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From the lab to the dorm room: metacognitive awareness and use of spaced study

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Abstract Laboratory studies have demonstrated the long-term memory benefits of studying material in multiple distributed sessions as opposed to one massed session, given an identical amount of overall study time (i.e., the *spacing effect*). The current study goes beyond the laboratory to investigate whether undergraduates know about the advantage of spaced study, to what extent they use it in their own studying, and what factors might influence its utilization. Results from a web-based survey indicated that participants ($n = 285$) were aware of the benefits of spaced study and would use a higher level of spacing under ideal compared to realistic circumstances. However, self-reported use of spacing was intermediate, similar to massing and several other study strategies, and ranked well below commonly used strategies such as rereading notes. Several factors were endorsed as important in the decision to distribute study time, including the perceived difficulty of an upcoming exam, the amount of material to learn, how heavily an exam is weighed in the course grade, and the value of the material. Further, level of metacognitive self-regulation and use of elaboration strategies were associated with higher rates of spaced study. Additional research is needed to examine student study habits in a naturalistic setting, and to explore effective ways to encourage behavior change through motivational and teaching techniques.

Keywords Metacognition · Spacing effect · Distributed study · Study strategies

Numerous laboratory studies have demonstrated that given a set amount of time, the distribution of learning over multiple sessions is superior to the massing of learning in a single session for the long-term retention of information (e.g., Cepeda et al. 2006; Kornell 2009; Kornell and Bjork 2008). This is known as the *spacing effect*, which has a long

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history extending back to Ebbinghaus' discovery of it in his classic memory studies (Ebbinghaus 1885). Conceptual explanations for the spacing effect include increased encoding and contextual variability that enhance the effectiveness of retrieval cues (Glenberg 1979), and increased between-session forgetting that leads to a need for more effort in later sessions to learn or re-learn the material (e.g., Cuddy and Jacoby 1982; Krug et al. 1990).

Prior research has shown benefits of spacing for little known facts (Cepeda et al. 2006), word lists (e.g., Balch 2006), inductive learning of artistic styles (Kornell and Bjork 2008), and more complex types of information such as mathematical knowledge (Rohrer and Taylor 2006), and other educationally-relevant material (e.g., Dempster 1988). Indeed, the spacing effect is one of the most robust psychological phenomena. More recently, it has been investigated through a metacognitive lens, and also in educational settings with a focus on students' retention of course material. Relevant to this applied focus, a recent meta-analysis suggested the spacing advantage is especially large over longer retention intervals (i.e., a week or more) (Cepeda et al. 2006), a timeline that is meaningful for learning and memory in undergraduate courses.

Metacognition and the spacing effect

Metacognition can be defined as the ability to know, monitor, and regulate what one knows (e.g., Halpern 1998). It is associated with the broader literature on self-regulated learning, or self-regulated study, the goal of which is to effectively and strategically adapt to different learning situations (Wolters 2003). Prior research with undergraduate students has demonstrated moderate positive correlations between metacognitive ability and cognitive strategy use (e.g., Sperling et al. 2004) suggesting that individuals who are better at monitoring and adapting their strategies tend to utilize more deeper processing methods of learning.

With regard to spaced study, recent research results have suggested a lack of metacognitive awareness. For example, participants experiencing the benefits of spacing incorrectly judge the effectiveness of their learning and, in a display of erroneous metacognition, rate massing as more useful (Kornell and Bjork 2008; Kornell 2009). Kornell and Bjork (2008) presented paintings to participants by 12 different artists; depending on the condition, the paintings were presented in either massed or spaced (interleaved) fashion, and participants were later tested on inductive learning of the artistic styles. Results from two experiments showed that, in support of the spacing effect, 85 % of participants did as well or better in the spaced compared to the massed condition; however, 83 % of participants rated the massed condition as being equally as or more effective than the spaced condition. A plausible theoretical explanation relevant to these results is that newly learned knowledge that seems fluent and easily accessible during a single (i.e., massed) session does not necessarily lead to successful retrieval at longer intervals; this has been conceptualized as one type of *metacognitive illusion* (e.g., Kornell and Bjork 2008; Karpicke et al. 2009).

However, even when participants do not directly experience the massed and spaced conditions, and as such have no opportunity to be fooled by an illusion of fluency from massing, they are still unable to predict the benefit of spacing as it was implemented in the Kornell and Bjork (2008) study. McCabe (2011) found extremely low metacognitive awareness of the spacing (interleaving) advantage when participants simply read and made predictions about learning outcomes from the conditions described in Kornell and Bjork.

These findings taken together illustrate a metacognitive disconnect between what is actually effective (at least in laboratory studies) and what is perceived by participants to be best for learning.

Interestingly, laboratory studies that have given participants the option to either distribute or mass their learning have demonstrated that participants will choose to space material more than if it were left to chance (Son and Kornell 2009), and more than they choose to mass it (Pyc and Dunlosky 2010). Therefore, even if people believe that massing is better, some research suggests that in real-time behavior they will still practice spaced study. These inconsistencies in what people experience, believe, and actually do highlight the complex metacognitive picture involved in understanding the spacing effect.

Further, metacognition may play a role in determining when and under what conditions students choose to space or mass their study. One critical factor in this decision may be the ease or difficulty of the to-be-learned information. Studies investigating this factor have found discrepant results, possibly due to differences in paradigms. Son (2004) asked participants to make metacognitive judgments of learning about word-pairs that were viewed for 1 s, and then decide how (and whether) to study them in the future. Results showed that participants spaced more of the easy items and massed the difficult ones. In contrast, a study by Benjamin and Bird (2006), in which the time frame for initial encoding was longer (5 s) and in which participants were required to space half of the items and mass the other half, found that easier items were massed and difficult items were spaced. Pyc and Dunlosky (2010) attempted to clarify this discrepancy by suggesting that non-metamemory causes, such as difficulty in perceiving the material in the Son (2004) study, could at least partly explain why participants allocated their study times differently in the two paradigms (also see Toppino et al. 2009). Thus, in typical circumstances, with longer presentation times, spacing may be utilized more for difficult material (but see Son and Kornell 2009, for evidence suggesting no relationship between item difficulty and spacing use). Aside from the difficulty variable, little research has investigated other factors that students may consider in their decision to space or mass when they are in control of their study time.

