Summary and Keywords

The spacing effect (also known as distributed practice) refers to the finding that two or more learning opportunities that are spaced apart, or distributed, in time produce better learning than the same opportunities that occur in close succession. A number of theories have been proposed to account for the spacing effect. These include deficient processing, encoding variability, study-phase retrieval, and consolidation. According to the deficient processing account, learning opportunities that are spaced apart in time, compared to non-spaced or "massed" learning opportunities, are more likely to receive a learner’s full attention, ultimately leading to better quality learning. The encoding variability account proposes that spaced learning opportunities, because they are separated in time, are more likely to be associated with a number of different contextual cues that can benefit later memory for the information learned. Study-phase retrieval is based on the premise that retrieval benefits learning, and spaced learning opportunities are more likely than massed learning opportunities to involve retrieval of the previous learning experience. More recent evidence suggests that spacing learning opportunities across different days may benefit memory due to sleep-dependent neural consolidation processes. Research in authentic educational contexts shows that spacing benefits learning of a wide variety of materials, from basic facts to complex scientific concepts and skills. Regarding the practical question of when spaced learning opportunities should occur, the ideal scheduling of these opportunities depends upon how long the information needs to be remembered in the future, such that retention over longer intervals of time benefits most by longer spacing between repeated learning opportunities. Despite its promise for enhancing student learning, spacing can be challenging to implement in authentic educational contexts due to the intuitive notion that immediate repetition is better for learning, and the difficulties involved in setting a spaced study schedule in advance and adhering to it. To realize the full potential of spacing to enhance educational practices, future studies are needed that can measure implementation of spacing by students and teachers in real educational environments.

Keywords: distributed practice, spacing effect, lag effect, memory, repetition
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Practice makes perfect. In order to learn something well, it has to be done over and over again. This goes for a variety of different things like riding a bicycle, learning a new computer program, or rehearsing lines for a play. In all learning situations, the same thing has to be done multiple times in order to get better at it. The same goes with schoolwork. Learning mathematical rules, language skills, scientific concepts, and content in any domain requires students to revisit what they are learning a number of times before the information sticks and sinks in over the long haul. Although it seems quite obvious that repetition is necessary for learning, it is not particularly obvious how those repetitions should be carried out. The current article focuses on the *timing* of repeated learning opportunities, showing that simple changes to a learning schedule can produce powerful benefits on long-term learning.

The Spacing Effect

More than a century of research has been devoted to studying *when* students engage in repeated learning opportunities, and the effects it has on the long-term durability of the information learned (e.g., see Ebbinghaus, 1913). To illustrate, consider a situation in which a student is studying Spanish vocabulary for an upcoming exam. She creates flashcards for 50 Spanish words, and goes through the deck to try to remember their meanings. She most certainly will not learn them all on the first try, so she will need to go back through the deck again. But when? Should she go back through the deck immediately? Or, should she wait a while before going back through the deck a second time?

The research shows, somewhat counterintuitively, that it is better to wait. When students study information on two or more occasions that are separated in time (as opposed to occurring back to back), they learn it better. This finding has been referred to as distributed practice, or the spacing effect. The name comes from the fact that two learning opportunities that are spread out—i.e., distributed, or spaced—in time lead to better learning than the same two opportunities that occur closer together in time, which are usually referred to as massed repetitions. In this article, the term spacing effect will be used, for simplicity, to describe this phenomenon.

Figure 1 shows the design of a typical study on the spacing effect. Here learners have an opportunity to learn some information, followed by one or more additional opportunities to learn the same information again after a period of time usually referred to as the spacing gap. After another period of time, referred to as the test delay, learners complete a test over the information. Performance on this test reveals that, even when the test delay is held constant between a group that does massed repetition and a group that does spaced repetition, longer spacing gaps typically lead to better learning than no spacing gaps.
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For example, in a recent study by Schutte et al. (2015), third grade children completed four practice activities to learn basic math skills using different spacing gaps. Some children completed the practice activities back to back, with no break in between (i.e., no spacing gap, or massed repetitions), and others completed the same four activities with a two-hour break in between each one (i.e., a spacing gap of two hours, or spaced repetitions). After a ten-day test delay, both groups of children were given a test of proficiency over the skills they learned, and the group that practiced with the two-hour spacing gap significantly outperformed the group that practiced with no spacing gap.

