The spacing effect: Organizing educational content across a curriculum

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Executive Summary

Memories are stored in plastic changes of neural networks.
When we "remember" something, the memory that we are recalling is re-consolidated in a more stable and permanent way.
Thus, each "remembering" reinforce the memory.
Not all king of recalling memories are equal: spaced recall is most effective than massed recall to reinforce the memory in the long term (this is called "spacing effect")
The spacing effect was demonstrated across various curricular contents, ages and with different testing situations.
It will be important for teachers (to organize curricular content and practice) as well as for students (to organize study times) to know about the spacing effect

How are memories stored in the brain?

From a neuroscience perspective, learning is coding information in memory so that it can be retrieved when it is needed (https://solportal.ibe-unesco.org/articles/learning-and-memory-how-the-brain-codes-knowledge/). In other words, memories can be understood the brain's representations of information acquired by learning (https://solportal.ibe-unesco.org/articles/neuroplasticity-how-the-brain-changes-with-learning/).

But how does our brain code information in memory? Memories are stored in plastic changes of neural networks. Those plastic changes can involve the modification of preexisting neural networks, or the generation of new circuits, to become more stable over time[1,2]. One kind of plastic change is when connections in a neural network in which memories are stored are reactivated – that is, when we "remember" something. When such retrieval and reactivation of a memory occurs, the memory that we are recalling is actually slightly changed and then re-consolidated in a more stable and permanent way[3]. Because retrieving a memory reactivates some of the same neurons and connections that were activated in the original learning session, each "remembering" reinforce the memory[3]. However, not all types of retrieval work with the same efficacy to reinforce memories.

