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The value in rushing: Memory and selectivity when short on time

Catherine D. Middlebrooks [a,*], Kou Murayama [b,c], Alan D. Castel [a,*]

[a] University of California, Los Angeles, United States
[b] University of Reading, UK
[c] Kochi University of Technology, Japan

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ABSTRACT

While being short on time can certainly limit what one remembers, are there always such costs? The current study investigates the impact of time constraints on selective memory and the self-regulated study of valuable information. Participants studied lists of words ranging in value from 1–10 points, with the goal being to maximize their score during recall. Half of the participants studied these words at a constant presentation rate of either 1 s or 5 s. The other half of participants studied under both rates, either fast (1 s) during the first several lists and then slow (5 s) during later lists, or vice versa. Study was then self-paced during a final segment of lists for all participants to determine how people regulate their study time after experiencing different presentation rates during study. While participants recalled more words overall when studying at a 5-second rate, there were no significant differences in terms of value-based recall, with all participants demonstrating better recall for higher-valued words and similar patterns of selectivity, regardless of study time or prior timing experience. Self-paced study was also value-based, with participants spending more time studying high-value words than low-value. Thus, while being short on time may have impaired memory overall, participants' attention to item value during study was not differentially impacted by the fast and slow timing rates. Overall, these findings offer further insight regarding the influence that timing schedules and task experience have on how people selectively focus on valuable information.

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1. Introduction

Whether a student, a parent with toddlers, or a busy employee, it often feels as if there is never enough time in the day. Time limitations can negatively impact what is later remembered—what might have been remembered given more time is otherwise forgotten—the consequences of which can be wide-ranging. While limited study time is known to notably diminish the likelihood of remembering overall (Mackworth, 1962; Murdock, 1962; Posner, 1964; Roberts, 1972), it is unclear how people attempt to remember valuable information when they have limited time in which to do so. For example, how might a student approach a textbook in light of an upcoming exam? Does the student attempt to read as much of the textbook as possible, foregoing entire chapters once out of time, or does the student selectively focus on what seems important?

The impact of time constraints on the construction and execution of study agendas has been predominantly investigated with respect to the self-regulated study of information varying in difficulty. People tend to spend more time studying difficult items than easier or well-learned items (Dunlosky & Hertzog, 1998; Mazzoni, Cornoldi, & Marchitelli, 1990; Nelson, Dunlosky, Graf, & Narens, 1994; Thiede, Anderson, & Therriault, 2003). When the amount of time available to study all of the information is insufficient, though, there is a shift in study, with a prioritization instead of easier materials (Dunlosky & Thiede, 2004; Son & Metcalfe, 2000; Thiede & Dunlosky, 1999). The effect of time constraints on the study of valuable information is less clear.

Research suggests that memory lapses suffered as a consequence of having too much information to remember may be tempered by selectively focusing on the most important information at the expense of that which is deemed less critical (e.g., Castel, Benjamin, Craik, & Watkins, 2002). This prioritization based on item value or importance has been referred to as value-directed remembering (Castel, 2008; Castel, McGillivray, & Friedman, 2012). As in the case of having too much to remember, having insufficient time in which to remember all of the information might similarly encourage strategizing during study, with an eye towards allocating one's resources and efforts during encoding in

* Corresponding authors at: Department of Psychology, University of California, Los Angeles, 1285 Franz Hall Box 951563, Los Angeles, CA 90095, United States.
E-mail addresses: cmiddlebrooks@ucla.edu (C.D. Middlebrooks), castel@ucla.edu (A.D. Castel).

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a manner that will maximize study productivity and later recall in spite of time limitations.

Even in the absence of time constraints, though, learners often require multiple trials or continued task experience before exhibiting value-directed remembering (Castel, 2008; Castel et al., 2012). When there is less time available to study presented information, there may also be less time to properly evaluate prior experiences and devise a corresponding course of action. Moreover, learning difficult information is intrinsically time demanding, while learning valuable information is not necessarily so. In fact, it is often the case that some to-be-remembered information is more valuable than other information despite being of similar ease/difficulty to remember (e.g., recalling the new telephone number of a close friend as opposed to that of a mere acquaintance). If the to-be-remembered information is of similar ease/difficulty to remember, as in the current study, then the successful encoding of low-value information should not inherently require more or less time than that of high-value information. Contrarily, difficult information necessarily requires more time to successfully encode than easy information. Thus, the limitations that time constraints during study present to learning may be more salient when the to-be-learned information is easy or difficult than when it varies in importance.

It may also be the case that learners continue to recognize the importance of adopting a value-based agenda when time is limited, but that they are less able to *efficiently* execute such an agenda in light of time constraints. The degree to which learners are selective represents the efficiency of their study: of the *n* items that one can successfully recall, are they the *n*-most important? It is possible that learners will continue to study selectively when time is limited, accommodating the decrease in allotted study time and consequential decrease in total recall by implementing more stringent criteria when determining to which subset of valuable items to attend. On the other hand, it may be that learners continue to generally prioritize high-value items over less valuable items when short on time, demonstrating value-directed remembering, but that the efficiency with which this strategy is executed diminishes. The odds of recalling a 10-point item over a 1-point item, for instance, might be lower when participants have limited study time than when time is far less constrained, indicating reduced selectivity. Learners may be less able to efficiently attend to and remember the most important information when they find themselves short on time, indicating not only quantitative costs to memory owing to time limitations, but also qualitative.

2. Study goals

The primary goal of the current experiment was to directly examine the potential impact of time constraints on the study of valuable information: is it beneficial to study at a faster rate, in that it encourages a more selective and efficient study effort, or does memory for high-value information comparably decline with overall recall relative to a slower rate of study?

