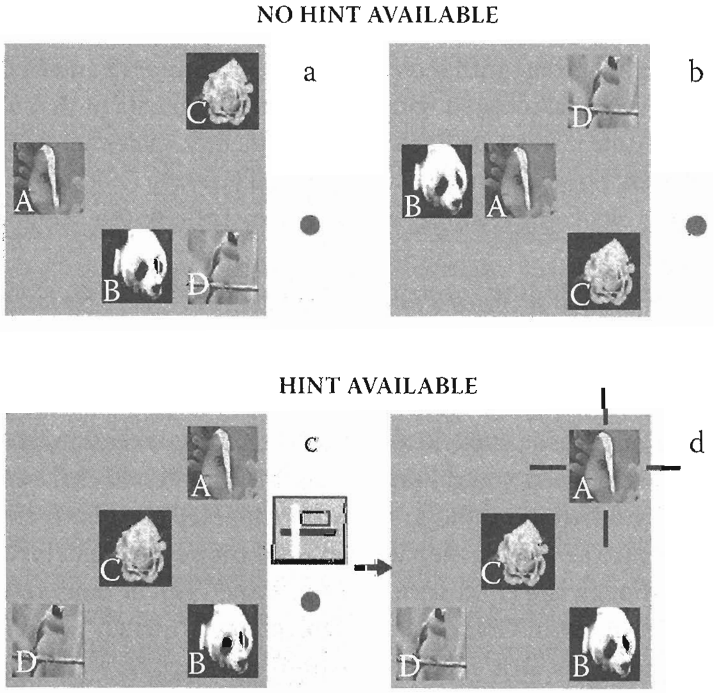


Figure 3 Sample trials of a monkey list-learning task in which the monkeys had to touch a set of photographs in a certain order. On the right of the screen there was a "hint" icon that, when pressed, represented an "I don't know" state. If the hint icon was pressed, blinking lines appeared on the screen surrounding the next correct response in the list of photographs. (Originally published in Kornell, Son, & Terrace, 2007.)

Factors That Affect Study Time Allocation

Almost all previous research on study time allocation has focused on what people chose to study as a function of item difficulty. (The central variable controlling study decisions in both discrepancy reduction and the region of proximal learning model is difficulty.) However, other factors affect study time allocation as well. For example, Dunlosky and Thiede (1998) showed that a range of factors affect study decisions (e.g., the number of points awarded for remembering a given item and the likelihood that an item would be tested), each illustrating the importance of motivation in study decisions. In 1999, Thiede and Dunlosky took a first step toward a general model of study time allocation by focusing on the role of goals in study decisions. Participants were either told to set a low performance goal (remember 6/30 items) or a high performance goal (remember 24/30 items). They chose to study easier items in the former condition than in the latter. This was only true when the items were displayed simultaneously, however, which led to the hypothesis that working memory constraints, which were greater with sequential than simultaneous presentation, are also a factor in time allocation decisions (also see Dunlosky & Thiede, 2004). Thus, in addition to the difficulty of an item, when people make time allocation decisions they consider their learning goals and their level of extrinsic motivation (as well as intrinsic motivation; see Son & Metcalfe, 2000).

There are also interpersonal factors that can affect study time. One example is aging. In general, aging brings with it memory deficits. Dunlosky and Connor (1997) showed that aging is also associated with metacognitive deficits in that older adults' allocation of study time is less entrained by item difficulty. Older adults are still able to monitor fairly well, however, and as Dunlosky and Hertzog (1997) showed, at least in some situations, older and younger adults use essentially the same heuristic to select items for study.

At the other end of the aging spectrum is a group of people who study a lot and can probably use help: children. A more detailed description of some of our research on study time allocation in children is presented, but in general, children are remarkably metacognitive at a young age, and their patterns of study time allocation reflect that (Dufresne & Kobasigawa, 1989; Metcalfe, 2002). Dufresne and Kobasigawa were the first to examine children's time allocation abilities and tested children in Grades 1, 3, 5, and 7. The children were told to study two booklets, one hard and one easy, of paired associates for as long as they wanted until they could remember all of the pairs perfectly. Although the children in Grades 5 and 7 spent more time studying the difficult booklet, those in Grades 1 and 3 spent approximately equal amounts of time on each, suggesting a lack of self-regulation. However, in a subsequent study, Kobasigawa and Metcalf-Haggert (1993) found that when the materials were pictures of familiar objects rather than verbal paired associates, even first graders used a self-regulating strategy: They allocated more study time to materials that were more difficult. In summary, the study choices of both children and older adults show some impairment but mostly adeptness.