Survey research on study behaviors

As related to education, the temporal spacing (or distribution) of learning sessions is one of several study techniques classified in the category of *desirable difficulties* (Bjork 1994), which includes strategies that aid long-term retention but that initially may slow learning and cause errors. Thus, *desirably difficult* learning strategies require a significant amount of effort, but are advantageous in the long run. The challenge facing educators is to support students' implementation of such effortful strategies for learning, based on the accumulating evidence that they enhance memory for course material. Specific to the spacing effect, Dempster (1988) encouraged further application of research on distributed study to educational contexts. An important initial step, however, is to understand student behaviors and beliefs about how they study.

Although there is a large amount of laboratory research on the spacing effect, a more ecologically valid understanding can be gained only by investigating what students are actually doing when they study, and the extent to which they know about and use this type of desirable difficulty. Prior survey research on the most commonly reported real-world study behaviors has found that students prefer to reread their notes and textbook, rewrite their notes, and use flashcards when preparing for exams (Karpicke et al. 2009; Van Etten et al. 1997). Laboratory research has shown, however, that behaviors such as rereading are not as effective as they seem for long-term memory (Callender and McDaniel 2009), especially compared to such strategies as spacing (e.g., Rohrer and Pashler 2007) and also testing (e.g., Roediger and Karpicke 2006). With regard to the latter, a recent survey study by Karpicke et al. (2009) showed that undergraduates are overall unaware of the memorial benefits of the desirable difficulty of practicing retrieval (i.e., the *testing effect*; also see Karpicke 2009).

To our knowledge, a comparable survey study has not been conducted with regard to the spacing effect. One qualitative interview-based study examining students' test preparation behaviors found that students know that spreading out their studying is better than cramming, but do not always put this knowledge into practice (Van Etten et al. 1997). Factors involved in the decision to distribute or mass study sessions were not investigated. Given the lack of research on undergraduates' use and knowledge of the benefits of spaced study, the current study examined these issues using survey methodology.

The current study

The main goal of the current study was to move beyond the laboratory and explore undergraduates' knowledge and reported use of spacing when they study on their own time. As discussed above, laboratory research on spacing has shown its advantage over massing but has also demonstrated low metacognitive awareness of the spacing benefit. Further in-depth investigation of this topic is important in order to understand students' behaviors and beliefs with regard to effective ways to study, as well as to contribute to the application of cognition research to real-world issues in higher education.

Our research examined four central questions: (1) Do students know about the spacing effect? (2) To what extent do they use spaced study while studying on their own time? (3) What critical factors contribute to the decision to space or mass study? (4) Are there individual differences in metacognitive self-regulation and/or use of elaboration strategies that are correlated with knowledge of the spacing effect and use of spaced study?

To address the first question, students reported their beliefs about what research has shown regarding the advantage of spaced versus massed study. We did not have a strong prediction about whether students would report metacognitive awareness of the spacing effect. To the extent that the advantage of spacing is a relatively intuitive or well-known learning strategy, as suggested by Van Etten et al. (1997), we may find strong endorsement of spacing. On the other hand, to the extent that our findings might parallel the survey results of another desirable difficulty (i.e., testing) described above (Karpicke et al. 2009), awareness of the memory benefits of spacing may be quite low. This latter prediction would also be consistent with the metacognitive findings of Kornell and Bjork (2008). However, it is important to note that in the current study, as in McCabe (2011), participants did not directly experience the learning conditions, and as such could not base their responses on real-time mnemonic cues that may lead to metacognitive illusions associated with massing (e.g., Kornell and Bjork 2008; Kornell 2009). Our participants, instead, were forced to rely on the type of *extrinsic cues* discussed by Koriat (1997) in his cue-utilization framework for metacognitive judgments; specifically, judgments in the current study were presumably based on participants' assessment of learning conditions presented in the survey questions, in the context of their own theories of learning.

In an attempt to elicit further information about students' knowledge of spacing, we also inquired about how they would distribute their study time over the course of several days leading up to a test, in both ideal and realistic conditions. Here, we predicted higher levels of spacing in ideal compared to realistic circumstances, based on the idea that students may end up cramming for a test even if they know it is not as effective in the long-term (Van Etten et al. 1997).

To address the second question, and to situate the study behaviors of spacing and massing in the context of other common learning strategies, the survey included rating scales for the frequency of use of a variety of study behaviors.

Next, the survey included items relevant to the third question, examining potential factors in the decision to space or mass (e.g., difficulty level of the upcoming test, level of interest in the material, type of upcoming test, and academic commitments). Other than examination of the difficulty factor (e.g., Son 2004; Benjamin and Bird 2006), this is a relatively unexplored area of research.

Finally, we examined the fourth question by including independently-validated scales of *metacognitive self-regulation* (MSR) and *elaboration* (Pintrich et al. 1991). MSR measures components of metacognition, and, by extension, self-regulated learning, by tapping the extent to which students monitor, and take strategic action to improve, their own learning. Higher scores on the MSR scale reflect the ability to monitor one's memory and be able to adjust strategies if necessary. The elaboration scale was included to provide a measure of the extent to which students use more effortful study strategies (i.e., desirable difficulties). Higher scores on this scale generally reflect more integration and connection of information to prior knowledge. We hypothesized that students who score higher on the MSR and elaboration scales would report more use of the study strategies listed in the survey, and would specifically report more knowledge and more frequent use of spaced study.