An additional goal was to investigate whether learners adjust to shifts in study time and the impact such change can have on value-based study. Perhaps those participants who have only studied under a constant rate are able to optimize their study by selectively allocating their attention to high-value items, while participants who experience a change in study time are less able to recover or adapt a prior strategy in the short-term.

A further goal was to examine whether prior study time experiences might transfer to situations in which study is entirely self-paced. Although shifts in study may result in an immediate decrement in selectivity, it may also be the case that learners with more varied study experiences, such as with fast *and* slow study, are better equipped to optimally self-regulate their study than learners who were only familiarized with a constant study rate.

3. Method

3.1. Participants

Participants consisted of 192 undergraduate students[1] at the University of California, Los Angeles (142 female, 1 unreported), ranging in age from 18 to 26 years ($M = 20.34$, $SD = 1.41$). Participants received partial credit for a course requirement.

3.2. Materials

The study was designed and presented to participants via the Collector program (Gikeymarcia/Collector, n. d.). Stimuli consisted of 12 lists containing 20 novel words apiece. Each of the words was randomly assigned a value ranging from 1 to 10, with two words assigned to each value. The words in each list were randomly selected without replacement from a larger word bank of 280 random nouns and verbs (e.g., twig, button, point, taste). Word length ranged from 4–7 letters and averaged to 8.81 ($SD = 1.57$) on the log-transformed Hyperspace Analogue to Language (HAL) frequency scale[2] with a range from 5.48 to 12.65 (Lund & Burgess, 1996). The 240 studied words were randomly selected from this bank for each participant in order to avoid any potential item effects (Murayama, Sakaki, Yan, & Smith, 2014). Thus, the words studied in List 1 for one participant might have been entirely different from another participant's List 1. Furthermore, one participant might study the word “drizzle” while another might not, or might have studied “drizzle” as a 3-point word while another studied it as a 9-point word.

3.3. Procedure

Participants were told that they would be shown a series of word lists, each containing 20 different words. They were further told that each word would be paired with a value ranging from 1 point to 10 points and that there would be two words per point value within each list. Participants were instructed to remember as many of the words in each list as possible while also striving to achieve a maximal score, a sum of the points associated with each word correctly recalled. They would be asked to recall the words from each list at the end of its presentation, at which point they would then be told their score (out of 110 possible points). Participants were also told that the words would be presented on the screen one at a time at a rate of which they would be informed just prior to each list's commencement.

Participants were randomly assigned to one of four study time conditions which determined the rate of presentation during the first eight lists: Constant-Fast [1–1], Constant-Slow [5–5], Speed Up [5–1], or Slow Down [1–5]. Participants in the Constant conditions studied the words in Lists 1–8 at a rate of either 1 s (Constant-Fast) or 5 s per word (Constant-Slow). Participants in the Speed Up condition studied at a rate of 5 s per word during Lists 1–4 and then 1 s per word during Lists 5–8; thus, their rate of study increased. Contrastingly, participants in the Slow Down condition studied at a rate of 1 s per word during Lists 1–4 and then 5 s per word during Lists 5–8; thus, their rate of study decreased. Study was self-paced for all participants during Lists 9–12, with a cap on neither the per-item nor per-list study time. This design created three different timing segments: Segment 1 consisted of Lists 1–4; Segment 2 of Lists 5–8; and Segment 3 of the self-paced Lists 9–12.

[1] The current study is based on a pooled set of original data ($N = 96$) and replication data ($N = 96$). The results from the original data are largely consistent with those reported from the pooled data and can be obtained from the corresponding author upon request.

[2] The Log HAL frequency measure of the words included in the English Lexical Project ranges from 0 to 17, with an average frequency of 6.16 and a standard deviation of 2.40 (Balota et al., 2007).

Table 1
Recall probability as a function of segment, list, and study condition.

Condition	Segment 1					Segment 2					Segment 3				
	L1	L2	L3	L4	Average	L5	L6	L7	L8	Average	L9	L10	L11	L12	Average
Constant-Fast [1–1]	0.28 (0.12)	0.30 (0.12)	0.29 (0.13)	0.28 (0.08)	0.29 (0.09)	0.31 (0.12)	0.30 (0.13)	0.31 (0.11)	0.30 (0.09)	0.31 (0.09)	0.51 (0.21)	0.48 (0.23)	0.50 (0.26)	0.45 (0.23)	0.49 (0.21)
Constant-Slow [5–5]	0.40 (0.15)	0.47 (0.16)	0.47 (0.17)	0.48 (0.17)	0.46 (0.13)	0.49 (0.18)	0.49 (0.20)	0.48 (0.18)	0.44 (0.18)	0.47 (0.16)	0.53 (0.24)	0.52 (0.22)	0.47 (0.24)	0.45 (0.23)	0.49 (0.21)
Speed Up [5–1]	0.46 (0.17)	0.43 (0.17)	0.47 (0.19)	0.47 (0.20)	0.46 (0.15)	0.28 (0.11)	0.28 (0.17)	0.28 (0.11)	0.29 (0.14)	0.28 (0.10)	0.51 (0.24)	0.46 (0.24)	0.48 (0.25)	0.41 (0.22)	0.47 (0.21)
Slow Down [1–5]	0.28 (0.10)	0.30 (0.13)	0.30 (0.14)	0.30 (0.12)	0.30 (0.09)	0.49 (0.20)	0.49 (0.19)	0.50 (0.19)	0.50 (0.19)	0.49 (0.17)	0.57 (0.23)	0.52 (0.24)	0.48 (0.20)	0.48 (0.23)	0.51 (0.20)
Average	0.35 (0.16)	0.38 (0.17)	0.38 (0.18)	0.38 (0.18)	0.37 (0.14)	0.39 (0.18)	0.39 (0.20)	0.39 (0.18)	0.38 (0.18)	0.39 (0.16)	0.53 (0.23)	0.50 (0.23)	0.48 (0.24)	0.45 (0.23)	0.49 (0.21)

Note. Standard deviations are presented in parentheses. "L1" through "L12" refer to Lists 1 through 12.

