Journal of Experimental Psychology:
Learning, Memory, and Cognition
2015, Vol. 41, No. 3, 851–858

0278-7393/15/$12.00 http://dx.doi.org/10.1037/xlm0000046

The Efficacy of Self-Paced Study in Multitrial Learning

Mario de Jonge, Huib K. Tabbers, and Diane Pecher
Erasmus University Rotterdam

Yoonhee Jang
University of Montana

René Zeelenberg
Erasmus University Rotterdam

In 2 experiments we investigated the efficacy of self-paced study in multitrial learning. In Experiment 1, native speakers of English studied lists of Dutch–English word pairs under 1 of 4 imposed fixed presentation rate conditions (24 × 1 s, 12 × 2 s, 6 × 4 s, or 3 × 8 s) and a self-paced study condition. Total study time per list was equated for all conditions. We found that self-paced study resulted in better recall performance than did most of the fixed presentation rates, with the exception of the 12 × 2 s condition, which did not differ from the self-paced condition. Additional correlational analyses suggested that the allocation of more study time to difficult pairs than to easy pairs might be a beneficial strategy for self-paced learning. Experiment 2 was designed to test this hypothesis. In 1 condition, participants studied word pairs in a self-paced fashion without any restrictions. In the other condition, participants studied word pairs in a self-paced fashion but total study time per item was equated. The results showed that allowing self-paced learners to freely allocate study time over items resulted in better recall performance.

Keywords: self-pacing, study time allocation, multitrial learning, metacognitive control

Intuitively, giving learners control over the pacing of their own study seems the right thing to do. But is it really wise to give learners control? In general, literature on metacognition paints a pretty bleak picture concerning the decisions learners make during study. It has been argued that, in order to become an effective self-guided learner, one needs to go against certain intuitions and have a reasonably good understanding of the processes that underlie durable learning (Bjork, 1999; Kornell & Bjork, 2007). Unfortunately, people often do not understand all of the complexities of their own memory, and they have many metacognitive misconceptions about remembering and learning (Kornell & Bjork, 2009). Although research has suggested that, in some situations, people do have accurate metacognitions, it is unclear if they are able to put this knowledge to use (Son & Metcalfe, 2000). Given that people may not be very good at making the right decisions during learning, a pessimist could argue that it might be best to take away control from learners as much as possible. On the other hand, it might be a bit rash to give up on the self-paced learner altogether. Although learners might not make optimal decisions during self-paced study, it is still not clear whether what they do is really that ineffective (Metcalfe & Kornell, 2003, 2005; Tullis & Benjamin, 2011). In the present study, therefore, we investigated to what extent learners are able to effectively allocate study time during multitrial learning. To this end, we compared a situation where learners had control over the allocation of study time to conditions where learners had no control.

One important finding in the literature on study time allocation is that learners tend to devote most of their time to the more difficult items. In a review of the literature, Son and Metcalfe (2000) looked at 19 published reports on metacognitive control in study time allocation. They found that, in approximately 75% of treatment combinations, learners displayed a clear preference for a strategy of allocating the most study time to the more difficult materials. This strategy is often referred to in the literature as *discrepancy reduction* (Dunlosky & Hertzog, 1998) and suggests that students try to compensate for the experienced difficulty of items in a list by differentially allocating study time. Although, at first glance, this might seem like a logical strategy (Mazzoni & Cornoldi, 1993), it could in fact be suboptimal. It is often argued that learners are unable to successfully compensate for the difficulty of items, and it has been shown that allocating more study time to items can yield little or no gain in later recall performance (Mazzoni & Cornoldi, 1993; Mazzoni, Cornoldi, & Marchitelli, 1990; Nelson & Leonesio, 1988). This has led researchers to suggest that the strategy of allocating more study time to the more difficult items in a list might be a form of *labor-in-vain* (Nelson & Leonesio, 1988). Similar arguments have been made by other researchers. For instance, Metcalfe and Kornell (2003) have suggested that focusing on the most difficult items in a list can be suboptimal because these items provide a low rate of return on a subsequent recall test.

This article was published Online First August 18, 2014.

Mario de Jonge, Huib K. Tabbers, and Diane Pecher, Department of Psychology, Erasmus University Rotterdam; Yoonhee Jang, Department of Psychology, University of Montana; René Zeelenberg, Department of Psychology, Erasmus University Rotterdam.

Correspondence concerning this article should be addressed to Mario de Jonge, Erasmus University Rotterdam, Department of Psychology, Woudestein, T13-07, P.O. Box 1738, 3000 DR Rotterdam, Netherlands. E-mail: dejonge@fsw.eur.nl

Even though a fairly large body of work exists on how learners allocate study time during self-paced study, it is still an open question whether what learners do is effective or not. Only a few studies have directly compared a self-paced condition to an experimenter-imposed fixed-pace condition. Moreover, these comparative studies on the effectiveness of self-paced study have come up with somewhat equivocal results (Tullis & Benjamin, 2011). For instance, in a study by Mazzoni and Cornoldi (1993), participants who self-paced their study rate showed better recall performance compared to those who studied words presented with a fixed pace (the average rate of presentation in the self-paced condition). However, Koriat, Ma'ayan, and Nussinson (2006) did not replicate this result. Furthermore, several of these studies (e.g., Koriat et al., 2006; Mazzoni & Cornoldi, 1993) incorporated test trials or asked participants for metacognitive judgments during study. Research has shown that test trials given during study are not merely neutral assessment trials but can have a profound effect on later recall (see Roediger & Karpicke, 2006, for a review). The same argument has been made about judgments of learning and remember/know judgments. It has been suggested that measuring the state of memory during study may change the state of memory itself (Jönsson, Hedner, & Olsson, 2012; Kimball & Metcalfe, 2003; Naveh-Benjamin & Kilb, 2012; Spellman & Bjork, 1992).

