RETRIEVAL PRACTICE AND THE MAINTENANCE OF KNOWLEDGE [1]

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ABSTRACT

A critical aspect of the maintenance of knowledge is maintaining access to that knowledge in memory. The key to maintaining such access is to use that information: The act of retrieving an item from memory facilitates subsequent retrieval access to that item. The most efficient scheduling of such "retrieval practice" is in terms of an expanding sequence, as shown by Landauer and Bjork (1978). As a mnemonic technique, expanding retrieval practice has a number of practical advantages, and the non-semantic nature of that technique has implications re the nature of storage in and retrieval from human memory.

Recently, a Research Psychologist for the United States Army told me that the Army is increasingly concerned with the "retention and maintenance of critical skills and knowledge." It is one thing to carry out training until some performance criterion is reached; it is another to structure training and post-training experience to insure that performance is maintained over time. The real problem, of course, is keeping information retrievable. Knowledge, once successfully integrated into long-term memory, tends to remain there, but as time goes on and/or contexts change, we are frequently unable to access some knowledge that was readily accessible to us at some earlier point. When that knowledge is necessary to solve some realworld problem, it is often not recallable, though a recognition or cuing procedure would usually reveal that the "missing" information exists in memory (e.g., Bahrick, Bahrick, & Wittlinger, 1975; Wagenaar, 1986).

RETRIEVAL AS A MEMORY MODIFIER

One key to maintaining access to knowledge in memory is to use--that is, retrieve--that information periodically. In contrast to other memory systems, such as a tape recorder or the memory in a computer, where retrieving stored information does not alter the state of that information in memory, human memory is altered in significant ways by an act of retrieval. The retrieved information becomes more retrievable in the future than it would have been without such an act of retrieval, and certain related items of information in memory may become less retrievable (e.g., Bjork, 1975; Roediger & Neely, 1982). It is not my goal here to discuss the empirical or theoretical details of such effects. Rather, I want to focus on retrieval practive as a mnemonic technique.

[1] In M.M. Gruneberg, P.E. Morris, & R.N. Sykes (Eds.), Practical Aspects of Memory: Current Research and Issues. New York: Wiley 1988, pp. 396-401.

Basic Results. Assume a situation where one is presented with an initial opportunity to store some information in memory. That information might be relatively simple, like a name, number, or foreign vocabulary item--or more complex, like a chapter in a book. Assume further that at some later point (T1), one attempts to retrieve that information. That attempt might be successful or unsuccessful, but assume there is no external feedback as to whether what one recalled, if anything, was correct or incorrect. Now assume that at some still later point (T2) there is a second test of our ability to recall that same information. To the extent that performance on the second test exceeds performance in the case where there was no first test, we can say that the first test was valuable as a learning (memory enhancing) event.

The empirical facts of importance for present purposes are the following. (a) In general, without considering whether the effort to retrieve at T1 was successful or not, performance at T2 profits substantially from the existence of a first test. (b) Under some circumstances such positive effects of a first test on a second test, unconditional on the outcome of the first test, can exceed the positive effects (on performance at time T2) of a second study opportunity presented at time T1. (c) Failure to retrieve the item correctly at T1, however, does not help recall at T2. The probability of successful recall at T2 given a failure to recall at T1 is typically very close to zero.

A Retrieval-Practice Interpretation. Given that an initial act of retrieval facilitates a later effort to retrieve, it remains to specify the mechanisms through which that facilitation takes place. The idea I want to push here is that an initial retrieval aids a later retrieval to the extent that it constitutes practice for that later retrieval--that is, to the extent that the processes involved in the initial retrieval overlap the processes required to retrieve that item later. Retrieval of information from long-term memory is a complex, highly fallible aspect of human memory. As such it is a kind of skill, and like other skills, can profit greatly from practice.

A central assumption of the retrieval-practice idea is that an act of retrieval does not simply strengthen an item's representation in memory, but, rather, enhances some aspect of the retrieval process per se. Among the considerations supporting that assumption are the following. (a) If an initial retrieval simply strengthened an item's representation in memory, one might expect that an initial test of recall might facilitate a later test of recognition as much as it does a later test of recall. Typically, however, the effects of an initial recall test on a later recognition test are far less than on a later recall. (b) If, on the other hand, one makes a later recognition test more difficult in ways that might be viewed as making that recognition test more recall-like, than the positive effects of an initial recall test are much larger (Gelfand, Bjork, & Kovacs, 1983). (c) Similarly, as Whitten and Leonard (1980) have shown, as one makes an initial test of recognition more difficult, and recall-like, by increasing the alternatives on an initial forced-choice test, performance on that test decreases but later recall increases.

The effects of delaying a first test on performance on a second test also support the retrieval practice interpretation. As we delay the first test, P(T1), the probability of successful recall at the time of the first test, decreases. Because failure to recall at T1 does not help performance at T2 (i.e., P(T2 given not T1) equals zero), we might expect that the positive effects of a test at T1 on performance at T2 (given a fixed interval from T1 to T2) would decrease. In fact, real data often show a strong increase in performance at T2 as T1 is delayed from essentially zero to some moderate interval, even though performance at T1 shows a strong drop over that range.