Based on prior research (e.g., Castel, Farb, & Craik, 2007; Middlebrooks, McGillivray, Murayama, & Castel, 2016), a rate of 5 s per word was chosen in order to provide sufficient time for participants to identify the word's value, determine whether or not it met any sort of strategy criterion, and/or to potentially engage in some form of elaborative rehearsal. The 1-second rate was chosen as a contrasting time; insufficient for any lengthy and elaborative rehearsal, it was still enough time for intentional encoding. Including multiple lists within each timing segment provided participants with the chance to learn from prior list performance and subsequently update their strategies (Castel, 2008; Castel et al., 2012; Metcalfe, 2002). The within-subject manipulation of study time was also intended to increase the saliency of the study time allotments. The perception of limited or insufficient study time is largely a relative judgment; participants who have only studied at a rate of 1 s per word, for instance, might not feel as short on time as participants who had previously studied at 5 s before dropping to 1 s. This potential difference in perception could mean that a particular study rate has a divergent impact on attention allocation during study and selectivity.

4. Results

4.1. Overall recall performance

Analyses were first conducted to determine whether there was an effect of study time on overall recall performance, irrespective of item value, in order to verify that the 1-s and 5-s rates were sufficiently different in terms of encoding and recall and that shorter study time did indeed lead to a decline in recall. The proportion of items recalled as a function of study time and list are provided in Table 1.

A 4 (Condition: Constant-Fast [1–1], Constant-Slow [5–5], Speed Up [5–1], Slow Down [1–5]) × 3 (Segment: Lists 1–4, Lists 5–8, Lists 9–12) repeated-measures ANOVA on total recall revealed a significant Condition × Segment interaction, $F(6, 376) = 32.36$, $MSE = 0.01$, $p < 0.001$, $\eta^2_G = 0.13$. There was a significant effect of Condition within Segment 1 and Segment 2, $ps < 0.001$, but not Segment 3, $p = 0.76$. Within Segment 1, the Constant-Fast and Slow Down conditions recalled significantly fewer items than the Constant-Slow and Speed Up conditions, $ps < 0.001$. There were no significant differences between the Constant-Fast and Slow Down conditions, nor between the Constant-Slow and Speed Up conditions, $ps > 0.62$. In other words, those conditions that studied the items at a rate of 1 s per word recalled significantly fewer words than those conditions studying at a 5-second rate. The same pattern emerged in Segment 2: participants in the Constant-Fast and Speed Up conditions (each studying at a 1-second rate) recalled significantly fewer words than the Constant-Slow and Slow Down conditions (5-second study rate), $ps < 0.001$, and there were no significant differences between conditions studying at the same rate, $ps > 0.24$. These results confirm that reduced study time led to reduced recall in the current experiments.

4.2. Value-directed remembering and selectivity

Recall performance as a function of value and timing segment is presented in Fig. 1. One method of determining whether value during study impacts subsequent recall would be to collapse the data according to predetermined value bins (e.g., items worth 1–3 points as "low" value items, items worth 4–7 as "medium," and 8–10 as "high") and then to conduct a repeated-measures analysis of variance (ANOVA). There are two considerable limitations with this method, though. Firstly, an ANOVA can only indicate whether the average recall of one subset differs from that of another (e.g., the low-value bin versus the high-value bin), treating the values as discrete categories rather than as part of a continuum. It cannot answer the question of whether there is a direct relationship between value and recall, of whether the odds of recalling an item increase with increasing value. While there is