Recently, Tullis and Benjamin (2011) investigated the effectiveness of self-paced study in isolation (without test trials or metacognitive judgments given during study) on later recognition test performance. In Experiment 1 of their study, one group of participants studied a list of words in a self-paced fashion. They could study each word for as long as they wanted before proceeding to the next item on the list. In the other condition, participants were yoked to one of the self-paced participants. The yoked control group did not have any control over study time; the presentation time of the words was determined by calculating the average presentation time per word of the previous participant in the self-paced condition. This way total study time was equated between the two study conditions. The results showed that self-paced learning resulted in better performance on a subsequent recognition test compared to the yoked control condition. In Experiment 2 of their study, this result was replicated and extended by showing that self-paced study was even more effective than a condition in which study time was allocated to individual items based on normative item difficulty (based on performance of the yoked control condition in Experiment 1). In addition to test performance, Tullis and Benjamin also looked at the study strategies used by the self-paced group. They noted that the advantage of self-pacing was apparent only in those participants who allocated more study time to the more difficult items (discrepancy reduction). Tullis and Benjamin's results thus seem to suggest that, during single trial learning, learners can be quite proficient when it comes to allocating study time.

Research on self-pacing and study time allocation has mostly focused on single-trial learning instead of multitrial learning. In practice, however, when students acquire new knowledge (e.g., foreign vocabulary or anatomy), they probably do not study each item just once. Rather, one would expect students to go over the materials multiple times before terminating study. Also, memory researchers have considered self-pacing mainly as an incidental procedural aspect of their experimental design rather than the object of actual investigation. Therefore, little is known about what learners actually do during multitrial self-paced study. Hence, for practical considerations as well as to extend existing theoretical frameworks, it is important to find out how effectively students allocate study time during multitrial learning.

In a review of the literature on self-regulated learning, Kornell and Bjork (2007) also reported their own data from a pilot experiment on multitrial learning, in which participants were instructed to study a list of word pairs multiple times during a 10-min self-paced learning phase. The results showed that participants started out with a reasonably long (7.4 s) presentation rate per item during the first study cycle, but that they eventually ended up with a very fast (<1 s) presentation rate by the last study cycle. Although the authors did not report any statistical analysis concerning these self-paced study data, as these were not their primary interest, the pattern of results suggests that learners increased the rate of self-paced presentations as learning progressed. On the one hand, one could argue that increasing the rate of presentation could be an effective strategy, because participants experienced a larger number of study trials than they would have if they had stuck to their initial presentation rate. On the other hand, research has also shown that, with total study time equated, a large number of very fast (e.g., 1 s) presentation rates results in suboptimal learning compared to a smaller number of intermediate (e.g., 4 s) presentation rates (de Jonge, Tabbers, Pecher, & Zeelenberg, 2012; Zeelenberg, de Jonge, Tabbers, & Pecher, in press). The pilot experiment of Kornell and Bjork contained no fixed-paced control condition to which performance in the self-paced condition could be compared. Thus, it is still unclear whether learners' distribution of study time during multitrial self-paced learning is effective or not.

In the present study we investigated the effectiveness of self-paced study in a foreign vocabulary learning task. In Experiment 1, we investigated the efficacy of self-paced multitrial learning relative to fixed-pace multitrial learning (i.e., when presentation duration is determined by the experimenter and not under the control of the learner). Because presentation rate has a large influence on learning, even when total study time is held constant (de Jonge et al., 2012; Zeelenberg et al., in press), we compared a variety of fixed-presentation rates to a condition where participants were allowed to self-pace. For the self-paced condition, we expected the study time per item to decrease across cycles. Also, we expected that more study time would be allocated to items of high normative item difficulty (discrepancy reduction). Most important, if it is beneficial to control study time allocation during multitrial self-paced learning, then self-pacing should result in better recall performance relative to the fixed presentation rates. In Experiment 2, we investigated whether differential allocation of study time over items is a crucial factor in self-paced study during multitrial learning with regard to later recall performance. To this end, we compared two self-paced study conditions: one in which participants were allowed to freely allocate study time over items (unrestricted) and one in which total study time per item was equated (restricted).

Experiment 1

Method

Participants. One hundred twenty-eight undergraduate students at the University of California, San Diego, participated for course credit. The data from one participant were discarded because of a computer malfunction. This participant was replaced so that the design of the experiment remained completely counterbalanced across participants.

Materials. A total of 48 Dutch–English word pairs (e.g., *kikker–frog*) were used in the experiment. Translation pairs were noncognates, that is, the Dutch word and its English translation equivalent were orthographically and phonologically dissimilar. All words (both Dutch and English) were between three and seven letters long and consisted of one or two syllables. The mean word length of the Dutch words was 4.75 ($SD = 1.23$); the mean word length of the English words was 4.90 ($SD = 1.01$). The mean word frequency per million of the English words (Brysbaert & New, 2009) was 63.66 ($SD = 115.75$). The 48 word pairs were divided over four 12-item lists. E-prime (Schneider, Eschman, & Zuccolotto, 2002) was used to create and run the experiment.

