# Distributed Practice and ALEKS's Memory Stacks Algorithms

Facts and skills are more efficiently and more permanently mastered if the learning experiences are spaced over time rather than massed in a short period. This was recognized by the German psychologist Hermann Ebbinghaus as early as 1885, and was confirmed by numerous experimental studies since then. The name attached to this method is *distributed practice*[1]. Its superiority over *massed practice* has been demonstrated for a wide variety of contents, including the retention of mathematical facts and rules (see, among many other relevant references Caple, 1996; Clayton, 1974; Good and Grouws, 1979; Reynolds and Glaser, 1964).

The design of ALEKS QuickTables is based on this important principle. In the case of the multiplication table, QuickTables initially presents the student with only a very small number of problems, say: $3 \times 7$, $4 \times 6$ and $5 \times 4$. This means that the student may be asked to solve, in a random succession, a sequence of multiplication problems such as

$$3 \times 7 = ?, \quad 4 \times 6 = ?, \quad 5 \times 4 = ?, \quad 3 \times 7 = ?, \ldots \text{etc.}$$

When the student reliably responds 21 when presented with $3 \times 7$ in this context of only 3 different problems, the $3 \times 7$ problem is moved into a larger context involving more multiplication problems, and then gradually into larger and larger ones, until perfect recall is achieved, which implies a permanent storage of the association (between the operation and its result) in long-term memory. Obviously, the sizes of the successive contexts and other details of these temporal successions are critical, and may vary with the type of operation.

This concept is implemented in ALEKS by a computer algorithm based on a number of *memory stacks* as illustrated by Figure A. We outline this algorithm here without going into all the intricate details of the program. During the initial stage of memorizing the result of $3 \times 7$, this operation is stored in the computer in *Memory Stack 1* which is equipped with a small number of slots, say three. Thus, three operations are stored there. The computer presents these three operations in a random sequence until the student's responses have reached a predetermined criterion of successful recall for a particular problem, say $3 \times 7 = 21$. This problem is then moved into *Memory Stack 2*, which contains a larger number of slots. When this memory stack is filled, the student is tested for the problems in that stack, also presented in a random sequence. As Memory Stack 2 contains more slots than Memory Stack 1, the time interval between two tests of $3 \times 7 = 21$ tends to be longer. As a consequence, the recovery of the association between $3 \times 7$ and 21 from memory is more demanding, and begins to exercise long-term memory retrieval mechanisms.

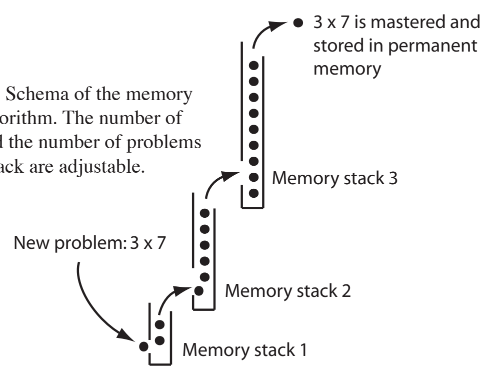


**Figure A**. Schema of the memory stacks algorithm. The number of stacks and the number of problems in each stack are adjustable.

[1] Also called *spaced practice*.

Ultimately, $3 \times 7 = 21$ ends up in the last stack and is tested as before. Whenever the student's response for $3 \times 7$ reaches the criterion for that stack, that particular problem is removed from Memory Stack 3 and the problem is regarded as having been mastered, which is a reasonable surmise in view of the large number of problems in that stack.

For obvious reasons, the various parameters of this memory stack algorithm, namely, the number of stacks, the number of slots in each stack, and the criterion of success for each stack, are optimized on the basis of experimental data to ensure both the efficiency of the learning process and the permanence of the acquisition. The design of the other ALEKS QuickTables—for addition, subtraction and division—is similar.

The references listed below are but a small sample from the literature on the distributed practice phenomenon, which is considerable.

# References


C. Caple. *The effect of spaced practice and space review on recall and retention using computer assisted instruction.* Doctoral dissertation, University of Michigan, Ann Arbor, MI, 1996.

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