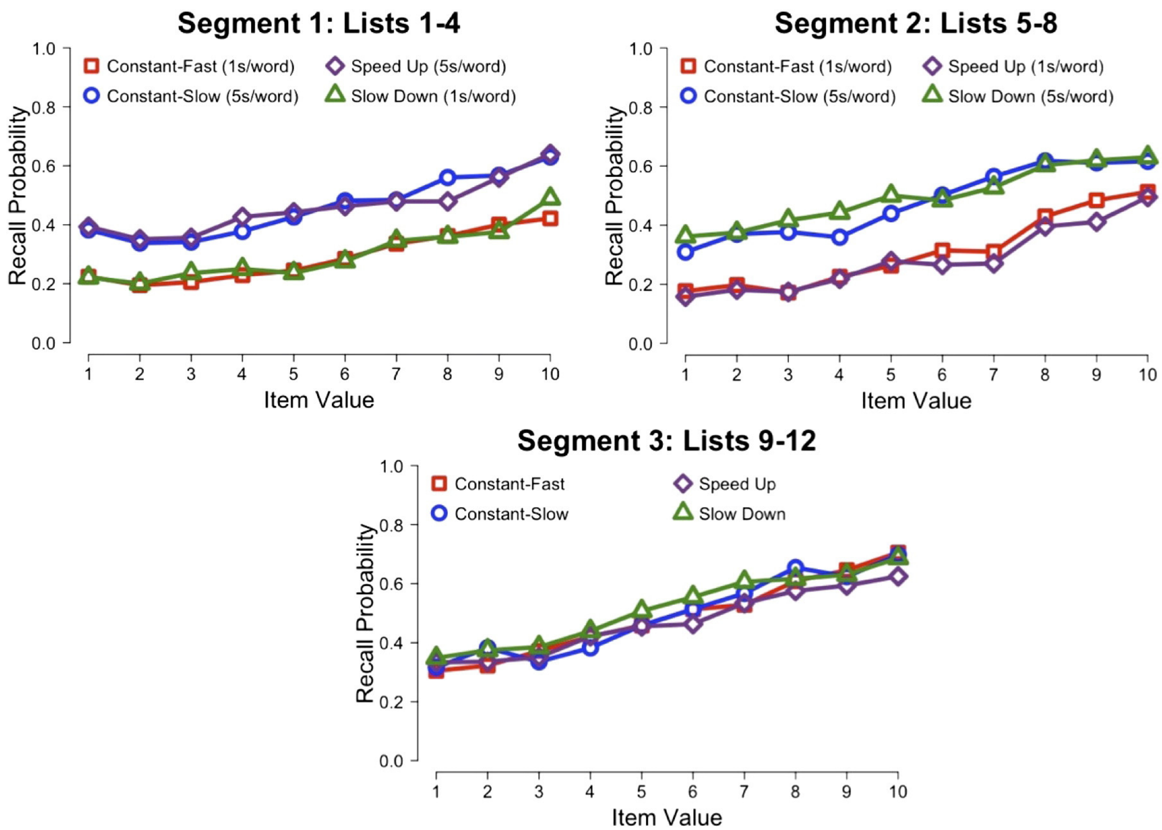

Fig. 1. Recall probability as a function of item value, list, and assigned study condition in Segments 1–3. As a reminder, study during Segment 3 was self-paced.

something to be gained from learning whether, on average, high-value items were better recalled than low-value items, such an analysis is ultimately not particularly sensitive to value-directed remembering as a strategy. There may well be changes between lists/segments in recall across the value continuum that would not be apparent from mean-based analytical techniques.

Table 2
Two-level hierarchical generalized linear model of recall performance predicted by Item Value, List, and Study Condition.

Fixed effects	Coefficient: Segment 1	Coefficient: Segment 2	Coefficient: Segment 3
Intercept (β_{00})	−0.20*	−0.14	−0.10
Predictors of intercept			
Cond1: CS v. CF (β_{01})	−0.80***	−0.85***	0.02
Cond2: CS v. SU (β_{02})	0.01	−0.94***	−0.09
Cond3: CS v. SD (β_{03})	−0.76***	0.09	0.13
Value (β_{10})	0.15***	0.19***	0.25
Predictors of value			
Cond1: CS v. CF (β_{11})	−0.000004	0.05	0.001
Cond2: CS v. SU (β_{12})	−0.02	0.02	−0.05
Cond3: CS v. SD (β_{13})	0.01	−0.03	−0.04
List (β_{20})	0.10**	−0.09*	−0.15**
Predictors of list			
Cond1: CS v. CF (β_{21})	−0.13**	0.04	0.07
Cond2: CS v. SU (β_{22})	−0.08	0.10^{+}	0.02
Cond3: CS v. SD (β_{23})	−0.10^{+}	0.10^{+}	0.004
List × Value (β_{30})	0.03^{+}	0.03**	0.01
Predictors of list × value			
Cond1: CS v. CF (β_{31})	0.01	0.01	−0.02
Cond2: CS v. SU (β_{32})	0.02	−0.02	−0.02
Cond3: CS v. SD (β_{33})	0.03^{+}	0.01	−0.02
Random effects	Variance	Variance	Variance
Intercept (person-level) (r_0)	0.25***	0.38***	1.23***
Value (r_1)	0.02**	0.01**	0.05***
List (r_2)	0.02***	0.03***	0.06***
List × Value (r_3)	0.002*	0.001**	0.002*

Note. The dependent variable is recall performance coded as 0 (*not recalled*) or 1 (*recalled*). Logit link function was used to address the binary dependent variable. Level 1 models were of the form $\eta_{lij} = \pi_{0j} + \pi_{1j}(\text{Value}) + \pi_{2j}(\text{List}) + \pi_{3j}(\text{List} \times \text{Value})$. Level 2 models were of the form $\pi_{0j} = \beta_{00} + \beta_{01}(\text{Cond1}) + \beta_{02}(\text{Cond2}) + \beta_{03}(\text{Cond3}) + r_{0j}$, $\pi_{1j} = \beta_{10} + \beta_{11}(\text{Cond1}) + \beta_{12}(\text{Cond2}) + \beta_{13}(\text{Cond3}) + r_{1j}$, $\pi_{2j} = \beta_{20} + \beta_{21}(\text{Cond1}) + \beta_{22}(\text{Cond2}) + \beta_{23}(\text{Cond3}) + r_{2j}$, $\pi_{3j} = \beta_{30} + \beta_{31}(\text{Cond1}) + \beta_{32}(\text{Cond2}) + \beta_{33}(\text{Cond3}) + r_{3j}$.
"CS" refers to the Constant-Slow condition [5–5]; "CF" to Constant-Fast [1–1]; "SU" to Speed Up [5–1]; and "SD" to Slow Down [1–5].
$^{+}$ $p < 0.10$. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Secondly, because participants differ in *how* they strategically attend to value during study and in what they consider to be important, it would be inappropriate to analyze the data simply by comparing the average recall across value points, binned or otherwise. A participant who expects to remember many items, for instance, may consider words worth 6 or more points to be worthy of attention during study. A less confident participant, however, may limit study to items worth only 9 or 10 points. In both cases, participants are executing selective, value-based study strategies. Binning items into specific value ranges, however, would mask individual differences in strategy use and selectivity, preventing a more fine-grained analysis of value-directed remembering.

