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Metacognitive Control and the Spacing Effect

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This study investigates whether the use of a spacing strategy absolutely improves final performance, even when the learner had chosen, metacognitively, to mass. After making judgments of learning, adult and child participants chose to mass or space their study of word pairs. However, 1/3 of their choices were dishonored. That is, they were forced to mass after having chosen to space and forced to space after having chosen to mass. Results showed that the *spacing effect* obtained for both adults and children when choices were honored. However, using a spacing strategy when it was in disagreement with the participant's own choice, or forced, did not enhance performance for the adults (Experiment 1). And although performance was enhanced for the children (beyond massing strategies), it was not as good as when the spacing decisions were self-chosen (Experiment 2). The data suggest that although spacing is an effective strategy for learning, it is not universal, particularly when the strategy is not chosen by the learner. In short, metacognitive control is often crucial and should be honored.

Keywords: metacognitive control, spacing effect, children's metacognition, spacing and massing

On the whole, *massing* has acquired a bad reputation. Synonymous with cramming, the practice has been described as suboptimal, reducing, and even harmful. A number of reviews and meta-analyses on existing data have showcased the drawbacks of massed study, particularly during long-term learning (for a review, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). Conversely, since being first described in 1885 by Ebbinghaus, *spacing,* or distributing study across time in short, interrupted sessions, has been shown to boost learning. Data and theory behind this *spacing effect* has been so overwhelming that it was at one point considered a law—*Neisser's law* (taken from Bjork, 1988, p. 399): "You can get a good deal from rehearsal, / If it just has the proper dispersal. / You would just be an ass, / To do it en masse, / Your remembering would turn out much worsal." The question addressed in this article is, Does using a spacing strategy absolutely improve learning, even if that strategy goes against one's metacognitive choice?

Spacing Imperfections

The spacing effect is one of the most well-documented cognitive phenomena in the literature (e.g., Bahrick, 1987; Bjork, 1979; Dempster, 1987; Glenberg, 1979). The effect has also been obtained in children (Cahill & Toppino, 1993; Rea & Modigliani, 1987; Toppino, 1991, 1993; Toppino & DiGeorge, 1984) and is well advocated by researchers and educators alike. Data supporting the spacing effect have also been backed by explanations for why spacing works. The *retrieval hypothesis* (Glover, 1989), which suggests that people take part in a more effortful retrieval process during spaced study than during massed study, has been proposed as one mechanism driving the effect. Effortful processing may strengthen or create retrieval routes to the correct representation of the target in memory (e.g., Bjork, 1975). Unfortunately, the extra effort that is necessary during spaced practice might also turn people away from spacing and toward massing strategies. Studies have, in fact, shown that during spaced study (more than during massed study), not only is acquisition slower but also confidence is lower (Bahrick et al., 1993; Zechmeister & Shaughnessy, 1980).

In addition to the potential unpopularity of spacing, there is also a documented set of circumstances where spacing is not always the better strategy. During one particular type of study using *expanding retrieval practice*, one first retrieves the to-be-remembered item at short lags—massing—and then with successive study trials waits longer before trying to retrieve the desired item from memory—spacing (e.g., Landauer & Bjork, 1978). In Landauer and Bjork's (1978) study, for instance, participants were presented with *massed*, *spaced*, and *expanding* cue–target pairs, interwoven into one long list. Each name was presented four times, the first time being a presentation trial and the final three being retrieval practice trials (i.e., cue only) without feedback. After the entire list had been presented, a cued-recall test was given. The results showed that final performance was better for spaced than for massed items—in line with the usual spacing effect—but better yet for the expanding items, where study consisted partly of massing. The authors theorized that spacing is a good strategy, but only if retrieval is successful (for similar theories, also see Bahrick, 1987; Melton, 1970; Rose, 1984; Underwood, 1961). In the expanding condition, items were spaced far enough apart that

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people benefited from effortful retrieval but not so far apart that retrieval was unlikely to be successful (i.e., during early learning).[1]

Other human and model data have supported the general notion of success in an expanding practice paradigm. For instance, more recently, Pavlik and Anderson (2005) have shown, using the adaptive control of thought–rational (ACT-R) model, that spacing is beneficial but that the effect is strengthened as more practice is accumulated. These findings suggest that interrupting study and using a spaced strategy would be best only when learning has reached some criterion level in the first place. However, when the item still feels novel or is situated in a fragile state, it would behoove the learner to mass study, allocating current and continuous time to help progress the item to a more secured position in memory. Indeed, recent findings have shown that people will choose to mass their study when encoding has not fully occurred (Toppino, Cohen, Davis, & Moors, 2009). This question of how people choose to schedule their study is next addressed.