Method

Participants

Participants were 285 undergraduates recruited through web postings on various websites, social networking sources, and the listserv for *APA Division 2: Teaching of Psychology*. Participants had the option of entering their email addresses to be placed into a drawing for a gift card at the completion of the survey.

A variety of undergraduate institutions were represented, including four-year universities (57.3 %), four-year colleges (32.5 %), and community colleges (10.2 %). The average age of participants was 23.00 years old ($SD = 6.84$; Median = 21; Mode = 20; Range = 18–59). Although the mean age is higher than the 'typical' college age range, the majority (73 %) were between 18 and 22 years old. Participants had completed an average of 3.57 years of college ($SD = 1.12$) with a mean GPA of 3.38 ($SD = 0.47$). The participants were predominantly female (64.2 %) and the majority were non-psychology majors (71.2 %).

Materials

Researchers designed a web-based survey that was identical for all participants. In addition to spacing-related and metacognition items described more fully below, there were also basic demographic questions (i.e., age, type of institution, major, number of years of college completed, and sex). The survey consisted of 59 items, and took approximately 10–15 min to complete.

The items of central interest to the study addressed knowledge of the benefit of spaced study, the frequency of using specific study strategies (including spacing and massing), and factors impacting decisions to space or mass study sessions. Below we present several of the items most directly relevant to our research questions. See Appendix A for a complete list of the spacing-related survey items.

With regard to participants' knowledge of the spacing advantage, we asked:

Which of the following strategies do you think research has found to be better for long-term retention of material, assuming the total amount of study time is the same?

(a) Studying the material in multiple sessions of shorter duration
(b) Studying the material in one longer session
(c) Both strategies are equally effective

To examine their use of specific study strategies, we asked:

When studying for a test, how often do you use the following strategies? (Scale 1 = "Never," 3 = "Sometimes," 5 = "Always")

(a) Reread notes
(b) Reread textbook
(c) Study all material in one session
(d) Make and use flashcards
(e) Reference material to myself
(f) Do practice problems
(g) Make outlines or study guides
(h) Use mnemonic devices
(i) Distribute studying over multiple sessions
(j) Self-test (practice recalling material)

To examine the different critical factors associated with deciding to space or mass study, we asked a variety of questions:

(1) When studying for a DIFFICULT test, do you change the way you study compared to how you would study for a test of average difficulty?

    (a) Yes, I spread out my studying more in the days before the test.
    (b) Yes, I do all of my studying in only one session.
    (c) No, I study the same way for tests of all difficulty levels.

(2) When studying for an EASY test, do you change the way you study compared to how you would study for a test of average difficulty?

    (a) Yes, I spread out my studying more in the days before the test.
    (b) Yes, I do all of my studying in only one session.
    (c) No, I study the same way for tests of all difficulty levels.

(3) After reading each comparison, please indicate on the scale whether you are more or less likely to spread out your studying over a few sessions. (Scale: 1 = "Much more likely to spread out studying," 3 = "Both strategies are equally likely," 5 = "Much more likely to study in only one session")

    (a) Upcoming test is multiple-choice (rather than short-answer or essay).
    (b) There is a high value of material for future courses or career (rather than a low value).

(c) I have many other academic commitments the same week as the test (rather than few other academic commitments).
(d) I have social commitments the same week as the test (rather than no social commitments).
(e) I have high confidence in my ability to learn the material (rather than low confidence).
(f) The material is interesting to me (rather than the material is not interesting).
(g) The test is weighed heavily in determining the final course grade (rather than the test is not weighed heavily).
(h) There is a lot of material to learn (rather than a little material).

The survey also included items more generally measuring use of deeper processing learning strategies and participants' self-regulatory metacognitive abilities from the *Motivated Strategies for Learning Questionnaire* (MSLQ; Pintrich et al. 1991). The two scales used were *elaboration* and *metacognitive self-regulation* (MSR), which have an average alpha level of .775 (Pintrich et al. 1991). Eighteen items (six from elaboration and 12 from metacognitive self-regulation) were included regarding students' study strategies and their ability to regulate and monitor their cognitions (see Appendix B). Each item was rated using a 7-point Likert-type scale with 1 being *not at all true of me* and 7 being *very true of me*. After reverse scoring several items, the mean ratings for each subscale were computed.

Procedure

To participate in the survey, participants clicked on the link provided to them and viewed the consent form. In order to consent, participants needed to click a button to signify that they had agreed to participate and also that they were at least 18 years old and current undergraduate students. Upon completing these questions, participants proceeded to the survey items.

Results

Demographics and survey items

Certain demographic factors were found to be associated with spacing-related survey items. A one-way ANOVA showed differences in number of days used to study under realistic conditions based on type of institution, $F(3, 270) = 3.11$, $p = .027$; follow up independent-samples t tests using the Tukey correction revealed that community college students ($M = 2.96$, $SD = 1.07$) indicated more days of realistic study compared to both four-year college students ($M = 2.34$, $SD = 1.00$), $p = .017$, and four-year university students ($M = 2.41$, $SD = 1.07$), $p = .030$.

Further, a set of Pearson correlation analyses showed that age was significantly correlated with: (1) the number of days of study under realistic conditions, $r(269) = .255$, $p < .001$; and (2) scores on the MSR scale, $r(269) = .252$, $p < .001$. Not surprisingly, students' GPA was correlated with both the MSR, $r(245) = .233$, $p < .001$, and the elaboration, $r(245) = .263$, $p < .001$, scales. However, it was not correlated with other survey items.

Lastly, an exploratory Chi-square goodness of fit post hoc analysis indicated differences in the endorsement of the spacing effect by major. A greater portion of psychology majors (93.4 %) endorsed the benefits of spacing compared to non-psychology majors (81.8 %), $x^2(2) = 7.61$, $p = .022$; in addition, zero psychology majors endorsed the massing option, though 7.7 % of non-psychology majors did. Though tentative, these results at least suggest the possibility that students in the psychology major are more aware of the desirable difficulty of spacing as an effective study strategy.

