Temporal Spacing and Learning

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Studies going back a century and more have found that spacing learning episodes across time sometimes enhances memory. The so-called spacing effect is the topic of hundreds of articles, and one might assume that we know all we need to know about it. However, the subtitle of an article on spacing effects that Frank Dempster published in *American Psychologist* in 1988 — "A case study in the failure to apply the results of psychological research" — remains appropriate now. Whether one looks at classrooms, instructional design texts, or language learning software, there is little sign that people are paying attention to temporal spacing of learning.

Before pointing fingers, it is reasonable to ask: exactly what advice can we offer with confidence? Reviewing the literature, our research team (which includes John Wixted and Shana Carpenter from University of California, San Diego, along with the three of us), supported by Institute of Education Sciences concluded: "not very much" (Cepeda, et al., in press). Despite numerous papers, very few researchers have examined memory after retention intervals of even one week. In some pioneering studies, Harry Bahrick showed that long inter-study spacing can enhance learning over years, but he trained subjects to a criterion of mastery on each session, thus allowing study time to grow with spacing. All in all, we concluded that psychology could not yet offer specific advice about how to make the most efficient use of study time. Moreover, research has focused heavily on recall of word lists, and some have suggested that more complex or less "rote" forms of learning might not show spacing benefits at all. Our team has set about seeking to close some of these various gaps in knowledge to allow a translation of basic spacing research into practical contexts.

Optimal Spacing Intervals

In one recent study, we gave 161 subjects two learning sessions (separated by an inter-study interval, or ISI, from minutes to 3 months). Each session involved learning a set of obscure facts. Six months after the second session, subjects were brought back for a final test. Performance was best when the ISI was 10 to 20 percent of the retention interval (Cepeda et al., 2006). Similar results were found when the same subjects learned names of unusual objects depicted in photographs.

In a study currently under way using the Web, more than 2,000 subjects are being trained at inter-study intervals from minutes out to one year, with a final test taking place after an additional year. While data are still accruing, the results seem to provide clear support for the approximate ratio rule described above. Furthermore, the benefits of spacing seem to grow ever larger as retention intervals are lengthened; thus, for one-year retention, a one-month spacing produces a three-fold or greater increase in memory as compared to a day or even a week of spacing. While increasing spacing too much always produces some decline, as earlier short-duration studies had implied, the decline is invariably quite modest. Therefore, to facilitate retention over years, it seems critical to space training over several months at least, but avoiding overly long spacing seems like a relatively minor concern.

Mathematics Learning

To move beyond these somewhat "rote" learning tasks, the University of South Florida wing of our team under the direction of Rohrer has been teaching students abstract mathematics skills (e.g., Rohrer & Taylor, 2006). In a study run with Kelli Taylor, students learned to solve a type of permutation problem, and then worked two sets of practice problems. One-week spacing separating the practice sets drastically improved final test performance (which involved problems not previously encountered). In fact, when the two practice sets were back-to-back, final performance was scarcely better than if the second study session was deleted altogether. This fits with other research from our team showing that benefits of over-learning decline sharply with time (Rohrer, et al., 2005).

Interestingly, most mathematics textbooks follow precisely the approach that our studies find so ineffective: a brief lesson on a topic is followed by a practice set containing virtually every problem in the book relating to this topic. Far more useful, we suspect, is to intersperse problems related to older topics covered over past weeks and months.

We have also been looking at spacing effects in acquisition of visuospatial skills, such as artificial categorization tasks and classification of skin lesions as arising from melanoma versus other conditions. Interestingly, we have thus far found little spacing benefit in this domain.

Obviously, we have much more to learn about spacing, but from our results so far we are confident that the potential of spaced practice to reduce forgetting is enormous — and we are optimistic that an adequate empirical basis for choosing optimal timing of study sessions for practical purposes may finally be starting to emerge.

References

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