Metacognitive Spacing

Metacognitive control can be defined as the process of using one's own judgments to guide behavior. For example, a number of studies have tested the relation between one's judgments and the amount of time one allocates to study (for a review, see Son & Kornell, 2008). In general, data have shown that people choose to allocate the most study time to relatively difficult items, so long as learning is not hopeless and enough time is available (Kornell & Metcalfe, 2006; Metcalfe & Kornell, 2005). The issue of metacognitive control of spacing has been investigated less thoroughly (Benjamin & Bird, 2006; Son, 2004). In one study (Son, 2004), people were asked to make metacognitive judgments for cue–target pairs. Then they had to decide whether they wanted to mass or space the item's subsequent study session. If they chose to mass, then the pair would be shown again immediately in succession; if they chose to space, then the pair would not be shown again until after the entire list had been presented. The results showed that when given the choice, adults followed the strategy that seemed effective. That is, they spent more time spacing than massing, and their metacognitions guided their decisions in accordance to the expanding practice schedule: They spaced items that were judged easy and massed items that were more difficult. However, these findings were contradicted in another study (Benjamin & Bird, 2006)—people chose to space the more difficult items and mass the easier items.

There were, though, two main differences between the two studies. In Son's (2004) study, people were given the option of not studying; that is, they were given a *done* button. Benjamin and Bird's (2006) methods did not have this option—all of the items had to be restudied, in either a massed or a spaced manner. In addition, in Son's study, any number of items could be massed or spaced. In other words, if an individual wanted to mass every single item, they could choose to do so. In Benjamin and Bird's study, half of the items had to be massed and half had to be spaced. Recent findings have since rectified the inconsistency in people's spacing choices as driven by judged difficulty. Namely, people will choose to mass their study when encoding has been insufficient; people will tend to space their study when encoding is sufficient (Toppino et al., 2009).

Given the previous data and this new finding, a critical implication arises: One should be aware of how well-encoded items are before choosing to mass or space one's study. If one were to follow a simple rule, perhaps it would be the following: It is advantageous to space my study, but only when I feel that I have encoded the item sufficiently. If it is not sufficiently encoded, then I should continue to study the item now. Logically speaking, then, the spacing effect should not be universal; that is, the effect should disappear if the situation made it so that sufficient encoding could not be achieved. An example of this would be when one learns items that are extremely difficult and the mere task of reading them might take significant amounts of effort. This implication is further discussed in the final section.

How do children choose to space out their study? One study investigated spacing choices in children empirically (Son, 2005): Children in first grade were tested (using age-appropriate materials) on a paradigm similar to the one used with adults in Son (2004), where massing and spacing choices needed to be made. Results showed both a lack of metacognitive strategy as well as a larger inclination to mass than to space. Even for the items that were judged to be very easy, children preferred a massing strategy, going against what is thought to be best according to the expanding paradigm.[2] Such results may be due to the hypothesis that children are likely to be less aware than adults of how well encoded any to-be-learned materials are and, on top of that, have experienced fewer study strategies than adults have, including the experience of benefiting from spacing.

Given the data regarding metacognitive control of spacing (i.e., the lack of it in children) and in light of the overwhelming evidence for the spacing effect, the following question was asked: Would it be beneficial to impose a spacing strategy on the learner, even while defying one's metacognitive choice? In the current study, I tested this question by having people learn synonym pairs, make metacognitive judgments, and then decide whether they wanted to mass or space their study for each item. The computer then gave them massed or spaced study sessions, either in agreement with their choice or against their choice. The critical question was to see whether performance would be best for those items that were given spaced study (even though they had been chosen for massed study). Or could the spacing effect be eliminated?

Experiment 1A

As described above, one set of data has shown that adults use a systematic strategy for spacing (Son, 2004). Although they choose to mass relatively difficult items, they tend to space the easier

[1] Recently, not all of the retrieval practice results have been consistent (see, e.g., Balota, Duchek, Sergent-Marshall, & Roediger, 2006; Karpicke & Roediger, 2007).