Other studies have shown a significant spacing effect even when the spacing gap spans across different days. For example, Ambridge, Theakston, Lieven, and Tomasello (2006) compared children’s learning of grammar rules after completing 10 interactive activities that occurred all in one day (massed repetitions), or after completing two of the activities per day across five days (spaced repetitions). A later test of proficiency over the information learned revealed superior performance for the group that engaged in spaced repetitions compared to massed repetitions.

Hundreds of laboratory-based experiments have shown that spacing repetitions by a matter of mere seconds or minutes produces significant benefits on the ability to remember information, as well as the ability to apply rules and concepts to new situations (for recent reviews of this literature, see Carpenter, 2017; Gerbier & Toppino, 2015; Rohrer, 2015; Toppino & Gerbier, 2014). Spacing benefits learning for individuals of all ages, from young infants (Cornell, 1980) to older adults (Simone, Bell, & Cepeda, 2013), and even the learning of simple conditioned responses in non-human species (Deisig, Sandoz, Giurfa, & Lachnit, 2007; Tully, Preat, Boynton, & Del Vecchio, 1994).

Of particular interest to education, the benefits of spacing have been shown to last over meaningful time intervals. Goossens, Camp, Verkoeijen, Tabbers, and Zwaan (2012), for example, examined third grade children’s learning of new vocabulary words by completing either three instructional activities all on the same day (massed repetitions), or one instructional activity per day across three days (spaced repetitions). Spaced repetitions led to superior learning over massed repetitions even when students’ vocabulary proficiency was assessed five weeks after the learning activities. Sobel, Cepeda, and Kapler (2011) found a similar result, in that new vocabulary learned by fifth grade students ben-
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Effected more from spaced repetitions (two lessons spaced one week apart) than from massed repetitions (the same two lessons in one day) when vocabulary proficiency was tested five weeks after learning. Carpenter, Pashler, and Cepeda (2009) further found that eighth grade students’ memory of history concepts was better if those concepts were reviewed 16 weeks after learning them, compared to only one week after learning them, and the benefits of the spaced (i.e., 16-week) review were still apparent when knowledge of these concepts was tested after a nine-month interval of time.

Theoretical Perspectives on the Spacing Effect

Why does spacing benefit learning? Researchers have proposed a number of possibilities. These are not mutually exclusive, and it is possible that more than one of these mechanisms contributes to the spacing effect in any given instance. One theory—referred to as deficient processing—proposes that spaced repetitions benefit learning because learners are more likely to give their full attention to spaced repetitions compared to massed repetitions. When information is repeated too soon (i.e., massed), it is perceived as highly familiar, garnering less attention and perhaps even a feeling of boredom. However, when the information is repeated with breaks in between (i.e., spaced), it is not as familiar and therefore more likely to receive a learner’s full attention. Consistent with this idea, laboratory-based studies on the spacing effect have allowed learners to spend as much time as they like on material learned via spaced repetitions vs. massed repetitions, and have found that learners choose to spend less time on repetitions that are massed compared to spaced (Delaney, Spirgel, & Toppino, 2012; Rundus, 1971; Shaughnessy, Zimmerman, & Underwood, 1972).

Another theory of the spacing effect—encoding variability—proposes that spaced repetitions benefit learning because they are associated with a greater variety of contextual cues that aid memory. Learning information at two distinct points in time—as is the case with spaced repetitions more so than massed repetitions—results in two distinct learning experiences. These different experiences involve diverse cues associated with, for example, the physical environment, the internal state of the learner, or the characteristics of the learned material. These additional cues provide a number of routes through which the learned information can be accessed in the future, increasing the chances that it will be successfully remembered.