Design and procedure. We used a 2 × 4 mixed design with pacing (self-paced vs. fixed pace) as a within-subject factor and fixed presentation rate (24 × 1 s, 12 × 2 s, 6 × 4 s, and 3 × 8 s) as a between-subjects factor. Note, however, that the design was not fully crossed, because presentation rate was not manipulated in the self-paced condition. Thus, each participant received the same self-paced condition in combination with one of four different fixed presentation rate conditions. Half of the participants started with self-paced study followed by fixed-pace study; the other half received the opposite order. Participants were randomly assigned to one of the four fixed presentation rate conditions and to one of the two orders.

In the self-paced condition, participants studied a total of 24 word pairs divided over two lists during two consecutive self-paced study blocks. In each block, participants were given 288 s of total study time to learn a list of 12 items (i.e., an average of 24 s per word pair). Participants were told that they could determine the rate of individual study presentations. The instructions emphasized that each study block would take approximately 5 min to complete regardless of pacing. Word pairs were presented one at a time on the computer screen in a random order, and participants could progress to the next item by pressing the *Enter* key. If participants did not press the *Enter* key in the first 16 s of the block, a reminder appeared on the screen informing them that, if they wanted, they could use the *Enter* key to move on to the next pair. This was done because in a pilot study some participants studied the first presented word pair in the self-paced condition for a disproportionately large amount of time (perhaps due to a failure to carefully read or remember the instructions). Importantly, due to the reminder used in the present study, this problem did not reoccur. As discussed in the Results section, most participants cycled through the study materials several times. All pairs on the list were presented once in a random order before the pairs were presented again in a different random order.

Upon completion of the two self-paced study blocks, participants first solved multiplication problems for 1 min as a distractor task and then were given a cued-recall test. On the test, the 24 Dutch words were presented on the computer screen in a random order, one at a time, and participants were asked to type the correct English translations. The cued-recall test was self-paced, and participants could simply progress to the next item by pressing the *Enter* key.

In the fixed-pace condition, participants studied two lists of 12 word pairs during two consecutive study blocks. As in the self-paced condition, participants were given 288 s of total study time for each list. However, unlike the self-paced condition, participants had no control over the presentation rate. In the 24 × 1 s condition, each list of word pairs was presented 24 times with a presentation rate of 1 s per pair. In the 12 × 2 s condition, each list was presented 12 times with a presentation rate of 2 s per pair. In the 6 × 4 s condition, each list was presented six times with a presentation rate of 4 s per pair. Finally, in the 3 × 8 s condition, each list was presented three times with a presentation rate of 8 s per pair. All pairs on the list were presented once in a random order before the pairs were presented again in a different random order. Participants were informed in advance how many times each word pair would be presented and at what rate. They were also informed that each study block would take approximately 5 min to complete. Upon completion of the two fixed-pace study blocks, participants received a distractor task followed by a cued-recall test. The procedure for the distractor task and cued-recall task were identical to those in the self-paced condition.

A total of eight counterbalanced versions were used. Across participants, each word pair was presented equally often in each condition (i.e., self-paced vs. fixed pace), each of the fixed-pace presentation rates, and each of the four study blocks.

Results and Discussion

Recall performance. Figure 1 shows the mean proportion of correct cued recall in Experiment 1. The results show that, overall, self-paced study resulted in higher performance than did fixed-pace study. In all but one of the fixed-pace conditions, participants

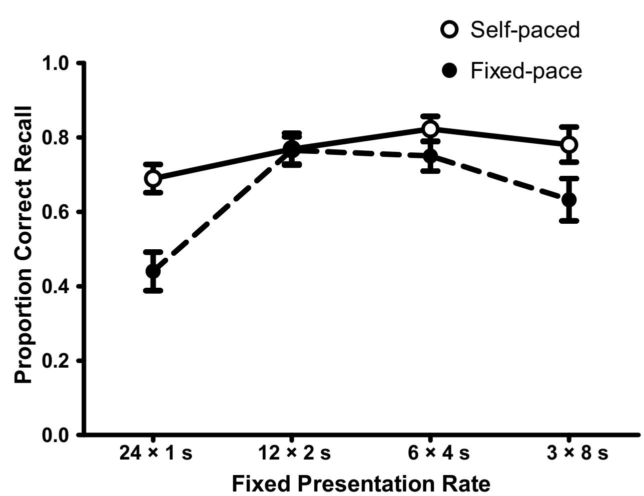

Figure 1. Proportion correct cued recall in Experiment 1 as a function of study condition (self-paced vs. fixed pace) and fixed presentation rate group. Error bars represent standard errors of the means.

recalled more words when they could determine the presentation durations themselves than when the presentation rate was imposed by the experimenter. These observations were supported by a 2 × 4 mixed analysis of variance (ANOVA) with study condition (self-paced vs. fixed pace) as a within-subject factor and presentation rate (24 × 1 s, 12 × 2 s, 6 × 4 s or 3 × 8 s) as a between-subjects factor.[1] The ANOVA showed a main effect of study condition, $F(1, 124) = 45.06$, $p < .001$, $\eta_p^2 = .27$, indicating that overall, more words were recalled in the self-paced study condition than in the fixed-pace study condition. There also was a significant main effect of presentation rate, $F(3, 124) = 6.14$, $p < .001$, $\eta_p^2 = .13$. Importantly, however, these main effects were qualified by a significant Study Condition × Presentation Rate interaction, $F(3, 124) = 8.92$, $p < .001$, $\eta_p^2 = .18$, indicating that the difference between self-paced and fixed-pace study was not the same for each presentation rate. Follow-up analysis revealed that recall performance was unaffected by presentation rate for the self-paced condition, $F(3, 124) = 1.85$, $p = .14$. However, in the fixed-pace condition, there was a significant effect of presentation rate, $F(3, 124) = 10.15$, $p < .001$, $\eta_p^2 = .20$. This was to be expected because presentation rate was manipulated for the fixed-pace condition but not for the self-paced condition. Note that the inverted U-shape relation between presentation rate and recall performance in the fixed-pace condition observed in Figure 1 is in line with earlier research on the effect of presentation rate on recall (e.g., de Jonge et al., 2012).