Although there were a few connections between the survey variables of interest and demographic factors, the large majority of survey items were not related to institution type, age, level of education, sex, or GPA. This suggests that our results should be generalizable, within reasonable limits, across these demographic categories.

Knowledge of spacing effect

Descriptive statistics were computed for participants' awareness of the spacing effect (see Appendix A, Item 1). A frequency analysis showed that 84.9 % of participants endorsed the long-term benefits of distributing study sessions, 5.8 % believed that studying in only one session was superior, and 9.3 % believed that both strategies were equally effective in promoting long-term retention.

To measure knowledge of the spacing advantage in a different way, we asked participants to predict how they would space or mass their studying under ideal versus realistic conditions (see Appendix A, Items 2 and 3). If participants reported that they would distribute their studying over several days (at least in the ideal condition), then we would infer that they understand there is an advantage to spaced study.

Participants indicated how many hours (zero through five) they would study on each of 4 days leading up to a test; the total number of hours reported had to equal five. Raw number of hours studied was converted into a total number of days of study, such that a participant who would report studying all 5 h on 1 day would be using 1 total day of study, while a participant who would report studying 2 h on 1 day and three on another would be using 2 total days of study. This conversion resulted in a range of one (corresponding to complete massing) through four (corresponding to the most spacing) days of study.

A frequency analysis showed that, for ideal conditions, the category of "1 day" included the fewest participants (9.8 %), and this number steadily increased to a high for 4 days of study (46.7 %). Under realistic conditions, however, no such trend was found, and the percentages of participants in each category were more evenly distributed across number of days of study, with 2 days of study being the most common (35.1 %) (see Fig. 1). To describe the data in a different way, 9.8 % of participants would study in a completely massed fashion (i.e., 1 day) under ideal conditions, whereas twice as many (20.7 %) reported massed study under realistic conditions.

A paired-samples *t* test comparing mean ideal and realistic number of days of study showed a significantly higher mean for ideal ($M = 3.09$, $SD = 1.02$) compared to realistic conditions ($M = 2.47$, $SD = 1.07$), $t(284) = 11.45$, $p < .001$; thus, participants reported they would space their studying moreso under ideal compared to realistic conditions.

Self-reported study strategies

For all subsequent analyses, we used the Bonferroni correction for multiple tests, which resulted in a more conservative alpha level of .001. Only the results approaching or meeting this criterion for significance are reported below.

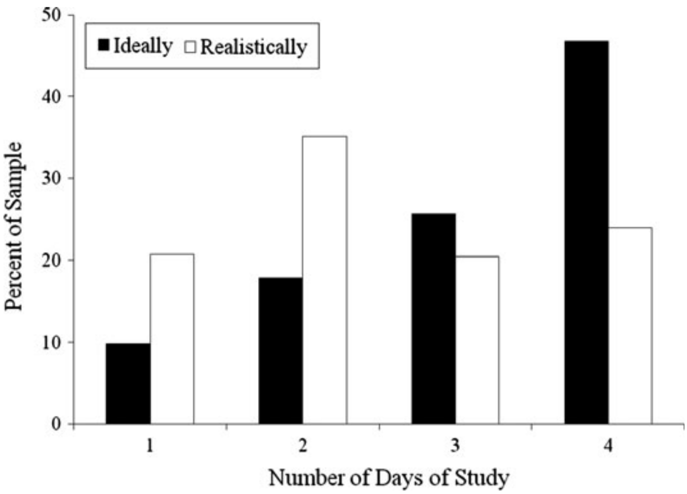

Fig. 1 Percentages of participants reporting various numbers of study days under ideal and realistic conditions. For reference, 1 day of study represents full massing, and higher numbers indicate different degrees of spacing

Table 1 Means and standard deviations for frequency of use of study strategies

Study strategy	*M*	*SD*
Reread notes[a, b]	4.14	1.01
Self-test (practice recalling material)[a, b]	3.53	1.27
Make outlines or study guides[a, b]	3.43	1.30
Reread textbook	3.34	1.11
Do practice problems[a]	3.25	1.16
Distribute studying over multiple sessions[a, b]	3.24	1.21
Reference material to self[a, b]	2.94	1.15
Study all material in only one session[a, b]	2.93	1.15
Use mnemonic devices[b]	2.68	1.27
Make and use flashcards	2.51	1.23

Note Ratings on a 5-point scale, 1 = Never; 3 = Sometimes; 5 = Always

[a] $p < .001$ Correlations with MSLQ *Metacognitive Self-Regulation* Scale

[b] $p < .001$ Correlations with MSLQ *Elaboration* Scale

All correlations were positive except for *Study all material in only one session*

Descriptive statistics were conducted on a list of 10 common study strategies. Participants rated, on a 5-point scale (1 = *never*; 3 = *sometimes*; 5 = *always*), how often each is utilized (see Appendix A, Item 4). Table 1 shows the list of study strategies ranked from highest to lowest by their reported average frequency of use. A visual inspection of the list shows that distributed study was the 6th most commonly used strategy ($M = 3.24$, $SD = 1.21$), whereas massed study was 8th ($M = 2.93$, $SD = 1.15$). A repeated-measures ANOVA including all the strategies was conducted to examine the possibility of