Consistent with the encoding variability account, some studies have varied the contextual details of repetitions and have found that varied context has more of an impact on massed repetitions than on spaced repetitions (Gartman & Johnson, 1972; Glover & Corkill, 1987; Krug, Davis, & Glover, 1990). For example, Verkoeijen, Rikers, and Schmidt (2004) presented massed vs. spaced repetitions of words on a computer screen in the context of the same background or a different background at each repetition, and found that the spacing effect was actually eliminated when the repetitions appeared on different backgrounds. These findings suggest that contextual variability benefits memory, but only when applied to massed repetitions, as such processing is presumed to already be occur-
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ring during spaced repetitions. Along similar lines, Bercovitz, Bell, Simone, and Wiseheart (2017) taught participants Swahili–English word pairs, and found that the benefits of spacing over massing were eliminated when participants completed the first and second learning session in different rooms, compared to the same room, prior to taking a final test over the word pairs.

A third theoretical account—study-phase retrieval—proposes that spaced repetitions are more likely than massed repetitions to involve retrieval of the previous experience of having learned the information. Anytime information is repeated, the current experience is likely to remind learners of their previous experience with that same information. When the information is repeated too soon, as with massed repetitions, the previous experience is not likely to be retrieved from memory because it is still fresh in mind. However, when the information is repeated after some time has passed, learners can bring to mind a distinct prior experience of having engaged with that information. Retrieving information from memory has been known to produce significant benefits on later memory for that information (Carpenter, 2012; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Karpicke, 2017; Rowland, 2014). The idea of study-phase retrieval thus proposes that spacing is more beneficial than massing because it is more likely to encourage retrieval of the information learned during a previous experience. Consistent with this idea, the benefits of spacing have been shown to be larger under conditions that encourage participants to retrieve the previous occurrence of a repeated presentation (Wahlheim, Maddox, & Jacoby, 2014).

Finally, recent discussions of the spacing effect have included consolidation as a potential contributor. Consolidation is a set of active neural processes that function to stabilize memories over time. Even after an experience has ended, these processes continue to work, unconsciously, to form durable long-term memories of that experience. Consolidation requires time to run its course, as factors that interfere with these processes early, while memories are still being consolidated—particularly neural trauma (Zola-Morgan & Squire, 1990)—result in permanent disruptions to the formation of long-term memories.

Contributing to the benefits of spacing, therefore, could be the greater likelihood that spaced presentations (compared to massed presentations) involve consolidation. Because of the time that passes in-between repeated spaced presentations, the first learning experience is more likely to be consolidated by the time the second learning experience occurs, resulting in a second learning experience that is distinct from the first and capable of generating its own consolidation processes. In contrast, the second learning experience associated with massed presentations is less likely to be distinct from the first, reducing the likelihood of additional neural activation—and further consolidation—because the neural activity from the first experience is still active. This idea, proposed by Landauer (1969), has been supported by recent neuroscience studies showing that the neural activity associated with repeated spaced presentations is greater than that associated with repeated massed presentations (Scharf et al., 2002; Smolen, Zhang, & Byrne, 2016).
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Some studies have suggested that consolidation is enhanced by sleep. When participants learn a new task and then sleep afterwards, their proficiency at that task tends to be better on a later test, compared to participants who learned the same task but did not sleep afterwards (Mazza et al., 2016). Although much has still to be learned about the neural processes engaged during sleep and how they contribute to consolidation, this raises the interesting possibility that sleep contributes to the spacing effect. Particularly in situations where spaced repetitions occur across different days, compared to massed repetitions all on the same day, the benefits of spacing could be partially accounted for by the fact that participants most likely sleep in between the spaced repetitions but not in between the massed repetitions. In one study that appears to support this idea, Bell, Kawadri, Simone, and Wiseheart (2014) had participants learn foreign language vocabulary across two sessions that occurred on the same day (massed), versus two sessions that occurred 12 hours apart that involved sleep in-between the sessions (spaced-sleep) or no sleep in-between (spaced-no sleep). On a later test over the vocabulary, the spaced-sleep group did best, outperforming both the massed group and the spaced-no sleep group.