In subsequent analyses, we compared test performance in the self-paced condition to that in the fixed-pace condition for each of the presentation rates separately. For participants in the 24 × 1 s condition, performance in the self-paced condition was better than that in the fixed-pace condition, $t(31) = 6.12$, $p < .001$, $d = 1.14$. For participants in the 12 × 2 s condition, performance in the self-paced condition did not differ from that in the fixed-pace condition, $t(31) < 1$. For participants in the 6 × 4 s condition, performance in the self-paced condition was better than that in the fixed-pace condition, $t(31) = 2.21$, $p < .05$, $d = 0.40$. Finally, for participants in the 3 × 8 s condition, performance in the self-paced condition was better than that in the fixed-pace condition, $t(31) = 4.28$, $p < .001$, $d = 0.78$. Thus, for all but the 12 × 2 s condition, participants performed better in the self-paced condition than in the fixed-pace condition.

Self-paced study. In order to gain insight into how people had distributed study time during self-paced study and how this may have affected their learning outcomes, we took a closer look at study behavior during the self-paced study blocks. Figure 2 shows the average self-paced study time per item as a function of study cycle for the first 10 cycles. As is clear from the figure, the average study time per item decreased across cycles. Study time per item decreased rapidly at first and subsequently decreased more slowly. Because different participants completed a different number of study cycles, in our statistical analysis we compared only the first, second, and last full cycle of each participant. Data were collapsed across study blocks, and for participants with missing data, cases were excluded listwise. The data were analyzed using a repeated-measures ANOVA. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of study cycle. Degrees of freedom were corrected using Greenhouse-Geiser estimates of sphericity. There was a significant effect of study cycle, $F(1.55, 170.72) = 98.92$, $p < .001$, $\eta_p^2 = .47$. Follow-up analysis

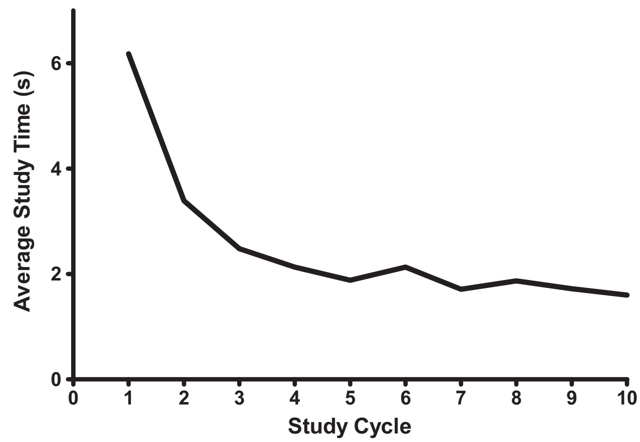

Figure 2. Self-paced study time per item in Experiment 1 as a function of study cycle averaged over participants.

showed that study time decreased from the first to the second cycle, $F(1, 110) = 55.17$, $p < .001$, $\eta_p^2 = .33$, as well as from the second to the last full cycle, $F(1, 110) = 81.55$, $p < .001$, $\eta_p^2 = .43$.

Allocation of self-paced study time. Figure 3 shows the average total study time for each item in the self-paced condition, plotted against normative item difficulty (defined as 1 minus the average proportion correct recall for the same item in the fixed-pace conditions; for a similar procedure, see Tullis & Benjamin, 2011). As can be seen in the figure, there was a strong positive correlation between self-paced study time allocated to the word pairs and normative item difficulty, $r(46) = .68$, $p < .001$. This finding is in line with the general finding that participants tend to allocate more self-paced study time to the more difficult items (Son & Metcalfe, 2000).

To sum up, in Experiment 1, we found that self-paced study resulted in relatively good performance compared to a variety of fixed-pace study conditions. Except for the 12 × 2 s condition, where recall performance was more or less equivalent, having control over pacing and study time allocation resulted in a significant recall advantage on a later test. One possible explanation for the results of the present experiment could be related to the allocation strategy employed by learners in the self-paced condition. In the present study, we replicated the general finding that learners tend to allocate more self-paced study time to the more difficult items (e.g., Dunlosky & Hertzog, 1998; Nelson & Leonesio, 1988). As already noted, in the Tullis and Benjamin (2011) study, the benefit of self-pacing was apparent only for those participants who were classified as discrepancy reducers. Likewise, in the present experiment, we explored the relationship between the degree of discrepancy reduction and subsequent recall performance in the self-paced condition. For each participant, we calculated the correlation across items between normative item difficulty and total study time allocated to each item. A more positive correlation indicates a higher degree of discrepancy re-

[1] An initial ANOVA also included condition order (self-paced study first vs. fixed-paced study first). The main effect of condition order and all interactions involving condition order were nonsignificant (all $ps > .30$). Condition order was therefore not included in the analyses reported here.