So, in order to account for potential within- and between-subject differences in value-based recall strategies, hierarchical linear modeling (HLM) was used to analyze recall within each segment as a function of list and item value between the four study conditions (Middlebrooks et al., 2016; Raudenbush & Bryk, 2002). HLM first clusters the data within each participant, thereby accounting for individual differences in strategy, and *then* considers potential differences in the impact of value and timing on recall across conditions, all while reflecting the to-be-remembered information as it was studied by participants and maintaining the overall data structure—a continuous value scale.

Separate HLM analyses were conducted for each of the three timing segments within the experiment. Within each segment, item-level recall performance (based on a Bernoulli distribution, with 0 = *not recalled* and 1 = *recalled*; level 1 = items; level 2 = participants) was modeled as a function of each item's value, the list in which it was presented, and the interaction between value and list. Value and List were entered as group-mean centered variables, such that Value was anchored on the mean value point (5.50) and List was anchored on the mean list of the given segment. The model further included the timing conditions as level-2 predictors of those level-1 effects via three dummy-coded variables, with the Constant-Slow [5-5] condition as the reference group.[3] Table 2 reports the tested model and its estimated regression coefficients for each segment's analysis.

As the models are essentially logistic regression models with a dichotomous dependent variable, the regression coefficients can be interpreted via their exponential (Raudenbush & Bryk, 2002). Specifically, exponential beta, Exp(B), is interpreted as the effect of the independent variable on the odds ratio of successful memory recall (i.e., the probability of recalling items divided by the probability of forgetting them) (Murayama, Sakaki, et al., 2014). Exp(B) of more than 1.0 indicates a positive effect of the predictor, while an Exp(B) of less than 1.0 indicates a negative (or diminished) effect.

4.3. Segment 1

Value was a significantly positive predictor of recall performance in the Constant-Slow condition during Segment 1 (β_{10} = 0.15, $p < 0.001$), and this relationship was not significantly different in the other conditions, $ps > 0.46$. In other words, participants across all conditions were $e^{0.15} = 1.16$ times more likely to recall an item for each one-unit increase in its value. The odds of recalling a 10-point item during Segment 1, for example, were thus $e^{0.15 * 10} = 4.48$ times greater than the odds of recalling a 1-point item.

There was a significant effect of List for participants in the Constant-Slow condition ($\beta_{20} = 0.10$, $p = 0.005$), and there was a significant cross-level interaction between List and Condition, wherein List had an increasingly reductive effect on total recall relative to the Constant-Slow condition, irrespective of item value, for those participants in the Constant-Fast ($\beta_{21} = -0.13$, $p = 0.005$) and Slow Down conditions ($\beta_{23} = -0.10$, $p = 0.05$) (i.e., those participants studying at a rate of 1-s per word).

There was also a marginally significant List × Value interaction in the Constant-Slow condition, such that the relationship between item value and recall probability increased with each successive list ($\beta_{30} = 0.03$, $p = 0.07$). Namely, participants demonstrated greater selectivity across lists, with recall increasingly conditional upon item value with each successive list. This interaction did not differ across conditions ($ps > 0.08$), indicating that participants across conditions demonstrated increased selectivity across successive lists in Segment 1.

4.4. Segment 2: within-subject timing shift

Value was once again a significantly positive predictor of recall performance in the Constant-Slow condition during Segment 2 (β_{10} = 0.19, $p < 0.001$), and there were no significant differences across the other study time conditions, $ps > 0.27$. Participants were exp(0.19) = 1.21 times more likely to recall an item for each one-unit increase in its value, demonstrating not only maintained selectivity, but somewhat greater attention to value than during Segment 1 (β_{10} = 0.15 versus 0.19).

There was a significant effect of List on recall in the Constant-Slow condition ($\beta_{20} = -0.09$, $p < 0.001$), with the probability of recalling

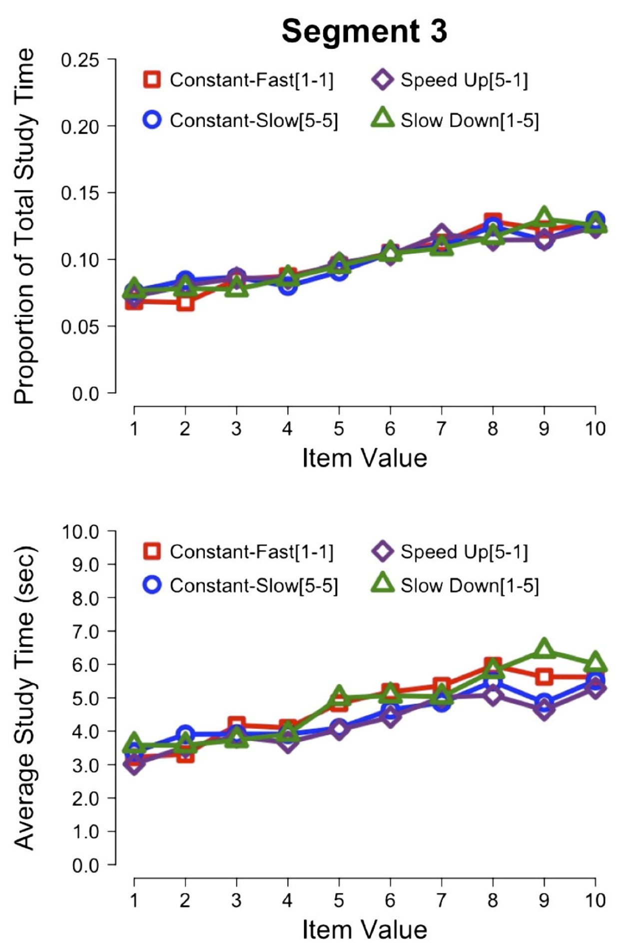

Fig. 2. The average proportion of self-paced study time and the average study time (in seconds) allocated to each item value across assigned study conditions in Segment 3. The rates at which participants in each condition studied during Segments 1 and 2, either 1 s per word or 5 s, are provided in brackets.