Key Questions About the Spacing Effect

The spacing effect represents a simple yet powerful way to enhance learning. By simply changing the timing of when learning activities occur—without changing the learning activities themselves—students can retain and use what they have learned much more easily. This approach has great promise for improving learning in educational contexts where long-term proficiency with course knowledge is of primary importance. Given the importance of durable long-term learning, three key questions arise with respect to the educational applicability of the spacing effect. First, how much spacing is best? Should teachers aim for a particular spacing gap—such as one day, one week, etc.—in order to maximize students’ learning? Second, does spacing promote conceptual understanding in addition to memory of a given subject matter? Third, does spacing consistently enhance learning in authentic educational contexts?

How Much Spacing is Best?

The evidence reviewed thus far has shown that learning is enhanced when some time is placed between repeated learning opportunities. Students and teachers wishing to use spacing to enhance learning may raise the question of exactly how much time should be inserted. Should learning opportunities be spaced apart as far as possible in time? Or is there an optimal spacing gap that they should aim for?

Research shows that longer spacing gaps are not always best. For example, Verkoeijen, Rikers, and Özsoy (2008) assessed students’ memory for a text passage (a) after studying the passage twice in a row, back to back (massed), (b) after studying the passage once and then again after four days (spaced short), or (c) after studying the passage once and then again after three and a half weeks (spaced long). When tested for their memory of
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the passage two days after the last study opportunity, students in the spaced short group performed best, followed by students in the spaced long group, and then students in the massed group. Other studies have demonstrated a similar pattern in which a shorter spacing gap produces better learning relative to a longer spacing gap (Kuepper-Tetzel & Erdfelder, 2012; Toppino & Bloom, 2002; Verkoeijen, Rikers, & Schmidt, 2005).

How do we know what the optimal spacing gap is? One study thoroughly examined this question by having participants learn information at various different spacing gaps and test delays. Cepeda, Vul, Rohrer, Wixted, and Pashler (2008) gave participants a number of trivia facts to learn across two different sessions. In the first session, participants completed quizzes over the facts and received feedback of the correct answers. The second session involved learning the same facts via the same quizzing-with-feedback procedure, and this second session occurred at either a zero-day spacing gap (i.e., on the same day as the first session), or a spacing gap of 1, 2, 4, 7, 11, 14, 21, 35, 70, or 105 days. Participants then completed the final test over the facts after a test delay of either 7, 35, 70, or 350 days.

The results of the study by Cepeda et al. (2008) showed that the spacing gap that was best for learning depended upon the test delay. As shown in Figure 2, when the test delay was relatively short—such as seven days—the one-day spacing gap was best. For example, when the final test was taken seven days after the completion of study, the group that studied on back-to-back days performed better compared to the group that studied with 21 days in between sessions. When the test delay became longer, however, the optimal spacing gap increased. For example, when the final test was taken 70 days after the completion of study, the group that studied with 21 days in-between sessions performed better than the group that studied on back-to-back days.

![Figure 2](image_url)

*Figure 2. Performance on the final test in the study by Cepeda et al. (2008) as a function of spacing gap and test delay. Participants experienced one of 26 different combinations of spacing gap and test delay. The ideal spacing gap depended upon the test delay, such that shorter spacing gaps produced the best performance at relatively short test delays, and longer spacing gaps produced better performance at longer test delays.*
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In other studies comparing longer vs. shorter spacing gaps, similar results have been found where it is typically the case that the optimal spacing gap becomes larger with increasing test delays (Cepeda et al., 2009; Kuepper-Tetzel & Erdfelder, 2012; Rawson, 2012). These results show that some spacing gaps produce better learning than others, and in order to maximize the benefits of spacing it may be useful to know how far into the future one wishes to be able to retain and use the knowledge learned.

As to whether there are potential detriments to using a “non-optimal” spacing gap, there is good news. The literature overwhelmingly shows that spacing benefits learning more than massing, and any spacing gap is typically better than no spacing gap. When faced with the practical question of exactly when to schedule spaced learning activities, therefore, teachers and students have a great deal of flexibility regarding when those activities can be scheduled. The general rule is to try to avoid scheduling a repeated learning opportunity too soon, when the learned information is still fresh in mind and highly familiar.