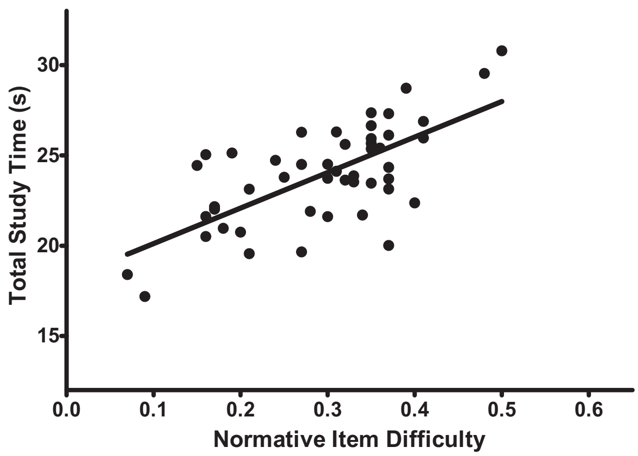

Figure 3. Average total study time for each item in the self-paced condition in Experiment 1 plotted against normative item difficulty (1 minus the average proportion correct recall in the fixed-pace conditions).

duction because more time was spent on items of higher normative difficulty. The data showed that 110 out of 128 participants (86%) in the present experiment could be classified as discrepancy reducers, in the sense that these participants spent more study time on the more difficult items. Analysis revealed that there was a significant correlation between the degree of discrepancy reduction and subsequent recall performance, $r(126) = .38$, $p < .001$. In other words, participants who displayed a strong tendency to allocate more study time to items of high normative difficulty recalled more items than did participants who displayed only a weak (or no) tendency.

Experiment 2

In Experiment 1 we found that recall performance following self-paced study was at least as good as and in most conditions even better than in fixed-pace study. In addition, we found a strong positive correlation between the amount of study time allocated to a word pair and its normative item difficulty (i.e., participants allocated more study time to difficult items than easy items). This suggests that one possible advantage of self-pacing study might be related to differential allocation of study time (discrepancy reduction) as a function of item difficulty. Experiment 2 was designed as a more direct test of this hypothesis. We compared an unrestricted self-paced condition, virtually identical to the one used in Experiment 1 (in which the total amount of available study time could be freely distributed over items), to a restricted self-paced condition where the total study time per item was equated. If discrepancy reduction (differential study time allocation) is a beneficial strategy, then one would expect that self-pacing without the opportunity to differentially allocate study time over items would result in lower recall performance compared to self-pacing without any restrictions.

Method

Participants. Forty-four undergraduate psychology students at the University of California, San Diego, participated for course credit. None of the participants had participated in Experiment 1.

Materials, design, and procedure. The materials were identical to those used in Experiment 1. We used a within-subject design with study condition (unrestricted vs. restricted) as an independent variable. For both unrestricted and restricted study conditions, the procedure was identical to that of the self-paced study condition of Experiment 1 except as noted.

In the restricted self-paced condition the total study time per item was fixed. Participants were told that each item was allocated 24 s of total study time and that as soon as the study time for an item had run out, the program would automatically terminate the presentation and continue to the next item. We anticipated that this procedure could result in a rather unpredictable study experience from the participants' perspective. That is, a key-press intended to make an item disappear that just happened to be "out-of-time" (i.e., an item for which the total time of 24 s had been used up and would consequently automatically disappear form the screen) might inadvertently end the presentation of a subsequent item. Hence, as a precaution, word pairs changed color (from blue to red) during the final 1,000 ms of total study time. Items for which the total amount of available study time had expired, did not reappear for further study.

In the unrestricted self-paced condition, participants were free to differentially allocate study time to the different items in the list. Participants simply studied the entire list of items continuously until the total study time (288 s) for the list had run out. To indicate that time had almost expired in the unrestricted condition, items were presented in red during the final 12 s of the total study time.

Immediately following each of the self-paced conditions (every two blocks), participants first received a 5-min distractor task that consisted of solving multiplication problems and then took a cued-recall test. Four counterbalanced versions were created in the same general manner as in Experiment 1.

Results and Discussion

Recall performance. Proportion correct recall was .71 (SD = .26) in the unrestricted self-paced condition versus .61 (SD = .24) in the restricted self-paced condition. A t test for paired samples showed that the difference between the two conditions was significant, $t(43) = 2.76$, $p < .01$, $d = 0.42$. Thus, withholding the possibility to differentially allocate total study time to the items in the lists during self-paced study resulted in lower recall performance.

Self-paced study. As in Experiment 1, we also looked at self-paced study behavior. Figure 4 shows the average study time per item as a function of study cycle and study condition for the first 10 cycles averaged over participants. The pattern of study times across cycles for the self-paced conditions was similar to the pattern observed in Experiment 1. In both conditions, study time per item rapidly decreased at first and then leveled off. Second, as is also clear from the figure, the average study times in the first study cycle were somewhat larger in the restricted condition compared to the unrestricted condition. Note that the dropping of items from the lists in the restricted condition resulted in increasingly shorter lists of items in this condition, while in the unrestricted condition lists remained intact throughout the study phase. Thus, a direct comparison of the study times in the two self-paced study conditions is problematic. For practical considerations, we compared the study times only in the first study cycle. A paired-samples *t* test confirmed that, in the first cycle, study times per item were longer in the restricted than in the unrestricted condition, $t(43) = 3.31$, $p < .01$, $d = 3.31$.[2]

As in Experiment 1, we analyzed the decrease in study times in the unrestricted condition during the first, second, and last full cycle of each participant. Data were collapsed across study blocks and for participants with missing data, cases were excluded listwise. The data were analyzed using a repeated-measures ANOVA. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of study cycle. Degrees of freedom were corrected using Greenhouse-Geiser estimates of sphericity. There was a significant effect of study cycle, $F(1.44, 46.12) = 20.88$, $p < .001$, $\eta_p^2 = .40$. Follow-up analysis showed that study time decreased from the first to the second cycle, $F(1, 32) = 16.07$, $p < .001$, $\eta_p^2 = .33$, as well as from the second to the last full cycle, $F(1, 32) = 12.42$, $p < .005$, $\eta_p^2 = .28$. For the restricted condition, analysis of the study times across cycles was limited to the first and second cycle. We did not look at the last cycle, because the durations of the last presentations for items in the restricted self-paced condition were not under the participants' control. The data were analyzed using a paired samples *t* test. As in the unrestricted condition, there was a significant decrease in study times from the first to the second study cycle, $t(39) = 6.32$, $p < .001$, $d = 1.0$.