[2] The major difference between the paradigm used with adults in Son (2004) and the paradigm used with the children in Son (2005) is that there was no *done* option for the children because in a previous study, when the done option was available, children tended to choose only that option. That is, they simply did not want to study further. Thus, although it would be good to compare both children and adults using a similar paradigm, given that children's motivation strategies may be different from those of adults, it is almost impossible to set up a perfect comparison, both from the past studies and in this article's study.

items, which presumably get an additional boost from the spacing effect. Is it reasonable to think that if adults were forced to space their study, including items that were selected for massed practice, performance would increase yet further? On the one hand, one prediction could be that the spacing effect is robust enough that regardless of metacognitive control and regardless of the hypothesis that massing might be beneficial under some situations, having people space their study would heighten learning. On the other hand, adults are systematic in their choices and may make those choices on the basis of real benefits, which might be evidence enough to reveal that metacognitive control of spacing works and should not be disturbed.

Method

Participants. Thirty-one introductory psychology students participated for course credit. Participants were treated in accordance with the ethical standards of the American Psychological Association.

Materials. The stimuli were 60 synonym pairs taken from a list of vocabulary words from the Graduate Record Examination (e.g., *hirsute–hairy*), randomly selected by the computer program for each participant from a pool of about 100 word pairs. It was hoped that random selection would result in a range of difficulty in the items being presented to each participant. The level of difficulty was assessed by each individual, using a judgment of learning (JOL) procedure typically used in the field.

Procedure. The general procedure came from Son's (2004) methods. Participants were tested on Macintosh computers. On beginning the experiment, the instructions for a practice session appeared on the screen, as follows:

> Welcome to the experiment! In this experiment, you will be presented with a series of 60 words and their synonyms to study. Please stay as attentive as you can. For each pair, you will be asked to make a rating of how confident you are that you will be able to type in the synonym when given only the word on a later memory test. You will be making your response on a slider, ranging from 0 to 100. If you are confident that you will not know the synonym given the word then move the slider to the far left, where it is labeled "don't know." If you are completely sure that you will be able to type in the synonym given the word, then move the slider to the far right, where it is labeled "know." If your confidence is somewhere in between, then move the slider accordingly. Your response is called a judgment of learning, or JOL. Once you have moved the slider, click on "submit JOL." You should submit your JOLs as quickly and as accurately as possible. If you take too long, then the computer will remind you to "Hurry!" When you move the slider to enter your response, a message will appear informing you of your JOL. Your JOL will not be recorded, however, until you have clicked on a button that is marked "submit JOL." Try a couple of practice trials first.

Once participants clicked on a *ready* button, they were given a set of five word–synonym pairs to study and make JOLs. Each of the pairs was presented for 1 s, and then the slider labeled from 0–100 appeared. We displayed the numeric value of their JOL during the practice phase so that the participants could get an idea of the numeric value of their JOL in terms of the position on the slider. During the actual experiment, these values were no longer shown.

Once the JOL practice session ended, another set of instructions was displayed, this time explaining the massing and spacing strategies, as follows:

> Very good! From here on out, the value of your JOLs will not be shown to you. After you have made your JOL using the slider for each word pair, you will then have another chance to study that word. You will have 3 choices. You can either study the word again immediately or you can wait to study the word again later on in the list. You may also choose not to study that word any longer. Three buttons will appear on the screen like this: [the buttons were labeled *study now*, *study later*, and *done*]. If you want to study again immediately, click on "study now." Once you do, the same word and its synonym will appear again on the screen immediately—*most of the time*—for a select very few of those trials, they will appear again later. If you want to study again later, click on "study later." Once you do, the list will move on to the next word, while that word is saved for later study (again, for a select very few, that word will not be saved for later and, instead, will be shown again immediately). If you no longer want to study a word, click on "done." These items will not be shown again at all. Although there will be a few trials during which you will get the opposite of what you selected, please be as sincere as possible in your re-study choices. When you are ready to begin study, click below. As soon as you click, the first word will appear.

If people chose to mass, the same pair would be presented again immediately for 3 s. If they chose to space, then the pair would not be re-presented until after having studied the entire list (again for 3 s). However, as was explained in the instructions, their choices were honored only part of the time. Specifically, their choices were honored two thirds of the time. On the remaining third of the trials, their choices were dishonored. That is, the computer forced participants to space when they chose to mass, and mass when they chose to space (see Kornell & Metcalfe, 2006, for the original use of the honor–dishonor paradigm in relation to study time allocation). All of the done items were honored; that is, items for which *done* was selected were dropped from any further study. Once all of the pairs had been presented a second time (if chosen for restudy), then the next phase began where people had to calculate two-digit by two-digit multiplication problems for 5 min on paper provided next to the computer. Participants were told to work on the math problems until they heard the computer beep.