Ideally, learning opportunities should be spaced at intervals that allow some forgetting of the previous learning experience, but not so much that the previous experience cannot be remembered at all. As students differ in their rates of learning and forgetting, there is no “one-size-fits-all” ideal spacing schedule that can be applied to an entire class of students. However, advances in technology can help with the development of adaptive spacing schedules that are tailored to individual students. Consistent with this notion, some studies have shown that computer-assisted adaptive spacing schedules—in which the spacing intervals for individual items are based on a student’s past performance on those items—fare better than fixed spacing schedules at enhancing long-term retention of the material learned (Lindsey, Shroyer, Pashler, & Mozer, 2014; Mettler, Massey, & Kellman, 2018).

Does Spacing Promote Conceptual Understanding?

Many studies show that spacing enhances memory for information, facilitating later retrieval of the same or similar information that was studied. A question of great importance to education is whether a given technique can also enhance conceptual understanding of information, so that it can be used and applied in new situations. Indeed, such flexible use of knowledge may be considered the ultimate goal of learning, as one never knows exactly when and how that knowledge might need to be used in the future.

Studies have begun to explore the effects of spacing on the abstraction and generalization of knowledge to new situations. In Kornell and Bjork (2008), students learned to classify paintings according to the artists who created them. To do this, students were shown several examples of paintings by various different artists. The examples were either massed such that all of the paintings by a given artist appeared one right after the other, or they were spaced such that no two paintings by the same artist ever occurred back to back. On a later test requiring students to classify new, never-before-seen paintings by the same artists, performance was better when students had previously learned to classify the paintings via spaced presentation compared to massed presentation. Subsequent
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studies have found similar results using the same type of paintings classification task (Kang & Pashler, 2012; Kornell, Castel, Eich, & Bjork, 2010; Verkoeijen & Bouwmeester, 2014; Zulkiply & Burt, 2013), as well as other classification tasks such as learning to differentiate bird species (Wahlheim, Dunlosky, & Jacoby, 2011) and diagnose psychiatric disorders (Zulkiply, McLean, Burt, & Bath, 2012).

Spacing has been shown to benefit the learning of concepts and categories in young children as well. For example, in Vlach, Sandhofer, and Kornell (2008), three-year-old children were taught the names of novel, never-before-seen objects. The objects were shown to the children repeatedly, with either no time breaks in between the presentations (massed) or with 30-second breaks in between (spaced). On a later test that required children to identify the object from its name, children performed better if they had learned via spaced presentation compared to massed presentation. They performed better on the test not only when the object was the same one that they had seen during learning, but also when the object was from the same category but had never been seen before. Similar results occurred using a similar type of learning task in a subsequent study with two-year-old children (Vlach, Ankowski, & Sandhofer, 2012).

Finally, spacing has been shown to promote children’s knowledge and application of scientific concepts. In Vlach and Sandhofer (2012), elementary school children completed four lessons over the scientific concepts involved in food chains within particular biomes such as oceans, grasslands, and deserts. The lessons were either all on the same day (massed), two per day across two days (clumped), or one per day across four days (spaced). On a later test, children’s knowledge of the concepts was tested, but with examples of animals in a different biome from the one they had learned. Children demonstrated that they could apply a particular concept they learned—such as the tendency for larger animals to eat smaller animals—to a new biome, and were better at applying these concepts if they had learned them through the spaced lessons compared to the massed or clumped lessons. Similarly, Gluckman, Vlach, and Sandhofer (2014) showed that spaced lessons were more effective than massed or clumped lessons at promoting the learning of concepts related to food chains in elementary school children, and this applied to questions that required simple generalization of the concepts learned (such as what particular animals eat), as well as more complex generalization (such as understanding what would happen to the population of turtles if all of the frogs were taken from an area). Thus, spacing is not only effective at promoting long-term memory retention, but it can also support conceptual learning and transfer.