[3] The Constant-Slow condition was intended to serve as the baseline condition in which there is a relative absence of time constraint based on timing rates used in prior research (e.g., Castel et al., 2007; Middlebrooks et al., 2016) and compared to the faster, 1-second timing rate experienced by the other conditions. The following results are, however, consistent regardless of the chosen reference group.

an item, irrespective of its value, significantly decreasing across lists. There was not a significant difference in this List effect between the Constant-Slow and Constant-Fast conditions ($\beta_{21} = 0.04$. $p = 0.40$), but there were marginally significant differences between the Constant-Slow condition and the Speed Up and Slow Down conditions ($\beta s = 0.10$, $ps = 0.07$), those conditions in which participants experienced a shift in their allotted study time.

Critically, there was a significant List × Value interaction in the Constant-Slow condition ($\beta_{30} = 0.03$, $p = 0.003$), and this did not differ across the other conditions, $ps > 0.25$. Thus, selectivity continued to increase across lists in Segment 2, but was impacted by neither study time differences during Segment 2 nor differences between groups regarding prior experience with Segment 1 study times.

4.5. Segment 3: self-regulated study

To determine whether learners transfer previously adopted strategies and prior study experiences to self-regulated study situations, study during the final four lists of the task (i.e., Segment 3) was entirely self-paced: participants could study each item for as long as they desired and there was no cap on how long they could study each list in total.

As in Segments 1 and 2, Value was a significant predictor of recall performance in the Constant-Slow condition ($\beta_{10} = 0.25$, $p < 0.001$), with no significant differences across the other study conditions, $ps > 0.35$. Participants were exp(0.25) = 1.28 times more likely to recall an item for each one-unit increase in its value. Again, this effect was greater than in either of the previous study segments ($\beta_{10} = 0.15$ versus 0.19 versus 0.25), indicating increasing attention to value as the task progressed. Similar to Segment 2, there was a significantly negative relationship between list progression and overall recall in Segment 3 ($\beta_{20} = -0.15$, $p = 0.001$), with no condition differences ($ps > 0.25$). Contrary to Segments 1 and 2, there was not a significant List × Value interaction in the Constant-Slow condition ($\beta_{30} = 0.02$, $p = 0.22$), nor in any of the other conditions ($ps > 0.18$).

These results indicate that, during this period of self-paced study, participants improved upon their strategy of selective study relative to the prior, experimenter-timed segments. Differing prior experiences across the conditions with respect to the allotted study times did not, however, appear to impact this self-regulation: participants across all conditions were similarly selective and maintained this selectivity across Lists 9–12.

4.6. Self-regulated study

Fig. 2 illustrates the average proportion of total study time spent per item value during Segment 3 as well as the average study time per item value. As study was self-paced, each participant spent a different amount of time studying each of the Segment 3 lists overall while also allocating their study time across the items within each list differently. In investigating how (or if) participants considered item value in allocating their study times during Segment 3, proper consideration of individual variance is critical. Thus, HLM analyses were again implemented. Item-level study time (in seconds) was modeled as a function of each item's value, the list in which it was presented, and the interaction between value and list, as in the previously conducted HLM analyses concerning value-based recall. The model further included the study conditions as level-2 predictors of these level-1 effects via three dummy-coded predictor variables, with the Constant-Slow [5–5] study condition as the reference group. Table 3 reports the tested model and its estimated regression coefficients.

There was a significant effect of Value on study time in the Constant-Slow condition, with 0.22 more seconds spent studying words with each one-unit increase in assigned value ($\beta_{10} = 0.22$, $p < 0.001$); this relationship did not significantly differ as a consequence of prior study condition, $ps > 0.21$. There was also a significant effect of List on study time in the Constant-Slow condition ($\beta_{20} = -0.58$, $p < 0.001$), such that significantly less time was spent studying each successive list overall. This was also consistent across conditions, $ps > 0.10$. There was evidence of neither a List × Value interaction in the Constant-Slow condition ($\beta_{30} = 0.01$, $p = 0.66$) nor of a three-way interaction between List, Value, and Condition, $ps > 0.21$.

Table 3
Two-level hierarchical generalized linear model of self-paced study time predicted by Item Value, List, and Study Condition.

Fixed effects	Coefficient: Segment 3
Intercept (β_{00})	4.46***
Predictors of intercept	
Cond1: CS v. CF (β_{01})	0.28**
Cond2: CS v. SU (β_{02})	−0.20
Cond3: CS v. SD (β_{03})	0.36
Value (β_{10})	0.22***
Predictors of value	
Cond1: CS v. CF (β_{11})	0.08
Cond2: CS v. SU (β_{12})	0.01
Cond3: CS v. SD (β_{13})	0.11
List (β_{20})	−0.58***
Predictors of list	
Cond1: CS v. CF (β_{21})	−0.18
Cond2: CS v. SU (β_{22})	−0.22
Cond3: CS v. SD (β_{23})	−0.34
List × Value (β_{30})	0.01
Predictors of list × value	
Cond1: CS v. CF (β_{31})	−0.03
Cond2: CS v. SU (β_{32})	−0.05
Cond3: CS v. SD (β_{33})	−0.05
Random effects	Variance
Intercept (person-level) (r_0)	10.89***
Value (r_1)	0.93***
List (r_2)	0.14***
List × Value (r_3)	0.01*