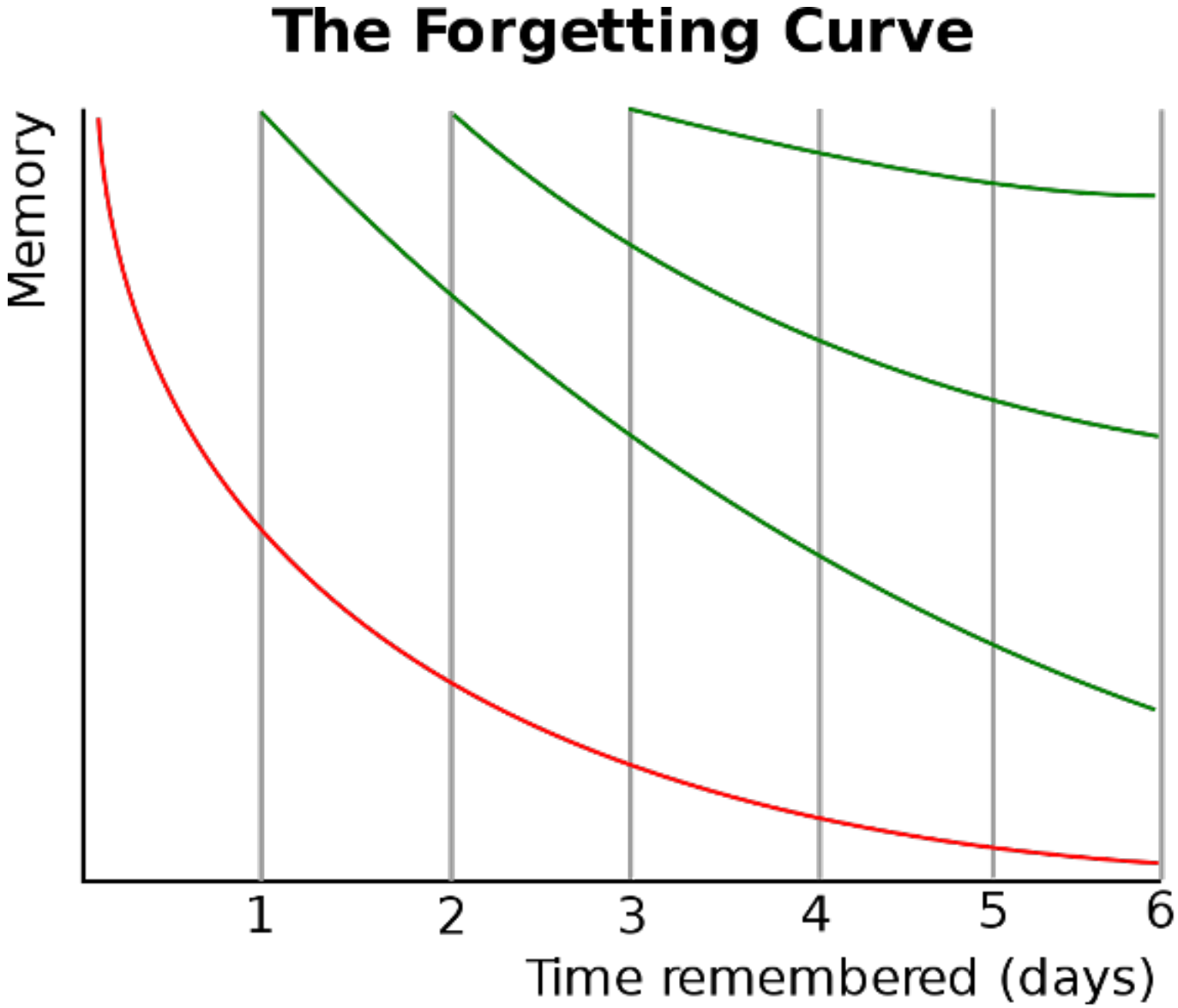
The spacing effect

One aspect particularly studied by psychologists is the difference in efficacy between retrieving information from memory in a spaced vs in a massed way. In other words, the question that has worried psychologists for more than one century [4,5] was whether studying a content including long intervals between retrieval sessions (spaced learning, for example when you study every day for 30 minutes until an exam) was better than studying the same content, during the same amount of time, but distributed in a massed way (training that includes short or not inter-trial intervals, for example, when you study everything the night before the exam). To be "better", in those studies, was to promote a more persistent formation of those content; to check what "method" is better, subjects are instructed to learn some content (usually, two lists of words), one of them throughout the spaced and the other throughout the massed way. The number of words recalled after each study method is compared. And usually, after some days, the number of words recalled is registered again, to see the efficacy of each method in the long term.

By far, the vast majority of studies analyzing this showed that spaced learning improves memory retention of the content in the long term. This well-demonstrated result is called "the spacing effect"[1,1] (Figure 1).

Figure 1. Scheme of the spacing effect: retrievals separated in intervals promote remembering.

Figure reprinted from: Forgetting curve. (2022, November 28). In *Wikipedia*. https://en.wikipedia.org/wiki/Forgetting_curve



Of main importance for educators, the spacing effect was also observed in classroom education, it is, with more complex content than mere lists of words. For example, one study conducted in Germany[6] analyzed the spacing effect regarding the learning of mathematical content across third grade of primary school and seventh grade of secondary school. To do that, 213 students first received a mathematical lesson according to their curriculum. Later, they were matched by their last grade in math and, balanced by that grade, they were divided into two groups: one of them had 3 sets of practice in the same day (massed group); the other group had the same practice but distributed in 3 consecutive days (spaced groups). In grade 3 the content taught was addition and multiplication. In grade 7th of secondary school, it was probability. Finally, their math performance was tested 1 and 6 weeks after the last practice session. Results showed that distributing mathematical practice across 3 days improved the mathematical performance of students in elementary and secondary school, at least up to 1 week after the last practice session. In secondary school, the advantage of spacing practice was also observed 6 weeks after the last session.

Similar results were found in other classroom studies[7]. This evidence suggests that, in real classrooms, organizing curricular content in a spaced way, might be beneficial to promote long term learning, in elementary and secondary school students.

