

Spaced Repetition

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Spaced repetition is a learning technique that incorporates increasing intervals of time between subsequent review of previously learned material; this exploits the psychological spacing effect. Alternative names include spaced rehearsal, expanding rehearsal, graduated intervals, repetition spacing, repetition scheduling, spaced retrieval and expanded retrieval.

Spaced repetition is particularly applied to vocabulary acquisition and learning Chinese characters as part of language acquisition, due to the volume of data involved - some programs, such as Anki, have specialized support for these goals - but it is of general applicability.

Research and Applications

The notion that spaced repetition could be used for improving learning was first proposed in the book *Psychology of Study* by Prof. C. A. Mace in 1932. In 1939, Spitzer tested the effects of a type of spaced repetition on 6th Graders in Iowa to learn science facts. Spitzer tested over 3600 students in Iowa and showed that spaced repetition was effective. This early work went unnoticed and the field was relatively quiet until the late 1960s when cognitive psychologists, notably including Landuaer & Bjork and Melton, explored manipulation of repetition timing as a means to improve recall. Around the same time, Pimsleur language courses pioneered the practical application of spaced repetition theory to language learning and in 1973, Sebastian Leitner devised his "Leitner system", an all-purpose spaced repetition learning system based on flashcards.

At the time, spaced repetition learning was principally being implemented via flashcard systems; these systems were somewhat unwieldy since any significant study base requires many thousands of flashcards. With the increase in accessibility of personal computing, spaced repetition began to be implemented with computer-assisted language learning software-based solutions in the 1980s. The aim of these programs was to tailor the repetition spacing based on learner performance. To enable the user to reach a target level of achievement (e.g. 90% of all material correctly recalled at any given time point), the software adjusts the repetition spacing interval. Material that is hard is shown more often and material that is easy is shown less often, with hard or easy being defined by the ease with which the user is able to produce a correct response.

There are several families of algorithms for scheduling spaced repetition:

Neural networks based

Sebastian Leitner system learning machines: 5 stages and an arbitrary number of stages

SM-family of algorithms (SuperMemo): SM-0 (a paper implementation) to SM-11 (in SuperMemo 2006)

Some have theorized that the precise length of intervals does not have a great impact on algorithm effectiveness, although it has been suggested by others that the interval (expanded vs. fixed

interval, etc.) is quite important; the experimental data regarding this point are mixed.

Pimsleur's graduated-interval recall

Graduated-interval recall is a type of spaced repetition published by Paul Pimsleur in 1967. It is used in the Pimsleur language learning system and it is particularly suited to programmed audio instruction due to the very short times (measured in seconds or minutes) between the first few repetitions, unlike other forms of spaced repetition which may not require such precise timings.

The intervals published in his paper were: 5 seconds, 25 seconds, 2 minutes, 10 minutes, 1 hour, 5 hours, 1 day, 5 days, 25 days, 4 months, 2 years.

By timing a Pimsleur language program with a stopwatch, it is possible to verify that the intervals are not followed exactly but have upper and lower bounds. A similar principle (graduated intervals with upper and lower bounds) is used in at least one open source software project (Gradint) to schedule its audio-only lessons.

Prominent researchers

Hermann Ebbinghaus

Thomas K. Landauer and Robert A. Bjork

Cecil Alec Mace

Prominent practitioners

Paul Pimsleur

Sebastian Leitner

Piotr Woźniak

Software

Most programs are modeled after the manual style of learning with flashcards: items to memorize are entered into the program as question-answer pairs; when a pair is due to be reviewed, the question is displayed on screen, and the user must attempt to remember the answer; when the user has succeeded or failed, the answer is manually revealed, and then tells the program how easily he recalled the answer or failed to. The program schedules pairs based on spaced repetition algorithms. Without a program the user has to schedule flashcards; this takes time and restricts to simple algorithms like the Leitner system.

Further refinements are found:

Question/answer can be a sound-file to train the recognition of spoken words.

Automatic generations of pairs; e.g. for vocabulary it's useful to generate a three question-pairs, written foreign word, its pronunciation and its meaning, but data has to be typed only once.

Show addition information retrieved automatically, like example-sentences containing a word.

Support advanced input formats such as LaTeX.

Using a web platform instead of an installable program.

Combine spaced repetition with online community functions, e.g. sharing courses.

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