Note. The dependent variable is study time in seconds. Level 1 models were of the form $\eta_{ij} = \pi_{0j} + \pi_{1j}$ (Value) $+ \pi_{2j}$ (List) $+ \pi_{3j}$ (List × Value). Level 2 models were of the form $\pi_{0j} = \beta_{00} + \beta_{01}$ (Cond1) $+ \beta_{02}$ (Cond2) $+ \beta_{03}$ (Cond3) $+ r_{0j}$, $\pi_{1j} = \beta_{10} + \beta_{11}$ (Cond1) $+ \beta_{12}$ (Cond2) $+ \beta_{13}$ (Cond3) $+ r_{1j}$, $\pi_{2j} = \beta_{20} + \beta_{21}$ (Cond1) $+ \beta_{22}$ (Cond2) $+ \beta_{23}$ (Cond3) $+ r_{2j}$, $\pi_{3j} = \beta_{30} + \beta_{31}$ (Cond1) $+ \beta_{32}$ (Cond2) $+ \beta_{33}$ (Cond3) $+ r_{3j}$.
"CS" refers to the Constant-Slow condition [5–5]; "CF" to Constant-Fast [1–1]; "SU" to Speed Up [5–1]; and "SD" to Slow Down [1–5].
* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

4.7. Bayesian analysis

The current analyses reveal a nonsignificant effect of Condition on the relationship between item value and recall probability, indicating that there is little evidence that value-directed remembering and one's ability to study selectively in the current task is influenced by study time. However, as these results are based upon null hypothesis testing, it is impossible to claim the absence of such effects (despite the large nature of the sample size, $N = 192$). Additionally, the current analyses are based upon an aggregation of the original sample and the replication sample, and interim analyses were conducted for the original sample. Although there was no intention to stop data collection contingent upon the obtained results, interim analyses make the interpretation of the obtained p-values ambiguous (Murayama, Pekrun, & Fiedler, 2014). Thus, in order to confirm this null effect of Condition suggested by the HLM analyses, and because interim analyses were conducted on this pooled data, a Bayesian analysis was also performed. By using Bayes factors computed in Bayesian analysis, it is possible to directly compare of the probability of obtaining the present results under the null hypothesis H_0 (no Condition differences in the value effect) to the probability of the results under the alternative hypothesis H_1 (Condition differences) (Jarosz & Wiley, 2014).

As it is difficult to directly compare Bayes factors with HLM (although Bayesian information criterion [BIC] computed in HLM can provide some proxy for computing Bayes factors), a two-step approach was used to allow for simpler Bayesian analysis with hierarchical data (see Lorch & Myers, 1990; Murayama, Sakaki, et al., 2014). Specifically, item recall was regressed on item value within each list for each participant using logistic regression, and the obtained value coefficients were averaged by segment. A 4 (Condition) × 3 (Segment) repeated-measures Bayesian ANOVA was then conducted on these value slopes with JASP software using default priors (Love et al., 2015). Results indicated that the Bayes Factor$_{10}$ (BF_{10}), reflecting the probability of the data under the alternative hypothesis relative to the null, for Condition was 0.06. In other words, the present data are $1/0.06 = 16.67$ times more likely to be consistent with the null model than with the alternative, providing strong evidence for a null effect of Condition (Jeffreys, 1961; Kass & Raftery, 1995). In sum, these results support the HLM analyses and confirm that selectivity during study was comparable across the timing conditions.

5. Discussion

We often find ourselves short on time and suffering memory lapses as a consequence. These lapses can be particularly frustrating when the information forgotten is of higher importance than that which is ultimately remembered: imagine returning home from a shopping trip in which everything was purchased except the very item you had most intended to buy! The current experiment examined whether the generally negative impact of time constraints on memory might be mitigated by strategic, value-based study. It further investigated learners' ability to adjust their strategies in light of changes in study time, whether speeding up or slowing down. Additionally, the current experiment assessed how learners self-pace their study of valuable information in light of prior study experiences.

While memory for the presented items was greater overall when participants were granted more time to study, there were no significant differences in participants' ability to selectively allocate their attention to the most valuable items. Participants studying at a rate of 1 s per word were just as likely to recall high-value items as participants studying at a slower (5 s) rate. Irrespective of study condition, participants showed an increase in selectivity across the lists of Segment 1. This is consistent with prior research demonstrating increases in selectivity with greater task familiarity (e.g., Castel, 2008; McGillivray & Castel, 2011; Middlebrooks et al., 2016) and is indicative of strategy modification and/or more successful execution of an established value-based strategy. This selectivity continued to increase during Segment 2 in spite of mid-task shifts in study time; prior experiences with an alternate study rate did not appear to impact selectivity under novel conditions.

Although the study times were directly contrasted between Segments 1 and 2 of the task, participants might have felt that there was simply *less* time during study rather than insufficient time, hence the comparable selectivity across conditions. While this is certainly a possibility, self-pacing during Segment 3 would presumably have reflected a preference in study closer to the 1-second rate if participants had truly believed it to be adequate, and this was not the case (see Fig. 2). Even the least valuable items (i.e., 1-point words) received approximately 3 s of study on average, indicating that participants generally considered a 1-second study rate to be far from sufficient. The 5-second study rate, on the other hand, was much closer to the rate at which participants chose to self-pace their study, particularly for those most valuable (10-point) items, which received approximately 6 s of study, on average. Thus, results from Segment 3 confirm not only that the 1-second study rate experienced by some of the participants was inadequate for proper study, but also that value-based study continued to be evident when participants were able to control the pacing themselves—participants allocated greater lengths of study to increasingly valuable words and preserved their selectivity across lists.