Along with the beep, instructions for the final test were presented on the screen, as follows:

> You are now ready to take the synonyms test. Each word will be presented to you on the screen. You task is to type in the synonym. Try to type in the EXACT synonym that you had studied earlier in the list. If you do not remember the correct answer, you can leave the item blank. Click on "begin test" when you are ready.

Each word was displayed randomly for each subject. All of the data, including JOL, strategy choice, whether the choice was honored or dishonored, and final test performance, were recorded by the computer.

Results

The JOL data were analyzed using normalized JOL scores, divided into six levels (vincentized into the top 1/6, next 1/6, etc.) for each participant. That is, for each individual participant, the JOLs were divided into sixths—depending on their mean JOLs and variations—and then recategorized from 1(lowest JOLs) to 6 (highest JOLs). Normalized JOLs were used specifically because of the variance in the use of the scale. For instance, some participants may have used the entire scale (from 0–100), whereas other might have used only a portion of the scale (0–50). Then, the former participant's highest JOL category might include those raw JOLs in the 80s and 90s; the latter participant's highest JOL category might include those raw JOLs in the 40s. Thus, for the final performance results, analyses of variance (ANOVAs) were conducted with JOL category level (1–6), honor–dishonor, and massing–spacing choice as the main variables.

JOL data. Before showing the main results, one can ask how JOLs related to both final test performance and study choice in general. Although a clean correlation between judgments and test performance cannot be achieved because of the additional study session in between, the rank-order gamma correlation (see Nelson, 1984) between judgments and final test performance was very high ($M = 0.43$), suggesting that items that were judged easier were, in fact, remembered better. A one-sample t test showed the correlation to be significantly different from zero, $t(29) = 11.84$, $SE = 0.04$.

How did JOL affect study choice? The top panel of Figure 1 displays adult choices at each level of normalized JOL. As can be seen, as JOL increased, people's selections of *spaced* and *done* items increased while the number of massed items decreased. This trend replicates the data that were previously obtained in Son (2004) and supports the notion that people may continue studying an item until it has been adequately encoded, in agreement with Toppino et al. (2009).

Performance data. The critical question pertains to the performance results. That is, does the spacing effect obtain for both