Does Spacing Enhance Learning in Authentic Educational Contexts?

The majority of studies on the spacing effect have been conducted in the laboratory. Although the benefits of spacing are quite consistent across hundreds of these studies, confidence in the power of spacing to enhance learning in real-world situations depends greatly on reliable demonstrations of the benefits of spacing in authentic educational contexts. Fortunately, an increasing number of studies conducted in classrooms has demon-
strated consistent benefits of spacing on learning diverse material among students at a variety of educational levels.

Spacing has been shown to enhance language and literacy skills all the way from primary school into adulthood. Seabrook, Brown, and Solity (2005) compared first grade children’s learning of pronunciation rules via activities that took place in three short (two-minute) sessions per day (spaced), or one longer (six-minute) session per day, over the course of two weeks. Students who learned via the spaced activities, compared to the massed activities, showed greater improvement in their performance on these skills by the end of the two-week period. Fishman, Keller, and Atkinson (1968), who studied fifth graders’ learning of spelling skills, found that spelling drills that were spaced two days apart led to better long-term retention of the correct spellings than the same drills that occurred on the same day. A number of studies have shown that spacing vocabulary exercises across different days, compared to having the exercises all on the same day, facilitates long-term retention of new vocabulary in third grade students (Goossens et al., 2012), fifth grade students (Sobel et al., 2011), and sixth grade students (Kuepper-Tetzel, Erdfelder, & Dickhaeuser, 2014), as well as learning of foreign language vocabulary in high school students (Bloom & Shuell, 1981). Spacing lessons across different days, compared to scheduling them all on the same day, has also been shown to benefit the learning of more complex grammatical rules in primary school children (Ambridge et al., 2006; Riches, Tomasello, & Conti-Ramsden, 2005), as well as college students learning English as a second language (ESL; Miles, 2014). In a semester-long study of adult ESL learners, Bird (2010) found that a longer spacing gap (grammar exercises every 14 days), compared to a shorter spacing gap (grammar exercises every three days), led to superior long-term learning of the grammar rules assessed two months later.

Studies in K-12 classrooms have shown that spacing enhances mathematics skills. Schutte et al. (2015) found that third grade students learned mathematics rules better when they completed drills spaced apart by two hours, compared to the same drills with no breaks in between. Similarly, Rea and Modigliani (1985) found that third grade students learned a particular mathematics rule better when repeated practice over that rule was separated by a short break that included practice over other rules, compared to repeated back-to-back practice over the same rule.

Other ways of introducing spacing into mathematics curricula involve the inclusion of practice problems from previous lessons within current lessons. When math instruction proceeds in a piecemeal fashion—lessons over a particular concept (such as adding fractions), followed by lessons over a different concept (such as multiplying fractions) with no revisiting of the previous concept—such instruction is akin to massed scheduling where the same skills and concepts are practiced repeatedly before moving on to another concept. Altering this routine slightly by introducing practice over previous concepts into a current lesson—for example, including some practice problems over adding fractions within the current lesson on multiplying fractions—provides opportunities for spaced practice. In two known studies that have implemented this approach, the revisiting of previous concepts produced better learning than focusing only on the concepts in the current lesson.
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rent lessons. Yazdani and Zebrowski (2006) found that high school students learned principles of geometry better when they completed problems that consisted of a mix of problems from the current lesson and from previous lessons, compared to only problems from the current lesson. In Rohrer, Dedrick, and Stershic (2015), seventh grade students practiced problems that required them to graph linear equations and find the slope of a line passing through two points. Students either practiced problems of one type (graph problems or slope problems) within a single assignment (massed), or they practiced the same number of problems of that type that were spread across different days and interspersed with problems of different types (fractions, percentages, etc.) on subsequent assignments (spaced). On a test of proficiency given one day and one month later, students scored significantly higher on new problems from the topic they had practiced with the spaced schedule compared to the massed schedule.