Choices About Study Techniques

As mentioned, most study time allocation research has focused on item difficulty; perhaps more important, it has also involved essentially two measures: which items participants choose to study and for how long they study (see Kornell & Metcalfe, 2006). Is self-regulated learning confined to those two decisions, made based on item difficulty? Far from it. There are any number of study techniques that people use (e.g., flash cards, underlining, summarizing their notes, practice quizzes), and each has some degree of overlap (or nonoverlap) with factors that are known to influence memory (e.g., spaced practice, deep semantic processing, knowledge integration, testing effects). Research on which techniques people fill their study time with, what they believe about those techniques, and how effective their choices are is just beginning in the realm of study time allocation research. These questions were foreshadowed by Edwards (1917), who showed (see section on history of time allocation) that studying efficiently (by reviewing) was more effective than studying without review, even if the amount of study time was held constant. In this section, we describe three sets of experiments concerning how people study but in which the variable of primary interest is not item difficulty.

William James believed, as described, that people have "no sense" for "empty time" but can accurately perceive time when it is "filled" with something like beats. In a study we conducted (Son & Kornell, in preparation), participants were asked to plan out a study schedule, and beats were provided in the form of visual slots on a computer screen, each of which represented a 3-second study event that participants could fill with any item they chose to study. With a nod to historical research on time allocation, two questions were asked: What time allocation strategy would be used? Would people's allocation strategies be *in vain*? We also asked a new question: Would people spontaneously space their practice?

The method was as follows: Participants were first presented with a list of 16 synonym pairs (e.g., saturnine–gloomy) to study for a later test. After a pair was presented, participants made a judgment, on a scale from 0 to 10, indicating how confident they were that they would be able to recall the synonym when given only the cue word on a later memory test. After the presentation/judgment phase, all 16 words (without synonyms) were shown on the left side of a computer screen simultaneously. On the right side of the screen, there was a list of study slots. The participant's task was to click on a cue that they wanted to restudy and drag it from the left-hand side of the computer screen into one of the slots on the right-hand side. Participants were told that each slot represented 3 seconds of study time. There were three conditions: We provided 8, 16, or 24 slots for study. In the 8-slot condition, for instance, at most half of the 16 items could be restudied. In the 8-, 16-, and 24-slot conditions, participants had a total of 24, 48, and 72 seconds, respectively, of total study time to allocate.

Participants were told that they would study the pairs in their list of slots from top to bottom, in whatever order they created. They were also told that they could study pairs as many (or few) times as they wanted. For instance, a participant could study one item zero times and another three times, and those three could be spaced apart or massed together. Thus, participants fully controlled the number of times every item was studied and the study schedule. The only constraint was that all of the slots had to be filled. Once the restudy list had been created, there was a restudy period during which the cue–target pairs were shown sequentially in the exact order that the participant had chosen. After a 3-minute distracter task, participants were given a cued recall test.

The data showed that the more difficult a participant judged a pair to be, the more study time was allotted to it. This is consistent with the discrepancy-reduction model and, because the participants' perception was that they could (for the most part) potentially learn most or all of the items they did not know, with the region of proximal learning model. The most important finding was that the amount of spacing was significantly greater than would be expected by chance (although it was also significantly smaller than the maximum possible spacing). In other words, participants chose to space their study. Although this is good news from a practical standpoint, it is also surprising in light of previous experiments showing that people give higher (or equivalent) ratings to massed than spaced practice (Baddeley & Longman, 1978; Dunlosky & Nelson, 1994; D. A. Simon & Bjork, 2001; Zechmeister & Shaughnessy, 1980; although delayed JOLs result in the opposite pattern, see Dunlosky & Nelson, 1994) and given one study showing that children prefer to mass practice (Son, 2005). A basic assumption of research on self-regulated learning is that study choices are guided by metacognitive judgments. That assumption may need to be reexamined, at least in this case, given that people choose to space but rate massing as more effective (also see Koriat, Ma'ayan, & Nussinson, 2006; Kornell & Son, 2006).

There has also been research on how spacing choices are related to item difficulty. In one set of experiments, people chose to space relatively easy items (Son, 2004), and in another case they chose to space relatively difficult items (Benjamin & Bird, 2006). In the Kornell and Son (under revision) study described here, the amount of spacing was approximately equal for easy and difficult items.