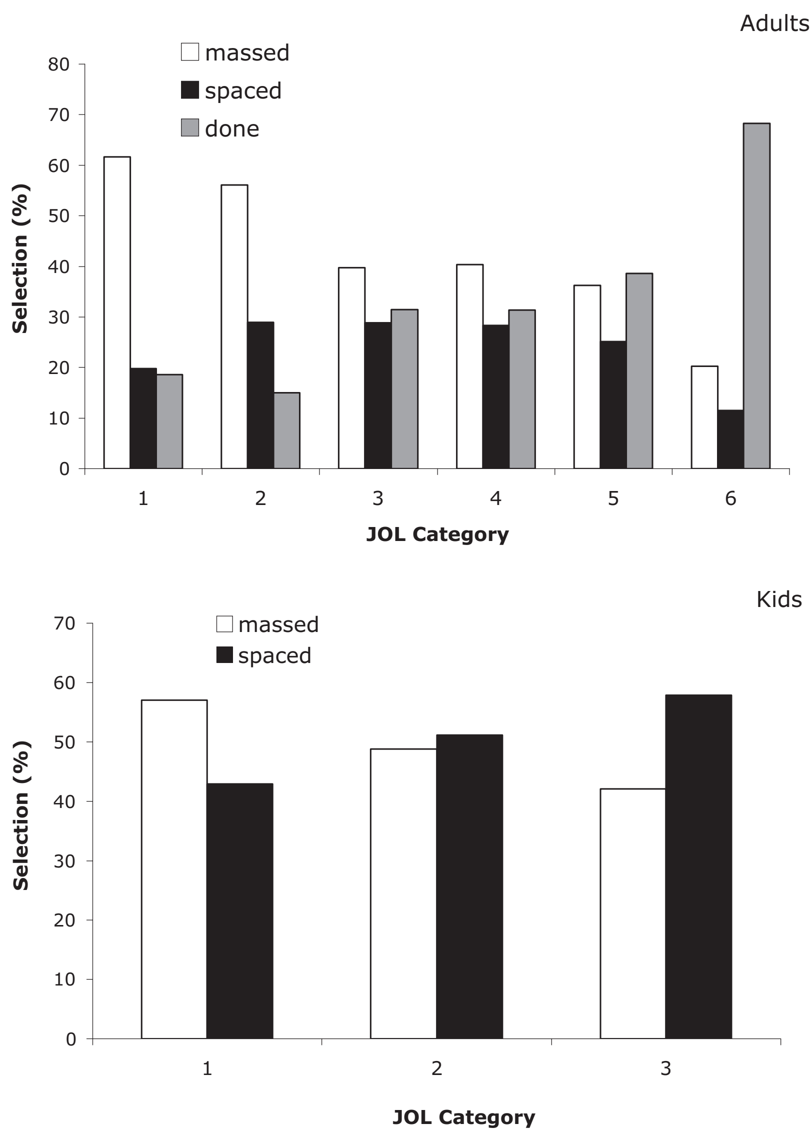

Figure 1. The mean proportion of massed, spaced, and done items across judgment of learning (JOL) level (z scores were calculated for each participant and split into six levels for adults and three levels for children, from least confident to most confident). The *done* option was included only in Experiment 1A, for adults. It was not available for children in Experiment 1B.

honored and dishonored items? The top panel of Figure 2 presents the data comparing honored and dishonored items collapsed across all items. As can be seen, there appears to be a classic spacing effect for items that were honored, $t(29) = 2.03$, $SE = 3.21$. The mean level of performance for items that were massed was 27.48, whereas that of spaced items was 34.02. However, the results showed no significant improvement for items that were forcibly spaced, against people's choices to mass: The mean performance for those items in which a spacing schedule was imposed was still low, at 28.90 (compared with a mean of 27.48 for the massed items). There was also no difference between performance for massed items when the massing was either chosen or imposed ($M = 27.61$).

An additional question can then be raised: At what levels of JOL does the spacing effect hold? In line with the expanding retrieval paradigm results as well as people's choices in general, for example, one might expect that the a spacing effect would not appear if spacing strategies were forced at the very low JOL levels, if those items were actually not fully encoded.[3] The overall ANOVA resulted in increased performance as JOLs increased, $F(3, 1879) = 59.37$, mean square error (MSE) = 8.76, $p = 0$, $\eta_p^2 = .087$, and better performance for spaced items than for massed items, $F(1, 1879) = 12.40$, $MSE = 1.83$, $p = 0$, $\eta_p^2 = .007$. There were also significant interactions between JOL level and honor–dishonor, $F(3, 1879) = 2.63$, $MSE = .388$, $p = .049$, $\eta_p^2 = .004$, and between massing–spacing and honor–dishonor, $F(1, 1879) = 10.34$, $MSE = 1.53$, $p = .01$, $\eta_p^2 = .005$. There was, however, no significant three-way interaction. In sum, then, although there were no systematic differences in spacing benefits across JOL levels, the data show that the spacing effect was not robust enough to obtain across all levels of judged difficulty.