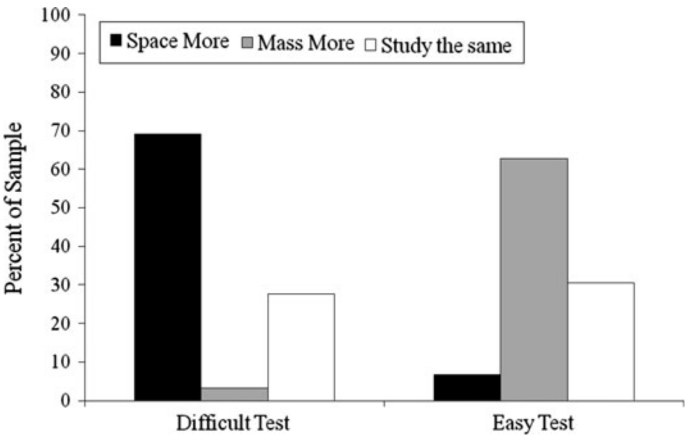

Fig. 2 Percentages of participants reporting one of three options for relatively easy versus relatively difficult tests: *Yes, I would spread out my studying more in the days before the test* (i.e., "Space More"); *Yes, I do all of my studying in only one session* (i.e., "Mass More"); *No, I study the same way for tests of all difficulty levels* (i.e., "Study the Same")

statistically ranking the various study strategies, $F(9, 2340) = 47.478$, $p < .001$.[1] Results from follow-up comparisons, however, did not present a clear enough picture to support meaningful strategy rankings.

Perhaps most critical to the current study, a paired-samples *t* test revealed that the difference between the distributed and massed study means approached, but did not reach, our conservative level of significance, $t(281) = -2.56$, $p = .011$.[2] In fact, the only strategy that was significantly different than all the others was rereading notes (all *p*s $< .001$). Amongst the other 9 strategies, as noted above, there was a great deal of overlap. For example, distributing study over multiple sessions was statistically similar to rereading one's textbook, studying all material in only one session, referencing material to self, doing practice problems, and making outlines or study guides; and studying all material in only one session was statistically similar to referencing material to self, doing practice problems, using mnemonic devices, and distributing study sessions (all *p*s $> .001$).

Factors in spacing versus massing

One potential factor in the choice to space or mass study is the level of difficulty of to-be-learned information, as indicated by past research (e.g., Son 2004; Benjamin and Bird 2006). We expanded on this by asking participants two questions about how they study for tests of different difficulty levels (see Appendix A, Items 5 and 6).

When preparing for a difficult test, 69.1 % of participants indicated they spread out their studying more compared to when studying for a test of average difficulty, whereas when preparing for an easy test only 6.7 % indicated they spread out their studying more. Thus,

[1] Given the nature of Likert-type survey data, Friedman's two-way ANOVA was conducted as a non-parametric equivalent to the repeated-measures ANOVA; this produced results leading to identical conclusions about the lack of meaningful rankings amongst the strategies, $x^2(9) = 363.586$, $p < .001$.

[2] A non-parametric Wilcoxon Signed-Ranked Test was also conducted. The results from this test were equivalent to those obtained using the paired-samples *t* test, $Z = -2.512$, $p = .012$.

Table 2 Means and standard deviations for ratings of critical factors in the decision to space or mass study

Factor	*M*	*SD*
There is a lot of material to learn (rather than a little material)	4.16**	1.13
The test is weighed heavily in determining the final course grade (rather than the test is not weighed heavily)	4.02**	1.23
There is a high value of material for future courses or career (rather than a low value)	3.89**	1.19
The material is interesting to me (rather than the material is not interesting)	3.41**	1.19
I have social commitments the same week as the test (rather than no social commitments)	2.90[a]	1.29
I have many other academic commitments the same week as the test (rather than few other academic commitments)	2.72**	1.44
Upcoming test is multiple-choice test (rather than short-answer or essay)	2.44**	1.20
I have high confidence in my ability to learn the material (rather than low confidence)	2.32**	1.23

Note Ratings on a 5-point scale, 1 = Much more likely to study in only one session; 3 = Both strategies equally likely; 5 = Much more likely to spread out studying

** $p < .001$. [a] $p = .178$, from one-sample t tests against the neutral "3" response

the pattern of spacing and massing choices was almost perfectly reversed for difficult versus easy tests (see Fig. 2).

Next, we used a 5-point Likert-type scale to examine other factors that could impact the decision to space or mass studying (see Appendix A, Item 7). Table 2 lists the factors in order of their influence on utilizing spaced study, with higher numbers indicating a higher likelihood of distributing study and lower numbers indicating a higher likelihood of studying in only one session. As "3" (corresponding to *"both strategies are equally likely"*) represented the middle, and this case neutral, value of the 5-point scale, we computed one-sample t tests for each mean compared to that middle value of "3." This allowed us to determine which (if any) of the factors were significantly different from "3", and therefore indicative of endorsement of a spacing or massing strategy. These tests showed that participants were more likely to space out their studying if there was a high future value of material, $t(274) = 12.47$, $p < .001$, if the material was interesting, $t(248) = 5.07$, $p < .001$, if the test was weighed heavily in determining the course grade, $t(249) = 13.14$, $p < .001$, and if there was a lot of material to learn, $t(247) = 16.18$, $p < .001$. Participants were more likely to mass their studying if the upcoming test was of multiple-choice format, $t(275) = -7.80$, $p < .001$, if they had many other academic commitments the same week as the test, $t(274) = -3.26$, $p = .001$, and if they had high confidence in their ability to learn the material, $t(249) = -8.75$, $p < .001$. Students were equally likely to space or mass their study if they had other social commitments the same week as the test, $t(275) = -1.35$, $p = .178$.

Correlations with *Metacognitive Self-Regulation and Elaboration* Scales

Bivariate Pearson correlations were computed between survey items and scores on the MSR and elaboration scales.

Using a 7-point scale, the mean for MSR was 4.51 ($SD = 0.90$), and the mean for elaboration was 5.16 ($SD = 1.06$). As expected, the two scales were themselves significantly correlated, $r(283) = .65$, $p < .001$.