Several studies show that spacing enhances the learning of science concepts as well. Randler, Kranich, and Eisele (2008) found that seventh grade students learned biology concepts better if they completed a lesson that was divided into four 45-minute sections delivered once a week, compared to one 180-minute lesson delivered within a single day. Reynolds and Glaser (1964) found that middle school students learned biology concepts better if they learned the terms and then reviewed the terms over the following two days, compared to reviewing them on the same day they had been learned. Using a similar type of design with longer spacing intervals, Kapler, Weston, and Wiseheart (2015) explored college students’ learning of information from a meteorology lesson according to whether they reviewed the information either one day (short spacing gap) or eight days (long spacing gap) after the lesson. On a test given 35 days after the reviews, students who reviewed with the long spacing gap performed higher than students who reviewed with the short spacing gap. Furthermore, as reviewed previously, spacing can benefit elementary school children’s learning of scientific concepts and their generalization to new situations (Gluckman et al., 2014; Vlach & Sandhofer, 2012).

Implications for Educational Practice

Spacing enhances learning of a variety of materials, across diverse student populations, in real classroom environments. Such findings suggest that spacing should be readily implemented by students and teachers as a way to improve learning of course material. The following two sections describe ways of implementing spacing within course curricula and potential challenges involved in doing so.

Ways of Implementing Spacing in Course Curricula

There are a number of ways that spacing could be implemented. First, lessons over a given topic could be organized into smaller doses and delivered with breaks in between, rather than delivering a single longer lesson over the same topic. Even small breaks in between learning opportunities can produce significant enhancements in learning.
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Second, instructors may incorporate into a given lesson some concepts from previous lessons. This could be accomplished via in-class activities, or on homework or other assignments where students work with material that they have learned at an earlier time, in conjunction with material that they are currently learning. This affords not only a chance to revisit previously learned material at spaced intervals, but also to compare and contrast concepts that may otherwise be confused (e.g., the procedure for adding vs. multiplying fractions), helping to clarify and solidify the knowledge of these important distinctions.

Third, instructors could create cumulative exams and quizzes. Such exams require students to engage with previously learned material and also encourage students to review previously learned material in preparation for the exams. Indeed, perhaps due to the spacing afforded by cumulative exams, there is some evidence that cumulative exams produce better learning of course concepts than non-cumulative exams (Lawrence, 2013).

Finally, students and teachers can harness the power of technology to implement spaced study and review. Students have a number of easy-to-use online tools at their disposal—such as calendars, flashcards, or Quizlet apps—that they can use to create a schedule (with automatic reminders) for studying course information at specific times. Teachers can also use course management systems or other online tools to schedule assignments and quizzes on particular days and times that are designed to provide spaced practice of the material being learned.

Potential Challenges Involved in Implementing Spacing

Some key challenges are likely to arise from incorporating spacing into educational curricula. First, when repeated learning opportunities are spaced in time, students are likely to forget some of what they have learned previously. When they re-encounter this information in a subsequent spaced learning opportunity, they may feel like they have not learned it very well. In contrast, when learning is massed into one continuous session, the information becomes highly familiar, so it is easy to feel like learning is occurring. Indeed, research shows that even though students learn better from spacing, they often report that they feel they learn better from massing (e.g., Birnbaum, Kornell, Bjork, & Bjork, 2013; Kornell & Bjork, 2008; Zulkiply & Burt, 2013). This feeling is misleading, however, as massing may create a sense of familiarity in the short term, but does not lead to durable learning in the long term. Spacing, although it introduces the feeling of difficulty, leads to much more effective learning. This sense of difficulty, although good for learning, may create a sense of discouragement in students, lack of effort invested in learning, or disinterest in the material. The non-intuitive nature of spacing can be a challenge for getting students to embrace it. However, consistent opportunities to learn via spacing, and to see the positive outcomes, provides the chance for students to directly witness these benefits and enhance their confidence in an approach that may be at first quite unfamiliar to them.
Second, students may not find it desirable to re-learn information they have already learned. Cumulative exams in particular do not tend to be widely popular among students, perhaps partly due to the impression that there is more information to learn than for non-cumulative exams. The more frequently information is reviewed via spacing, however, the more readily previously learned information can be remembered. This reduces the need to re-learn information that has been forgotten, and also increases the potential positive reinforcement associated with successfully remembering previously learned information.