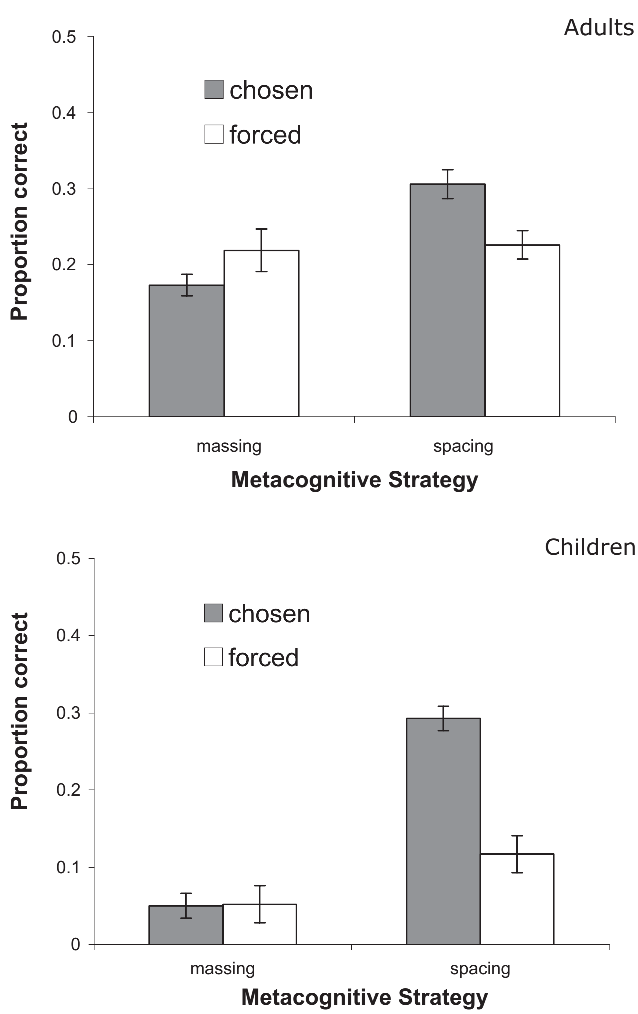

Figure 2. Mean proportion correct resulting from a massing or spacing strategy, either chosen or forced, collapsed across items. The error bars represent standard errors of the mean.

Discussion

In summary, the spacing effect was obtained, but only for honored items. When strategy choices were dishonored, the spacing effect disappeared. The short implication here is that deliberately imposing a "good" strategy on the learner, even one that has had overwhelming evidence and agreement in the laboratory, should be done with caution, particularly when the strategy has not been requested by the learner. The data also imply that there are specific reasons for why an individual should and would choose a spacing strategy over massing, and those reasons are only perfectly known to the learner him- or herself.

Experiment 1B

Experiment 1A found the spacing effect disappeared when a spacing strategy was forced against the participant's own choice. This result indicates that spacing is not an unconditional benefactor to learning. And, at least for the adults tested above, one's metacognitive decisions might, in fact, characterize the most optimal study schedule for the learner. This is reasonable given that adults are considered to be fairly experienced learners in the sense that they are likely to have seen the consequences of massing and spacing in real-world learning and may be more likely know what is best for themselves.[4]

What about a population whose metacognitive decisions might not be as experienced or optimal, as in the case of a child? Will a child's own decisions be the most optimal for that child? Previous data suggest not. The data demonstrated that very young children (in first grade) did not use their metacognitive knowledge to guide spacing choices (Son, 2005) and, to boot, preferred massing to spacing practices at all JOL levels. It seems rational, then, to believe that imposing a spacing strategy for children might actually enhance learning, at least at some JOL levels.

Method

The method used in Experiment 1B was the same as was used in Experiment 1A, except that the participants were 42 children in

[3] However, it is difficult to say whether this is actually so: An item might be given a low JOL because it is either not fully encoded or not fully perceived or because it has been fully perceived but is simply thought to be difficult to learn.

[4] It should be noted, however, that adult learners have been shown to be far from perfect (e.g., Metcalfe, 1998; Roediger, 1996).

Grades 3–5 rather than college students and the materials were appropriate for their learning level. In other words, the word pairs consisted of elementary school–level vocabulary (e.g. *occupation–job*) and the distractor task involved solving one digit by one digit multiplication problems. The children were also read aloud the instructions and emphasis was put on the fact that they should be as honest in their choices as possible. Finally, a critical difference was that there was no *done* option, because children at this age would be likely to cease any further study on most of the items because of lack of motivation.[5] The children were recruited from a local public elementary school, where parental consent for participation was obtained.

Results

JOL data. The children's JOL data were individually normalized, as had been done in the adults' experiment. However, the data were categorized into three levels (top third, middle third, and bottom third) rather than six, mainly because the children, more than the adults, were less likely to use a large range when rating JOLs and instead tended to give a very low JOL, a very high JOL, or one right near the middle (often meaning "maybe"). The mean gamma correlation between JOLs and final test performance was significantly positive, $M = 0.23$, $t(40) = 4.27$, $SE = .05$, as it was in the adults, although not as strong numerically. Still, this suggests that children at this age do in general know what they know and do not know. The bottom panel of Figure 1 presents the massing–spacing choice data for three levels of JOL. And like the adults (but different from the first graders tested in Son, 2004), the children responded such that the data followed the general trend showing that strategies were guided by JOLs: As JOLs increased, spaced choices increased as well.