In relation to the survey items targeting spacing and massing, MSR was positively correlated with frequency of using distributed study, $r(281) = .42$, $p < .001$, and negatively correlated with frequency of using only one massed study session, $r(282) = -.33$,

$p < .001$. Thus, as predicted, students high in MSR were more likely to space their study, and less likely to mass. MSR was also significantly correlated with ideal, $r(283) = .31$, $p < .001$, and realistic, $r(283) = .39$, $p < .001$, days of study prior to an upcoming test; therefore, students with higher metacognition scores tended to be the ones reporting spaced studying under both ideal and realistic circumstances.

Turning to the elaboration scale, scores were positively correlated with frequency of using distributed study, $r(281) = .26$, $p < .001$, and negatively correlated with frequency of using massed study, $r(282) = -.26$, $p < .001$. These results parallel those for correlations with MSR reported above, and further suggest that study behaviors involving making connections within the material and to prior knowledge are predictive of spaced study. Also similar to MSR results, elaboration was correlated with ideal, $r(283) = .24$, $p < .001$, and realistic, $r(283) = .21$, $p < .001$, number of study days prior to a test.[3]

Discussion

The goal of this study was to explore college students' awareness and implementation of spaced study when they prepare for tests. Researchers have repeatedly demonstrated the superiority of spacing over massing (e.g., Cepeda et al. 2006; Kornell 2009; Rohrer and Taylor 2006), and have put forth hypotheses about the cognitive mechanisms involved in the spacing advantage (e.g., increased encoding and contextual variability, Glenberg 1979; increased between-session forgetting, Cuddy and Jacoby 1982). Spacing is considered one of several *desirable difficulties* (Bjork 1994), which are learning strategies that are initially more effortful but result in enhanced long-term memory.

More directly relevant to the purpose of our study, prior laboratory research has examined metacognitive beliefs about spacing versus massing (e.g., Kornell and Bjork 2008; Kornell 2009). Our study adds to the literature by moving beyond the laboratory to focus on real-world study behaviors. Using survey methodology, we investigated metacognitive awareness regarding the mnemonic benefits of spacing, spacing-related behaviors in the context of other common study strategies, critical factors that may influence the use of spacing, and correlations with independent scales measuring metacognitive self-regulation (MSR) and use of elaboration strategies.

Results indicated that the large majority of participants were aware of the fact that laboratory research has endorsed the advantage of spacing over massing for long-term retention of material. These findings are inconsistent with those of Karpicke et al. (2009), who found that survey participants were overall not aware of the memory advantage of another *desirable difficulty* (i.e., testing, or retrieval practice). Although differences in question format (e.g., open-ended in Karpicke et al. versus forced-choice in the current study) may have influenced these discrepancies (e.g., Schwarz 1999), it is also possible that spaced study is a more intuitive and/or more widely taught strategy than testing. Future research should be conducted to tease apart these explanations. In the context of previous spacing effect research, our results also differ from prior findings of faulty metacognitive judgments concerning the superiority of massing over spacing. That is, several studies have shown a surprisingly large discrepancy between the objectively-assessed memory

[3] Non-parametric Spearman correlations were also run on the data leading to identical conclusions except in two cases. Correlations between the elaboration subscale and number of days used to study under ideal and real conditions were found to only approach our conservative level of significance, $r(283) = .191$, $p = .001$ and $r(283) = .178$, $p = .003$ respectively.

advantage of spacing over massing, compared to subjective perception that massing is superior to spacing (e.g., Kornell and Bjork 2008; Kornell 2009; McCabe 2011). Our results suggest that spacing is an obvious and well-known strategy to undergraduates, at least in the context of real-world academic situations.

Further evidence indicating awareness of the spacing advantage came from our survey items asking participants to distribute a consistent amount of study time over one to 4 days prior to a test. When comparing their choices to space versus mass study time under “ideal” versus “realistic” conditions, a clear pattern emerged: students would ideally distribute their study over more days, but do not tend to put this into practice realistically. Specifically, twice as many students indicated full massing (i.e., 1 day of study) under realistic compared to ideal conditions, and only half as many chose the largest amount of spacing (i.e., 4 days) when comparing realistic to ideal. These results taken together suggest that students may indeed realize that it is more effective to distribute than to mass their study, even if they do not act on this knowledge. The inconsistency between participants’ knowledge and utilization of spaced study may be related to the perceived increase in effort associated with implementing this study strategy. Therefore, the more immediate “difficult” nature of the strategy may be outweighing the longer-term “desirable” learning benefit.

Part of the discrepancy between our results and the metacognitive errors reported by Kornell and Bjork (2008) could be due to the fact that unlike prior laboratory studies, our participants did not actually experience spacing and massing conditions before making post hoc judgments of strategy effectiveness. In this way, they were not able to make judgments based on intrinsic mnemonic cues driven by, for example, fluency or ease of encoding. Because our participants were forced to judge the learning situation using extrinsic cues (Koriat 1997) (i.e., knowledge about the distribution schedule for learning), and further had to make judgments outside the context of a recently-experienced learning task, we argue that our data offer a cleaner look at spacing effect awareness, uncontaminated by real-time mnemonic cues that could lead to the illusion of competence associated with massing (e.g., Kornell and Bjork 2008). A related theoretical explanation is that judgments made in the current study should have been based more on analytic processes, such that they were influenced by participants’ theories of how memory operates (e.g., a belief that spacing is beneficial for memory), rather than on nonanalytic processes, which are driven by subjective experiences (e.g., interaction with a set of spaced and massed stimuli) (e.g., Matvey et al. 2001).

Overall, our data suggest higher metacognitive accuracy with regard to spaced study than what has been reported in the research literature thus far. Perhaps our choice to situate descriptions of this ‘desirable difficulty’ in a realistic educational context improved the depth (and therefore accuracy) of reflection regarding the relative advantages of spaced versus massed study.