Allocation of self-paced study time. Figure 5 shows the average total study time for each item in the unrestricted condition, plotted against normative item difficulty (i.e., 1 minus the average proportion correct recall for that item in the fixed-pace conditions of Experiment 1). Again, we found a positive correlation between self-paced study time allocated to word pairs and normative item difficulty, $r(46) = .56$, $p < .001$, indicating that participants differentially allocated total study time to items as a function of normative item difficulty in the unrestricted self-paced condition.

As in Experiment 1, we also evaluated the relationship between the degree of discrepancy reduction and subsequent recall performance. We found that 36 out of 44 participants (i.e., 82%) spent more study time on the more difficult items. Also, there was a correlation between the degree of discrepancy reduction and subsequent recall performance, $r(42) = .27$, $p < .05$ (one-tailed).

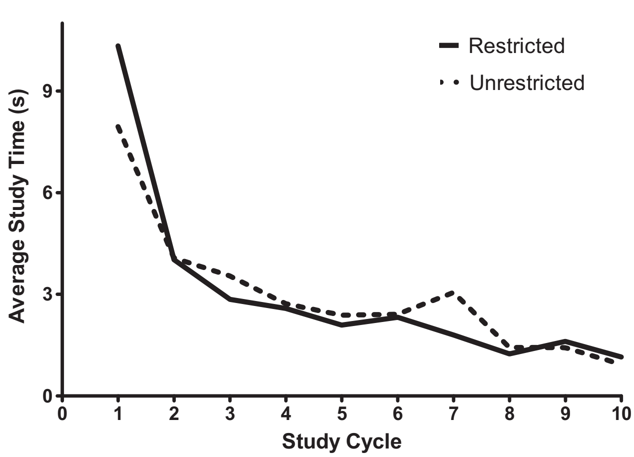

Figure 4. Self-paced study time per item in Experiment 2 as a function of study cycle and study condition averaged over participants.

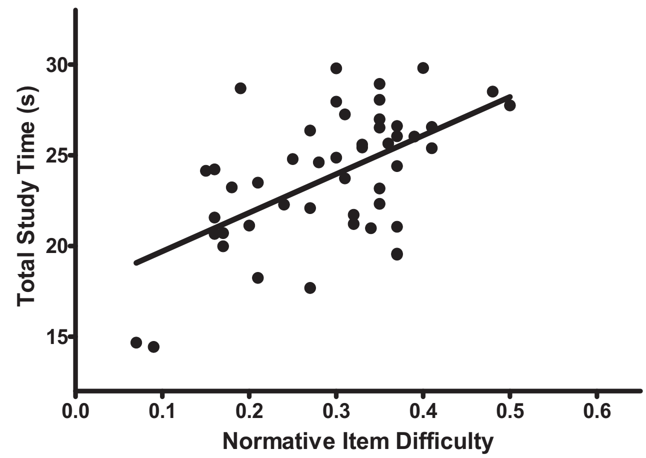

Figure 5. Average total study time for each item in the unrestricted self-paced condition of Experiment 2, plotted against normative item difficulty (1 minus the average proportion correct recall in the fixed-pace conditions in Experiment 1).

Thus, a larger degree of discrepancy reduction tended to be associated with better recall performance in the unrestricted self-paced condition.

General Discussion

In the present study we investigated the effectiveness of self-paced study during multitrial learning. In Experiment 1 we found that self-paced study resulted in higher performance than occurred in fixed-pace study. In all but one of the fixed-pace conditions, having control over pacing and study time allocation resulted in a significant recall advantage. Experiment 1 also showed that participants allocated more self-paced study time to normatively more difficult items. In Experiment 2, we found evidence suggesting that the opportunity to allocate more study time to the more difficult items on a list is one important factor determining later test performance. That is, test performance deteriorated when total study time per item was equated during self-paced study. Taken together, our results suggest that learners can be proficient when it comes to allocating self-paced study time during multitrial learning.

A particularly consistent result across the two experiments in the present study was the positive correlation between normative item difficulty and the amount of study time allocated to items. In both Experiments 1 and 2, we found that the majority of the participants (86% and 82%, respectively) allocated more self-paced study time to the more difficult items. The finding that learners tend to devote more study time to the more difficult items is in line with earlier research (see Son & Metcalfe, 2000, for a review). It has been

[2] Closer inspection of our data revealed that, in the restricted self-paced condition, eight of the participants used the total amount of available study time (24 s) for at least half of the items in the very first study cycle. Since this self-imposed strategy might have disadvantaged recall performance for these participants in the restricted self-paced condition, we conducted an additional exploratory analysis that excluded these participants. In this analysis, we still found a recall benefit for the unrestricted over the restricted self-paced condition, $t(35) = 2.30$, $p < .05$, $d = 0.38$.