Performance data. The mean final test performance for the children, collapsed across JOL level, is shown in the bottom panel of Figure 2. As is shown, the spacing effect was replicated for the usual condition, where learner decisions were honored. The mean for the massed items was 10.3; for spaced items, the mean was 36.2. The difference was highly significant, $t(40) = 8.72$, $SE = 2.98$. In adults, it was found that the spacing effect did not hold when the strategy was forced on the learner against the learner's metacognitive decision. For children, the forced spacing strategy led to a significant improvement over massing, doubling mean performance ($M = 20.7$). This mean score was also almost double that of the forcibly massed items, $M = 11.1$, $t(40) = 2.32$, $SE = 4.14$.

Where in particular does the spacing effect obtain when spacing is forced? The ANOVA showed that, like the adults, the children also performed better on items given higher JOLs, $F(2, 1218) = 3.77$, $MSE = .421$, $p = .023$, $\eta_p^2 = .006$, as well as on items that were spaced rather than massed, $F(1, 1218) = 53.44$, $MSE = 5.96$, $p = 0$, $\eta_p^2 = .042$. There was also a significant interaction between massing–spacing and honor–dishonor, $F(1, 1218) = 15.22$, $MSE = 1.70$, $p = 0$, $\eta_p^2 = .012$. However, there was no three-way interaction effect, suggesting that there were no consistent differences in spacing benefits across JOL levels.

The value of control. As the data show, although there were spacing benefits for even those items that were dishonored, those benefits were far less than what had occurred with chosen spacing. Going back to the children's data from Figure 2, one can see that performance after chosen spacing is much higher than performance after forced spacing: A one-way ANOVA resulted in a significant difference for those spaced items depending on whether they were chosen or forced, $F(1, 618) = 23.94$, $MSE = 4.18$, $p = 0$, $\eta_p^2 = .037$; there were no differences for the massed items. This implies several things: Like adults, children may have appropriate reasons for massing their study, including lack of sufficient encoding. And because there was no significant three-way interaction with JOLs (shown above), it could mean that sometimes even the items given high JOLs, although judged as easy to learn, may have not been encoded enough. And a child might have (appropriately) felt that massing would be best. At the same time, children may not always make the best choices and, thus, some degree of forced strategy would help a little, at least more than it would in adults, who may make slightly better choices on their own.

Discussion

As was the case with the adults, the spacing effect was upheld for items that were honored. However, unlike the forced spacing in adults, forced spacing in children resulted in a significant benefit (over massed study). Thus, it seems that performance can be improved by encouraging children to use the strategy, even if they would not choose to use it on their own. It is interesting, however, that there was evidence that metacognitive control may still be valuable at this age. That is, forced spacing strategies did not improve performance to the same degree than would have been reached had the children chosen to space their study on their own.

General Discussion

The data from the current study show that the usual spacing effect obtained universally only when learner choices were honored. Both adults and children remembered the spaced items better than the massed items when the spacing strategies were selected metacognitively. However, for the dishonored items, results were more complicated. Forced spacing appeared to help only the children, not the adults, on the basis of data that were collapsed across all items. This suggests that only when people's metacognitive decisions are more likely to be flawed, as in the case with young children, might it be profitable to advocate a strategy already known to be helpful. In addition, however, although forced spacing did improve performance somewhat, that improvement was not as good as what would have occurred had the spacing strategy been chosen by the child. In other words, metacognitive choice is valuable and a spacing strategy alone that goes against choice is not as effective as a spacing strategy driven by choice.

These results, that forced spacing may not boost performance at all times, may be consistent with the idea that there may be certain items in a participant's *region of proximal learning* (RPL). According to the RPL model (Metcalfe, 2002; Metcalfe & Kornell, 2003, 2005), it is best to allocate study time to items that fit a particular range; precisely, time should be allocated to those items that are slightly more difficult than those that are already well mastered. In the current case, although there were no specific

[5] In a previous pilot study, it was found that having the *done* option would encourage children to choose to cease study of almost all of the items, so it was decided to leave this option out.

findings in terms of when spacing strategies helped dependent on JOL levels, the lack of a spacing effect may be because individuals (particularly adults) may have good reasons to choose to mass, including the fact that an item may not have been well encoded (Toppino et al., 2009).