Third, implementing spacing into educational curricula requires teachers and students to set a particular schedule for spaced learning activities. Traditional instruction is typically set up in a “blocked” fashion, where one topic is taught until it is finished, and then another topic is introduced and taught in its entirety, followed by another, and so on, often without reference to previously learned topics. In mathematics instruction, for example, a given topic (e.g., adding fractions) is taught, complete with practice activities and homework, and then no longer revisited once the topic changes (e.g., to multiplying fractions). In foreign language instruction, particular grammar rules are usually covered in depth (e.g., conjugating verbs in the present tense) and not revisited again during a subsequent lesson covering a different rule (e.g., conjugating verbs in the past tense). Implementing spaced instruction requires making changes to this routine by creating lessons and assignments that incorporate previously learned concepts. This requires time and some advanced planning, which can be a challenge given the already very busy schedules of teachers. It is expected, however, that the payoffs in student long-term learning would make the investment of time and effort worthwhile.

Finally, when students set a spaced schedule for studying and reviewing course material, sticking to such a schedule can be difficult. Despite the best intentions, many students engage in the ever-popular practice of “cramming” for exams by doing all of their studying within a small window of time before the exam (Geller et al., 2018). This runs counter to what would be the more effective approach of studying and reviewing course information at regular spaced intervals. Given the natural tendencies of students to procrastinate on studying, spaced review may need to be incentivized by incorporating regular review quizzes or graded assignments at key times during the course.

Limitations of Existing Literature and Directions for Future Research

Research on the spacing effect shows that it has great potential to enhance learning in educational domains. The ultimate impact that it has on education, however, will depend on its successful implementation by students and teachers. Many promising ideas fail to impact education because they are not consistently implemented in everyday instruction (Henderson, Mestre, & Slakey, 2015). Henderson, Dancy, and Niewiadomska-Bugaj (2012) found that even when instructors are aware of effective learning principles and motivated to use them in their courses, over one third of instructors end up discontinuing the use of
these principles. This suggests that there may be external barriers to the implementation of particular pedagogical approaches that reduce the sustainability of these approaches, even for instructors who are eager to use them. If a given approach is difficult to implement, or not sufficiently supported, its potential to improve education is inherently limited.

The literature on spacing effects in educational settings shows that, when implemented fully (usually by the researchers who designed the study), a spaced learning schedule positively impacts learning. However, very little is known about how such findings translate into autonomous and consistent implementation by students and teachers, what barriers to implementation exist, and the ultimate long-term feasibility of using spacing on a regular basis. What is greatly needed, therefore, is systematic research on students’ and teachers’ use of spacing in real educational settings, and what factors influence their decisions to use it or not use it. In particular, how readily can the research on spacing effects be translated into a clear lesson plan? What are the challenges and barriers involved in creating such a plan, and how easily can it be sustained over time? Research that addresses these questions will shed new light on the promises and pitfalls of using spacing in education, and will identify points where resources should be provided to teachers to help facilitate implementation. For example, if a key concern is the time investment needed to create lessons that utilize spacing, research and development efforts could be invested in the creation of adaptable, prepackaged lessons with built-in spacing schedules that can be used as-is or easily modified by teachers to fit a variety of courses.

Realizing the full potential of spacing to improve education will require continued research efforts in educational settings and partnerships between researchers and teachers to discover optimal ways of implementing spacing within real-world educational environments. Such efforts must be equipped to adapt to ever-changing educational contexts, including the increased use of technology, the focus on individualized and adaptive learning, and efforts to understand the role that non-academic factors play in the learning process. As the spacing effect has stood the test of time (Ebbinghaus, 1913), it is hoped that continued efforts to understand more about the role of spacing in real-world learning can shed new light on its potential to be flexibly adapted to meet future education needs.

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**Further Reading**

Distributed Practice or Spacing Effect


References


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