Interestingly, though, there was a consistent decline in the total time that participants spent studying Lists 9–12, coupled with a decline in overall recall. Participants theoretically had unlimited time with which to study the items, so one might expect that study time and recall would actually *increase* across lists. That this was not the case may have been a result of prior task experience. The steady improvement in selectivity across Lists 1–8 suggests that participants were learning about their memory capacity ("how many items can I remember?") and learning *how* to study such that the limitations of their capacity were offset by the substance and quality of their recall. During these first eight lists, capacity limitations were, of course, partly based on innate ability, but also on the fact that participants had no more than either 1 or 5 s to study per item, depending upon their assigned condition. Thus, whatever participants learned about their memory capacity was partially contingent upon the limits of the task itself. Participants may have failed to recognize this when self-pacing their own study during Lists 9–12. Theoretically, participants could have studied each item for as long as it took to be fully mastered. If, however, they believed that their prior performance (again, based partly on now irrelevant task characteristics) reflected their upper limit, then there would be little sense in expending further efforts and allocating even greater time to each item. For instance, if a participant believes, based on prior performance, that he or she can recall roughly 12 items and achieve a score in the 60s, then it would be pointless to spend more time beyond what it takes to achieve that level if the participant also believes the probability of exceeding that performance level to be slim—to do so would be to "labor-in-vain"[4] (cf., Nelson & Leonesio, 1988). So, although participants clearly did not study the items long enough to improve, or even maintain, their overall recall during Segment 3, they continued to select a length of study that maintained their study *efficiency*, reducing their study time without jeopardizing their recollection of the most valuable items. This is consistent with active metacognitive judgments during study.

That evidence of value-directed remembering persisted despite time limitations might initially seem to conflict with recent work by Ariel and Dunlosky (2013), which demonstrated that participants were *less* value-driven in their item selections when under time pressure. Critically, however, participants in that study made item selections from triplet pairings that were presented to participants in a single row so as to activate habitual reading biases. Under time pressure, participants were less able to overcome their biases, choosing to initially select the left-most item more often for restudy than the highest-valued item. The methodology used in the current study, however, activated no such biases—the question was simply whether or not participants could develop and execute an appropriate, value-based agenda when short on time, not whether biases could be overcome under time constraints.

The fact that time constraints *did* have an impact in Ariel and Dunlosky (2013) but not in the current study, however, highlights the fact that selectivity and value-directed remembering may not always be as impervious to time constraints as in the current study—in some cases, selectivity may indeed change as a function of timing—and there are a number of factors that warrant additional consideration. For one, participants in the present study were not required to

[4] The so-called "labor-in-vain" effect refers to a lack of performance benefit for information that receives greater study than information that receives less study—no apparent gains result from the extra labor. For instance, Nelson and Leonesio (1988) reported that participants who were instructed to emphasize accuracy during study and a mastery of the material (trigrams or trivia questions, as per the specific experiment) studied the to-be-remembered information for significantly more time than did participants who were to emphasize speed during study. This extra study time on the part of the accuracy-group, however, reflected a "labor-in-vain," as there was no comparable increase in performance relative to the speed-group.

determine the value of the information they were attempting to remember—values were explicitly noted during the study session. Time constraints might have a pronounced impact on selectivity during study, though, if participants must first judge the importance of the to-be-remembered information before executing any sort of value-based study strategy. In the case of studying for an exam, for instance, a student must determine which information in the textbook is important—is it critical to a conceptual understanding; is it likely to be tested; et cetera—before being able to study selectively. When time is limited, are learners capable of identifying important information quickly enough to still execute a selective strategy? Moreover, are learners selective when making their evaluations in light of time constraints? If given 30 min to study a chapter, for example, perhaps 30% of the contents are deemed important enough to warrant attention. If given only 10 min, though, does that learner continue to ascribe equal importance to that 30%, or does he become more selective in his evaluations, thus becoming more selective in study? A critical step in furthering the current research is to understand the influence of time constraints on both attempts at selectivity (e.g., being more selective in evaluations) and the successful execution of selective study strategies (i.e., remembering those most important items) when evaluating importance is under the learner's purview.

Future research should also consider the potentially differential impact of time constraints and the feelings of pressure/anxiety *resulting* from time constraints on selectivity. Anxiety has been shown to markedly impair cognitive performance (Hembree, 1988; Pan & Tang, 2005; Veenman, Kerseboom, & Imthorn, 2000) and may well commandeer the very resources necessary for accurate metacognitive judgments and strategizing (Dunlosky & Thiede, 2004; Eysenck & Calvo, 1992). The current study did not assess feelings of anxiety, but, considering the lack of performance-related consequences (e.g., an exam grade), social pressures, etc., it is unlikely that any true anxiety was experienced during the task. Many of the real-world, time-sensitive situations that might benefit from selectivity, however, are likely to be accompanied by feelings of anxiety. The likelihood of selecting and successfully executing a selective strategy in such situations is presently unclear and warrants further investigation.

The current study serves as an early attempt to understand how being short on time can influence one's attempts to remember important or valuable information. Given the previously demonstrated influence of time limitations on memory and self-regulated study (e.g., Son & Metcalfe, 2000), it would not have been particularly surprising had there been a comparable impact on value-directed remembering. Participants in the current study, however, were able to plan, execute, and improve upon a value-directed and selective study strategy in spite of time limitations. They were also able to successfully adapt their acquired strategies to new study times and, when given free reign over study, continued to demonstrate comparably selective recall, with self-regulated study time allocation contingent on item value. Thus, while there are certainly memory-related costs owing to time constraints, the present findings suggest that, under certain circumstances, learners can nevertheless continue to selectively focus on, and remember, the most important information, even if they cannot remember it all.

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