To address the degree to which students choose to implement distributed study, we examined reported frequency of using spacing-related study behaviors in the context of other study strategies. We found only intermediate levels of use of both distributed study and massed study; perhaps more importantly, using our conservative alpha level, these strategies were statistically equivalent to each other, and to several other strategies on the list, all of which were ranked well below the most frequently used ones (e.g., rereading notes).[4] The lack of frequent utilization of distributed study resembles previously discussed

[4] An anonymous reviewer pointed out that several of the strategies (e.g., re-reading notes) could be performed using spacing or massing, which themselves are separate strategies listed in this survey item. This factor may have contributed to our difficulty in establishing meaningful rankings amongst the strategies.

survey findings on the testing effect (Karpicke et al. 2009). These desirable difficulties (Bjork 1994), which should result in increased long-term retention of material, are not being used often compared to other strategies (e.g., rereading notes) that may be both less effortful and less effective.

One of the more unique aspects of our study was the detailed investigation of various factors that may impact students' allocation of their study time. This issue is particularly important because we were able to show that most students know distributed study is better for long-term memory, but that under realistic conditions they are not spacing as much as they could. Having established this, the question becomes, *If students know that spacing their study sessions is better, why are they not doing more of it?* Our results indicate that participants were more likely to space their studying for material that held high value for future courses or careers and that was more interesting to them. This suggests that information more personally relevant may be more likely to be studied in a manner supportive of long-term retention. Other factors associated with spaced study included having a lot of material to review for a test, and knowing that an upcoming test is weighed heavily in determining the final grade for a course.

On the other hand, factors that led participants to report massing their studying more included a test being multiple-choice format (rather than short-answer or essay) and having high confidence in their ability to learn the material. Further, and not surprisingly, when a lot of other academic commitments occurred the same week as a test, students indicated (at a level approaching our conservative level of significance, $p = .001$) that they were more likely to mass their studying. This latter finding resembles that of Kornell and Bjork (2007) who, also using survey research, found that students were more likely to study whatever work is due soonest (59 % of students) rather than plan a study schedule in advance (11 % of students).

One critical factor we investigated more thoroughly was the difficulty level of an upcoming test. Given prior research on a similar difficulty factor (e.g., Son 2004; Benjamin and Bird 2006), we chose to investigate this topic in more depth by creating two survey questions to inquire about the choice to space or mass when studying for a relatively difficult versus a relatively easy test. We found that participants reported choosing to space their studying more when preparing for harder-than-average tests and mass their studying more for easier tests. Despite using a different methodology, our findings are consistent with those of Benjamin and Bird (2006) who found that participants were more likely to space difficult word pairs compared to easy ones.

One interpretation of our findings is that even given a high degree of metacognitive awareness of the long-term advantage of spacing over massing, students do not feel the need to study in ways that promote their future retention of course information. As such, they may be satisfied with their current massing-heavy study behaviors, assuming they are able to perform at acceptable levels on course assessments. It is important, therefore, to also examine motivational issues involved in the choice of study strategies, a topic beyond the scope of this research. Nonetheless, our results regarding critical factors could have implications for educators who want to encourage the long-term retention of the information they teach. For example, increasing the perceived interestingness, and showing the future value, of course material may motivate students to learn and study it in a more distributed, and therefore potentially more effective, manner. Also, our findings suggest that relying less on pure multiple-choice tests, and more on tests perceived to have a high difficulty level, may be an important step in encouraging distributed study.

Turning now to survey item correlations with the MSR and elaboration scales (Pintrich et al. 1991), we found consistent results suggesting that students who score high on MSR (i.e., the ability to self-assess and regulate study strategies) and elaboration (i.e., the use of deep-processing strategies for learning, such as connecting information to prior knowledge) were more likely to report using distributed study and, conversely, were less likely to report using massed study. Further, both scales were positively correlated with the number of days students would use to study under both ideal and realistic conditions. Clearly, there is a connection between aspects of general metacognitive ability tapped by the scales and the specific study choice to space learning sessions.

Though not the focus of this study, we noted in Table 1 those study strategies that were correlated with MSR and elaboration. Not surprisingly, and in further validation of the spacing-related correlations, one or both of these scales was positively correlated with the frequency of using all but three of the listed strategies, which is consistent with prior work demonstrating a relationship between metacognitive abilities and cognitive strategy utilization (e.g., Sperling et al. 2004). Particularly relevant were the correlations involving those strategies that would fall in the category of desirable difficulties (Bjork 1994), including self-testing, making outlines, and self-referencing. These correlations can be useful in terms of predicting students' use of effective strategies (including but not limited to spacing), as the MSR and/or elaboration scales can be easily and quickly administered to students at the start of a college course. This exercise could be followed by a self-assessment of results, and an instructor-led discussion of the benefits of the various strategies and behaviors described in the survey items (as suggested by Pintrich et al. 1991).

As with all survey-based research, there were limitations in the present study that could impact the generalizability of our findings. First, although we sought as diverse a sample as possible, we necessarily relied on a convenience sample based on personal and professional connections to our home and other institutions. In particular, our final sample had a mean age and education level that were higher than 'typical' undergraduates; as such, it is possible that we overestimated metacognitive knowledge by including more mature and advanced students. However, the lack of consistent correlations between age, education level, and spacing-related variables fails to support this argument. Similarly, aside from a few specific cases, there were no meaningful patterns of correlations between other demographic variables (e.g., institution type, sex, major) and spacing-related measures, further bolstering the generalizability of our results. Second, the nature of survey methodology is such that we were only able to analyze self-report data, which can have numerous biases (e.g., social desirability, memory inaccuracies). Thus, the data may not be accurately representative of undergraduates' behaviors.