Metacognition has been described as the ability to self-reflect and to know what is in the mind. Because of its uniquely personal and private nature, it has also been described as a form of *privileged access*—only I can know what I know. The current data provide support for this notion of privileged access: I might not always make good choices, but many times, the choices I make have value, and overriding those choices might not always lead to improvement. For both adults and children tested here, there were instances where forcing a seemingly optimal strategy of spacing against their own choice did not lead to improvements and, in fact, might have even hurt performance. A challenge, especially for educators, is to keep a sensible balance between a learner's choice and a good strategy. Although the children's data presented here highlight the fact that teaching holds considerable value (whether it is from a human teacher or, in this case, a computer program), on the flip side, the data also stress the notion that metacognitive control is driven by a personal mechanism and may be invaluable for optimizing one's learning. Merely imposing a spacing strategy did not increase performance as much as it would if the child had selected the strategy on his or her own.

At the same time, there were improvements when choices were defied, in particular for the children. Flavell (1978) once stated that control of study must be formally learned, especially in relating to children. With his colleagues, he also found empirically that if a strategy was explained explicitly to a very young child, the use of that strategy was transferred to a new task (Keniston & Flavell, 1979). The data presented here corroborate Flavell's theory and are encouraging in the sense that a child's flawed choices during learning may be reparable. Even adult learners may not be perfect learners on some tasks. Indeed, earlier data illustrate that a computer programmed to make an adult's study decisions improved learning enormously (Atkinson, 1972; Metcalfe, Kornell, & Son, 2007).

Might there have been another reason for the difference between the adults and the children? Although the methods were very similar for both groups, there was one critical difference that should be addressed. In Experiment 1A, where adults were tested, there was a *done* option, where restudy could be avoided altogether.[6] This could allow for more refined strategies where participants could choose not to study items that were "too easy" or, perhaps, even "too hard." This, in turn, would allow individuals to zone in more accurately on a region of proximal learning, lessening the effects of any forced strategy from the outside. In Experiment 1B, in which children were tested, there was no such *done* option. Being that this was the case, a larger range of difficult items was still included in the data for children, perhaps making it less likely to zone in on an optimal region and allowing for more varying and error-filled choices. Future research regarding the effects of studying in one's individual region of proximal learning would, therefore, be valuable.

In the current study, learners were simply forced to use a spacing strategy without explanation and without systematization. Like Flavell (1978) had predicted, recent research has shown that awareness of self-regulation (not mere self-regulation) is key to enhancing learning functions (e.g., Fuchs et al., 2003). For example, Fuchs et al. (2003) showed that when participants were explicitly instructed on how to solve math problems, as well as the meaning of transfer, results showed higher metacognitive awareness to transfer, subsequently leading to higher test performance. Greater reports of metacognitive strategy use also have been shown to lead to more effective self-regulated study (Thiede, Anderson, & Therriault, 2003) and increased motivation and decreased procrastination (Wolters, 2003). Here, children's performance scores were boosted by forcing a spacing strategy. However, the larger message is not to force people to use a particular strategy blindly but rather to make them more aware of their own thinking while doing so. Further research is necessary to better understand each of the ingredients essential for enhancing performance while encouraging metacognitive control. In all likelihood, a child will become an experienced metacognizer, but, in the meantime, a little intervention might help him or her to reach that goal.

[6] In previous studies testing adults, excluding the *done* button resulted in varying and complicated data, such that sometimes people would select the *study now* option for very easy items (rather than the hard items, as might be expected) because they wanted to "get those items over with." At the same time, sometimes people would select *study now* for very hard items, to further encode the item. Thus, a *done* option allowed for scraping off those items that were so easy that a massing strategy was used.

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Correction to Son (2010)

In the article “Metacognitive Control and the Spacing Effect,” by Lisa K. Son (*Journal of Experimental Psychology: Learning, Memory, and Cognition,* 2010, Vol. 36, No. 1, pp. 255–262), lenient scores were reported instead of strict scores in two Performance Data sections of the text. The strict scores were correctly used in the analyses and figures.

On page 259, the data corrections are as follows: The mean level of performance for items that were massed was 17.3 rather than 27.48, whereas that of spaced items was 30.6 rather than 34.02. The mean performance for those items in which a spacing schedule was imposed was 22.6 rather than 28.90, and the mean for the massed items was 21.9 rather than 27.48.

On page 260, the data corrections are as follows: The mean for the massed items was 5.0 rather than 10.3; for spaced items, the mean was 29.3 rather than 36.2. Children using the forced spacing strategy had a mean performance of 11.7 rather than 20.7. This mean score was still almost double that of the forcibly massed items, $M = 5.2$ rather than 11.1.