suggested that, by differentially allocating study time, learners try to compensate for the experienced difficulty of items in a list (Dunlosky & Hertzog, 1998). Although at first glance this might seem like a logical strategy to improve learning, some studies on study time allocation have suggested that it could in fact be suboptimal. For instance, it has been argued that learners are often unable to successfully compensate for the difficulty of items in a list and that allocating more study time to difficult items often yields little or no gain in later recall performance (Mazzoni & Cornoldi, 1993; Mazzoni et al., 1990; Nelson & Leonesio, 1988). This finding has led researchers to suggest that the strategy of allocating more study time to items in a list during self-paced study might be *labor-in-vain* (Nelson & Leonesio, 1988). Taking this point even further, some researchers have even suggested that metacognitive self-monitoring itself might be labor-in-vain (Begg, Martin, & Needham, 1992). Clearly, these claims seem hard to reconcile with the results from the present study and those of other recent studies (e.g., Tullis & Benjamin, 2011), where learners saw a return on their investment rather than having labored in vain.

One possible explanation for these seemingly conflicting results could be related to the research designs employed in some of the earlier experiments on study time allocation during self-paced learning. First of all, as we already noted, most of the earlier studies investigated the effects of study time allocation during single-trial learning instead of looking at multitrial learning. Interestingly, some researchers have already suggested that the labor-in-vain effect might disappear during multitrial learning (Nelson & Leonesio, 1988). One limitation of the present study was that we did not include a single-trial self-paced study condition. Thus, it would be interesting for future research to directly compare study time allocation strategies during single- and multitrial learning.

Second, and more important, earlier research on the effect of study time allocation has mostly focused on correlational evidence for the relationship between normative item difficulty, study time allocation, and subsequent recall performance (i.e., the finding that participants allocate more study time to normatively difficult items, yet recall these items less often than normatively easy items to which less study time is allocated). Although these correlational data have provided important insights about the kind of strategies learners employ during self-paced study, they do not enable us to answer the question whether what people do is effective or not. For instance, self-paced learners might be allocating study time effectively and, at the same time, show a negative correlation between allocated study time and subsequent recall performance. The extra time invested may not fully compensate for differences in item difficulty but still improve overall memory performance. Moreover, if learners use a discrepancy reduction strategy and the resulting correlation between item difficulty and subsequent item recall is equal to or greater than zero, this still does not imply greater efficacy. The observed correlation could suggest that learners were able to effectively compensate for the difficulty of the materials (increased recall of difficult items). However, at the same time, it could reflect deteriorated recall of the easier items. Thus, an experimental manipulation is essential to ascertain a causal relationship between study time allocation and subsequent recall performance. The results from Experiment 2 of our study suggest that, to a certain extent, learners are able to allocate study time effectively during multitrial self-paced learning. Although the benefits of differential study time allocation might not become apparent in a correlational design focusing on normative item difficulty, our results clearly show that, on an idiosyncratic level, self-paced learners can effectively compensate for some of the experienced difficulty of items in a list. When learners are forced to indiscriminately use an equal amount of study time for all items, their recall performance will deteriorate.

In Experiment 1 of our study, we found that self-pacing resulted in superior recall performance compared to most of the fixed presentation rate conditions. The difference between the 12 × 2 s condition and the self-paced condition, however, was not significant. This finding seems hard to reconcile with the results from Experiment 2, where allowing participants to differentially allocate study time was advantageous compared to having a fixed amount of total study time per item. In the 12 × 2 s fixed presentation rate condition, participants also had a fixed amount of total study time per item. Thus, one could argue that it is somewhat surprising that recall performance in this condition did not suffer relative to the self-paced condition. Of course, we can only speculate as to why performance between these two conditions did not differ. However, there were some other differences between the self-paced and the fixed-pace conditions in Experiment 1, besides having the opportunity to differentially allocate study time, that deserve consideration in light of this apparent inconsistency.

First of all, confirming earlier observations (e.g., Kornell & Bjork, 2007), we found that self-pacing learners tended to speed up the presentation rate over study cycles as learning progressed. In both Experiments 1 and 2, participants started out with a relatively slow presentation rate the first time through the list, but they ended up with a relatively fast presentation rate the last time through the list. In the present study, we did not investigate whether speeding up is effective or not. Perhaps self-pacers can allocate study time effectively over different items in a list, but on a study cycle to study cycle level they might not necessarily be making optimal decisions. For instance, the tendency of some self-paced learners to spend a relatively large amount of total study time on items during the first pass through a list of items might not be optimal. Likewise, the relatively fast presentation rate during the last pass through the list might also not be very effective. In the present study we did not investigate the efficacy of speeding up during learning. This issue should be addressed in future research.

One possible disadvantage of self-paced study over fixed-pace study is the fact that self-pacers, in addition to studying the items in a list, also have to decide during each trial when it is time to terminate an ongoing presentation and move on to the next item in a list. It is a well-established finding in the dual-task literature that performing two concurrent activities at the same time can cause interference in even relatively simple tasks (see Pashler, 1994, for a review). Likewise, the metacognitive monitoring and decision-making processes involved in a self-paced learning task might also interfere with the learning process. In a similar vein, some researchers have argued that monitoring during self-regulated learning can be regarded as a secondary task that may, under some circumstances, hamper performance on a primary task (e.g., Van Gog, Kester, & Paas, 2011).