Despite these limitations, the findings from this study support increased research efforts on metacognitive aspects of the spacing effect, particularly in the context of real-world academic behaviors. For example, future research should examine the frequency of use of study strategies that vary in required level of metacognitive demand. This would allow for more in-depth analysis of how various study techniques (including massing and spacing) are utilized in relation to the degree of metacognitive ability associated with them.[5] Also, more naturalistic research is warranted to evaluate students' real-time study behaviors with regard to their frequency of utilizing spacing versus massing.

Researchers should examine ways to encourage students to use distributed study, and other such desirable difficulties, through motivational and informational (i.e., teaching) strategies. Although students did signify that they were aware of the benefits of spacing, it was not reported as a frequently used study strategy or as being used significantly more

[5] We thank an anonymous reviewer for this suggestion.

frequently than massing. A related extension of the current work would be to examine not only the fact that students know spacing is better than massing, but more specifically the extent to which they understand the cognitive mechanisms and conceptual explanations involved in the spacing advantage. Perhaps a focus on this educational element could enhance students' metamemorial knowledge and contribute to the motivation to incorporate distributed study into their repertoire of strategies.

In sum, the current study extends prior laboratory work on metacognition and the spacing effect by showing that undergraduates may indeed know about the benefits of distributed study. Although they did not report using spacing more frequently than massing when they study, we were able to identify numerous factors that might contribute to the decision to space or mass study sessions. Investigation of this topic, in the context of other effective study strategies, can enhance our understanding of how to improve long-term memory for course material, an essential goal of higher education.

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Appendix A: spacing-related survey items, organized by heading in the results section

Knowledge of spacing effect

(1) Which of the following strategies do you think research has found to be better for long-term retention of material, assuming the total amount of study time is the same?

  (a) Studying the material in multiple sessions of shorter duration
  (b) Studying the material in one longer session
  (c) Both strategies are equally effective

(2) If you had a total of 5 h to study for an upcoming test on Friday, IDEALLY how would you spread out your studying (if it took 1 h to study all of the material)? Please write a whole number in one or more of the spaces below, corresponding to the days leading up to the test. The total number of hours should equal 5.

(3) From past experiences and REALISTICALLY speaking, when you have had 5 h to study for an upcoming test, how have you spread out your studying (if it took 1 h to study all of the material in one sitting)? Please write a whole number in one or more of the spaces below, corresponding to the days leading up to the test. The total number of hours should equal 5.

Self-reported study behaviors

(4) When studying for a test, how often do you use the following strategies? (Scale 1 = "Never," 3 = "Sometimes," 5 = "Always")

  (k) Reread notes
  (l) Reread textbook
  (m) Study all material in one session
  (n) Make and use flashcards
  (o) Reference material to myself
  (p) Do practice problems
  (q) Make outlines or study guides

(r) Use mnemonic devices
(s) Distribute studying over multiple sessions
(t) Self-test (practice recalling material)

Factors in spacing versus massing

(5) When studying for a DIFFICULT test, do you change the way you study compared to how you would study for a test of average difficulty?

(d) Yes, I spread out my studying more in the days before the test.
(e) Yes, I do all of my studying in only one session.
(f) No, I study the same way for tests of all difficulty levels.

(6) When studying for an EASY test, do you change the way you study compared to how you would study for a test of average difficulty?

(g) Yes, I spread out my studying more in the days before the test.
(h) Yes, I do all of my studying in only one session.
(i) No, I study the same way for tests of all difficulty levels.

(7) After reading each comparison, please indicate on the scale whether you are more or less likely to spread out your studying over a few sessions. (Scale: 1 = "Much more likely to spread out studying," 3 = "Both strategies are equally likely," 5 = "Much more likely to study in only one session")

(a) Upcoming test is multiple-choice (rather than short-answer or essay).
(b) There is a high value of material for future courses or career (rather than a low value).
(c) I have many other academic commitments the same week as the test (rather than few other academic commitments).
(d) I have social commitments the same week as the test (rather than no social commitments).
(e) I have high confidence in my ability to learn the material (rather than low confidence).
(f) The material is interesting to me (rather than the material is not interesting).
(g) The test is weighed heavily in determining the final course grade (rather than the test is not weighed heavily).
(h) There is a lot of material to learn (rather than a little material).

Appendix B: survey items from the Motivated Strategies for Learning Questionnaire (MSLQ), Metacognitive Self-Regulation and Elaboration Subscales (Pintrich et al. 1991)

Instructions

The following questions ask about your learning strategies and study skills for recent or current college classes. There are no right or wrong answers. Answer the questions about how you study in classes as accurately as possible. If you think the statement is very true of you, click the last button; if a statement is not true at all of you, click the first button. If the statement is more or less true of you, find the button in between that best describes you. (Scale: 1 = "Not at all true of me," 7 = "Very true of me")

Metacognitive self-regulation subscale items

(a) During class time I often miss important points because I'm thinking of other things.
(b) When reading material for courses, I make up questions to help focus my reading.
(c) When I become confused about something I'm reading, I go back and try to figure it out.
(d) If course readings are difficult to understand, I change the way I read the material.
(e) Before I study new course material thoroughly, I often skim it to see how it is organized.
(f) I ask myself questions to make sure I understand the material I have been studying.
(g) I try to change the way I study in order to fit course requirements and the instructor's teaching style.
(h) I often find that I have been reading but don't know what it was all about.
(i) I try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying.
(j) When studying I try to determine which concepts I don't understand well.
(k) When I study I set goals for myself in order to direct my activities in each study period.
(l) If I get confused taking notes in class, I make sure I sort it out afterwards.

Elaboration subscale items

(a) When I study for class, I pull together information from different sources, such as lectures, readings, and discussions.
(b) I try to relate ideas from one course to those in other courses whenever possible.
(c) When reading material, I try to relate it to what I already know.
(d) When I study I write brief summaries of the main ideas from the readings and my class notes.
(e) I try to understand material by making connections between readings and concepts from lectures.
(f) I try to apply ideas from course readings in other class activities such as lecture and discussion.

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