What do we know about the spacing effect?

Has the spacing effect been demonstrated with various educational content?

Spaced learning is more effective than massed learning for facts, concepts, lists and actions related to a variety of educational contents[8].

For example, with elementary school children, advantage of spacing practice were demonstrated regarding learning about math[9], science [10], history content[11]; and vocabulary[12,13] between others. In adults, it was also shown regarding motor learning (e.g., pressing keys[14]), or physics (e.g., physic laws[15]). Together, the results of these studies suggest that the spacing effect does not depend on a specific educational content: instead, it seems a memory effect that occurs across multiple educational domains.

Does the spacing effect work with various "learning tests"?

One question in this context is whether the spacing effect is valid independently of which tests were used to evaluate the advantage of distributed practice. In other words, when you have to learn something for later recognizing it (for example when you have to recognize the correct option in a multiple choice test) is not the same cognitive process as when you have to remember the answer to a question without any cue. So, is the spacing effect valid in all those cases? Evidence suggests that it is. The spacing effect was demonstrated with different types of tests, including free recall (when you voluntarily remember something without any cue from the environment), cued recall (when you have a cue that helps you to remind something, for example, entering in the same room in which the memory was acquired might be a cue for recall), and recognition (when you are exposed to a stimulus, for example, images, and you have to remember if you have seen them or not before)[8]. Thus, various kinds of tests can work as retrieval for producing the spacing effect. In fact, testing is itself a fantastic way of enhance learning (see [16] for a review on how testing can improve content retention in memory).

Does the spacing effect work across all ages?

Research has demonstrated that spaced learning promotes memory across the lifespan, including infancy and childhood (e.g., [17,18]). Most studies about the spacing effect have been conducted with adults[19], but this effect has also been largely demonstrated in childen. Although we still do not know clearly whether the size of the spacing effect could vary according to age (e.g., [20]), the effect itself was clearly demonstrated across all ages.

What are the optimal times for the spacing effect?

We still do not have enough evidence to fully answer this question. The finding that spaced learning schedules promote memory has been observed across many timescales, from a matter of seconds to yearlong intervals (e.g., [21]) but, by now, it is not possible to say an optimal timing to teach a specific content. Instead, it is possible to affirm that in general results showed that less intense training, spread across a larger number of days, provides better learning of a content (e.g., [22]). But, besides that general claim, the optimal intervals needed to learn each content still remain unknown[19].

Conclusion

The spacing effect refers to a fundamental issue on learning and education in general: every day students are faced with the decision of when to study information; and teachers are faced with the decision of how to distribute practice of a given content across school time. The timing of practicing and study, and how it affects memory retention, has been explored for many years in research on human learning. The spacing effect has a robust support from psychology. Neuroscience has also started to shed ligh to the neural mechanisms explaining that effect.

What is the importance of the spacing effect for education?

On one hand, it gives an insight in how to organize content along the curricula. Some contents, as "reading", once acquired, are practiced in distributed ways and every day. But it is not the case of various other contents: school curricula have been, in a big part, is organized in a massed way[7]. Knowing about the spacing effect can help educators to distribute content in a more effective way. There are various ways of retrieval contents, for example, giving homework related with previously studied content, opening lessons with brief reviews and making cumulative tests (i.e., exams including the older and newer content).

On the other hand, knowing about the spacing effect has implications for the students themselves. To "cramming" for a test (e.g., trying to review all the material the night before a test) might not be useful if we really want to remember that content in the long term. Instead, distributing the time for studying across various days will be more effective and, in the end, you will be investing the same total amount of time. In sum, including information about the spacing effect could help students to organize their study time in better ways. Teachers can help students to organize that based on current knowledge of the

spacing effect. Students can try to make connections between old and new concepts (e.g., compare and contrast them). Finally, they can produce their own self-test, to produce the retrieval needed for the spacing effect.

In sum, including information about the teaching effect is important for students as well as teachers.

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