To sum up, there are many aspects of self-paced study that deserve consideration, and future research is essential to disentangle the exact costs and benefits of self-paced studying. In the present study, we focused on one important aspect (i.e., study time allocation), and we found that self-pacers allocated more total study time to the more difficult items. This is in line with the idea that learners try to compensate for the difficulty of the materials by differentially allocating study time (Dunlosky & Hertzog, 1998). Although some have suggested that differential study time allocation can be considered labor-in-vain (e.g., Nelson & Leonesio, 1988), we found that overall recall performance was actually relatively good when participants were allowed to differentially allocate study time. In Experiment 1, we found that participants' recall performance following self-paced study was at least as good, and in most cases better than, studying with a fixed experimenter-imposed pace. Critically, in Experiment 2 of the present study, we found that recall performance following self-paced study was better when participants were allowed to freely distribute study time over items in a list compared to a self-paced condition where they were forced to spend an equal amount of total study time for all items in the list. To conclude, the results from the present study seem to rehabilitate the self-paced learner concerning the allocation of study time policy (discrepancy reduction) employed during multitrial learning. Of course, we would not want to suggest that learners are able to fully compensate for the difficulty of to-be-learned materials. However, to a certain extent, learners seem well able to discriminate between items of differential difficulty, and they can allocate study time accordingly in a way to be effective.

References

Begg, I. M., Martin, L. A., & Needham, D. R. (1992). Memory monitoring: How useful is self-knowledge about memory? *European Journal of Cognitive Psychology, 4,* 195–218. doi:10.1080/09541449208406182

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

Brysbaert, M., & New, B. (2009). Moving beyond Kučera and Francis: A critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41,* 977–990. doi:10.3758/BRM.41.4.977

de Jonge, M., Tabbers, H. K., Pecher, D., & Zeelenberg, R. (2012). The effect of study time distribution on learning and retention: A Goldilocks principle for presentation rate. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 405–412. doi:10.1037/a0025897

Dunlosky, J., & Hertzog, C. (1998). Training programs to improve learning in later adulthood: Helping older adults educate themselves. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 249–275). Mahwah, NJ: Erlbaum.

Jönsson, F. U., Hedner, M., & Olsson, M. J. (2012). The testing effect as a function of explicit testing instructions and judgments of learning. *Experimental Psychology, 59,* 251–257. doi:10.1027/1618-3169/a000150

Kimball, D. R., & Metcalfe, J. (2003). Delaying judgments of learning affects memory, not metamemory. *Memory & Cognition, 31,* 918–929. doi:10.3758/BF03196445

Koriat, A., Ma'ayan, H., & Nussinson, R. (2006). The intricate relationships between monitoring and control in metacognition: Lessons for the cause-and-effect relation between subjective experience and behavior. *Journal of Experimental Psychology: General, 135,* 36–69. doi:10.1037/0096-3445.135.1.36

Kornell, N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin & Review, 14,* 219–224. doi:10.3758/BF03194055

Kornell, N., & Bjork, R. A. (2009). A stability bias in human memory: Overestimating remembering and underestimating learning. *Journal of Experimental Psychology: General, 138,* 449–468. doi:10.1037/a0017350

Mazzoni, G., & Cornoldi, C. (1993). Strategies in study time allocation: Why is study time sometimes not effective? *Journal of Experimental Psychology: General, 122,* 47–60. doi:10.1037/0096-3445.122.1.47

Mazzoni, G., Cornoldi, C., & Marchitelli, G. (1990). Do memorability ratings affect study-time allocation? *Memory & Cognition, 18,* 196–204. doi:10.3758/BF03197095

Metcalfe, J., & Kornell, N. (2003). The dynamics of learning and allocation of study time to a region of proximal learning. *Journal of Experimental Psychology: General, 132,* 530–542. doi:10.1037/0096-3445.132.4.530

Metcalfe, J., & Kornell, N. (2005). A region of proximal learning model of study time allocation. *Journal of Memory and Language, 52,* 463–477. doi:10.1016/j.jml.2004.12.001

Naveh-Benjamin, M., & Kilb, A. (2012). How the measurement of memory processes can affect memory performance: The case of remember/know judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 194–203. doi:10.1037/a0025256

Nelson, T. O., & Leonesio, R. J. (1988). Allocation of self-paced study time and the "labor-in-vain effect." *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 676–686. doi:10.1037/0278-7393.14.4.676

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116,* 220–244. doi:10.1037/0033-2909.116.2.220

Roediger, H. L., III, & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science, 1,* 181–210. doi:10.1111/j.1745-6916.2006.00012.x

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh, PA: Psychology Software Tools.

Son, L. K., & Metcalfe, J. (2000). Metacognitive and control strategies in study-time allocation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 204–221. doi:10.1037/0278-7393.26.1.204

Spellman, B. A., & Bjork, R. A. (1992). When predictions create reality: Judgments of learning may alter what they are intended to assess. *Psychological Science, 3,* 315–316. doi:10.1111/j.1467-9280.1992.tb00680.x

Tullis, J. G., & Benjamin, A. S. (2011). On the effectiveness of self-paced learning. *Journal of Memory and Language, 64,* 109–118. doi:10.1016/j.jml.2010.11.002

Van Gog, T., Kester, L., & Paas, F. (2011). Effects of concurrent monitoring on cognitive load and performance as a function of task complexity. *Applied Cognitive Psychology, 25,* 584–587. doi:10.1002/acp.1726

Zeelenberg, R., de Jonge, M., Tabbers, H. K., & Pecher, D. (in press). The effect of presentation rate on foreign language vocabulary learning. *Quarterly Journal of Experimental Psychology*.

Received January 10, 2014
Revision received May 27, 2014
Accepted June 6, 2014 ■