Like spacing, self-testing is an effective — if somewhat counterintuitive (Bjork, 1994) — study technique. When do people self-test? Son (2005) examined first-grade children's study decisions and found two things; first, they chose to self-test, and second, they did so especially for information they felt they knew. College students seem to do the same. Son and Kornell (under revision) asked participants to choose whether they wanted to (1) view word pairs intact or (2) see the cue first, test themselves, and then see the target. The first time through the list, participants chose presentation mode, but after going through the list two or three times and reaching the point at which they began to know the pairs, they switched to self-testing.

Thus, when making study decisions, people choose to space practice and self-test, both very effective strategies (e.g., Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Roediger & Karpicke, 2006a). There appears to be a disconnect, in both cases, between metacognitive judgments and study choices. As mentioned, people choose to space practice but tend to give higher JOLs following massed practice. The same appears to be true of self-testing; people choose to self-test, but there is some evidence, although it is mixed, that they give higher JOLs following re-presentation (Roediger & Karpicke, 2006b), although others have reported higher ratings following testing (Begg, Vinski, Frankovich, & Holgate, 1991; Mazzoni & Nelson, 1995).

We (Son & Kornell, in preparation) conducted a direct test of the disconnect between JOLs and study choices in the domain of self-testing. In that preliminary experiment, participants studied a list of 12 word pairs one at a time. Then, they were given a chance to study the list a second time, but this time they were given a choice: They could either have the list re-presented, or they could take a practice quiz, during which the cue would be presented, they would type in the answer (if they could remember it), and then they would be shown the correct answer. After making their choice and studying the list for the second time, participants were asked how many of the items they would be able to recall on a later test (i.e., "I will remember __/12," an aggregate JOL). There were four lists, and at the end of the last list, all four lists were tested.

The results showed that people strongly favored testing over re-presentation in their study choices, but JOL ratings were approximately the same in the two conditions. Thus, there was indeed a disconnect, even within single individuals, between study choices and JOLs. Furthermore, recall rates were higher after self-testing than presentation, demonstrating that self-testing was an effective strategy. If JOLs had not been recorded, one might have concluded that the reason people chose to test was because doing so improved learning. Paradoxically, it appears that, instead, people chose self-testing in spite of the fact that they believed — incorrectly — that testing and straight presentation work equally well. A postexperimental questionnaire further revealed that, in fact, rather than thinking that self-testing helps them *learn,* people instead think — rightly — that it helps them *monitor* their learning. That is, they realized that self-testing improves metacognitive accuracy (which it does; see Dunlosky & Nelson, 1992; Nelson & Dunlosky, 1991). Thus, people think self-testing sharpens their ability to monitor their learning but not their learning itself, and therefore they choose to self-test, not based on metacognitive monitoring, but instead to *serve* metacognitive monitoring.

Conclusion and Overview

Many pieces have been put together, but the puzzle of time allocation is far from solved. Learners seem to be systematic about their allocation decisions with respect to item difficulty. A virtually universal finding is that people do not study information they think they already know (Metcalfe & Kornell, 2005). In some situations, people allocate time to the most difficult items. In other situations, such as when they are pressed for time, they focus on easier items. As far as optimality, in some instances people make allocation decisions that significantly improve competence (e.g., Kornell & Metcalfe, 2006). In other situations, however, increases in time allocation appear to be labor in vain (Nelson & Leonesio, 1988). In some situations, such as when making decisions about spacing and self-testing — context in which time allocation is just beginning to be explored — people seem to make effective decisions (by choosing to space and self-test; see Son & Kornell, in preparation; and Son, 2005, respectively), even when they do not seem to realize that their decisions are effective (see Zechmeister & Shaughnessy, 1980, and Roediger & Karpicke, 2006b, respectively).

Part of the reason for the disconnect between metacognitive ratings and study choices is the wide array of factors that influence study decisions that are not directly related to metacognitive monitoring and vice versa. Many are commendable, like self-testing to monitor one's learning, or studying information that one finds interesting (Son & Metcalfe, 2000). But, others may be equally important. For example, which study technique is the most fun? What makes one *feel* like one is learning (which is often different from what makes one actually learn). What grade is one studying for (e.g., "studying for a B")? What is on TV? Finally, the question that seems to be the main determiner of which topic a student chooses to study next: What is the most overdue (Kornell & Bjork, in press)? These touch on what we consider to be the three general factors that are important for optimizing study, in particular the allocation of time: goals, motivation, and efficiency. Goals, of course, are the very foundation of study, and it is impossible to overestimate the importance of motivation. The most important objective of research on study time allocation, however, is to uncover ways of improving efficiency. As Benjamin Franklin said, "Do not squander time, for that is the stuff life is made of."

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