The implication of such delay-of-test effects can be seen most clearly in terms of elementary probability theory. The probability of correct recall at T2, P(T2), can be partitioned into

P(T2) = P(T2 given T1) P(T1) + P(T2 given not T1) P(not T1),

which simplifies to

P(T2) = P(T2 given T1) P(T1),

because P(T2 given not T1) is essentially zero. As T1 increases, we know that P(T1) decreases, but that P(T2) initially increases. That can only happen if P(T2 given T1) increases faster than P(T1) decreases. Apparently a successful retrieval becomes more potent as a learning event with delay—so much so that it offsets the decrease in the likelihood of success (for another type of demonstration that initial retrieval difficulty enhances subsequent recall, see Gardiner, Craik, & Bleasdale, 1973).

Such results have a straightforward interpretation in terms of the retrieval practice notion. As a first test is delayed, it becomes more like the second test in terms of the processes involved. An immediate effort to retrieve a just-presented name or number, on the other hand, though successful with probability close to one, constitutes poor practice for a later effort to retrieve that name or number from long-term memory.

The fact that tests can be more effective than presentations is also consistent with the retrieval practice interpretation. Being presented an item does not constitute retrieval practice. Whenever we ask someone to tell us a name or number that might be retrievable from our own memory, we rob ourselves of a learning opportunity.

RETRIEVAL PRACTICE AS A MNEMONIC TECHNIQUE

The Optimal Schedule. Ten years ago Tom Landauer and myself became interested in how one should best schedule one's retrieval practice. We were particularly interested in those real-world situations where information is presented once—such as being introduced to someone at a party. It is not good form to write a person's name down when one is introduced, nor is it seemly to keep asking someone their name. What one can do is to rehearse (practice retrieving) that person's name. But how should one schedule one's efforts to retrieve? What people tend to do (if they do any rehearsal at all) is immediate massed rehearsal. From the delay-of-test results mentioned above, and the retrieval practice interpretation of those results, one would not expect such rehearsal to be optimal. What about spacing one's rehearsals to

the maximum extent possible in the time available? That strategy runs the risk of producing a failure to recall on the very first effort to do so, which would lead to failures as well on the subsequent efforts.

To make a long story short, we discovered that there was a uniquely optimal way to sequence one's retrieval practice. A nearly immediate first rehearsal should be followed by additional rehearsals at successively longer delays. Such an expanding schedule constitutes a kind of optimal shaping procedure. Each successive retrieval helps insure a successful retrieval after the next (longer) interval, and as the interval gets longer each retrieval becomes more potent as a learning event. In principle, if one were able to do so, one should schedule each successive retrieval just prior to the point where one would otherwise lose access to the item in memory.

We also found, among the schedules we examined, that what people usually do--massed retrieval practice--is the uniquely non-optimal way to schedule rehearsals. When we presented our research at the first of these conferences, Ulric Neisser was moved to write the following verse. "You can get a good deal from rehearsal/ If it just has the proper dispersal./ You would just be an ass/ To do it en masse:/ Your remembering would turn out much worsal."

Practical Advantages. Expanding retrieval practice is a potent mnemonic technique. Landauer and Bjork (1978) found in their second experiment that a single presentation of a name followed by an expanding schedule of four tests on that name resulted in better long-term recall of that name than did five presentations of the name at the same intervals. In two pilot studies at UCLA (with names, paired associates) we found expanding retrieval practice to be roughly as effective as imagery-based mnemonic systems. Rea and Modigliani (1985) found that the retention of multiplication facts tested at expanding intervals was about twice that found after a massed series of tests.

Beyond being effective, expanding retrieval practice has other attractive attributes. It involves a low failure rate, for example, which can be useful in working with children and certain other populations. It is also a relatively low-level cognitive activity, which means that it can be interspersed during other demanding cognitive activities, such as introducing perople to each other, carrying out a conversation, or driving in a strange town. Imagery-based systems, on the other hand, can be disruptive of such activities because they are demanding from a cognitive standpoint.

Schacter, Rich, and Stampp (1985) attempted to take advantage of the foregoing attributes of retrieval practice in working with amnesic patients. Such patients have a learning-to-learn problem with traditional mnemonic techniques: A technique works to some degree while the patient is being guided in its use, but there is no transfer of training to later occasions when the patients are on their own. Schacter et al. reasoned that expanding retrieval practice might be a better technique from a transfer of training standpoint, and they found some evidence of such transfer in the four patients who served as subjects in their experiment.

Finally, expanding retrieval practice permits an efficient meshing of the retrievals of older items and newer items. The access to older items is maintained via less and less frequent retrievals, which creates "room" for the more frequent retrievals of newer items. That property is particularly desirable in acquiring and maintaining access to a large "vocabularly" of some kind. The study reported by Linton in this volume is a good example. Linton has used expanding retrieval practice as part of her multiyear study of her own acquisition and retention of the common and scientific names of flowers (she had learned the names for about 1600 flowers as of the time of this conference). As the pool of items grows, via new items being added, the "required maintenance" of old items also decreases in frequency, which means that the time demands of such an acquisition/maintenance project can remain relatively constant.

IMPLICATIONS OF THE RETRIEVAL PRACTICE IDEA

The Nature of Storage in LTM. As typically characterized, storing new information in long-term memory requires interpreting, elaborating, or interassociating that information in terms of existing knowledge in long-term memory. Consider, however, an expanding series of tests of the kind employed by Landauer and Bjork (1978). From the subject's standpoint, the whole intertwined series of presentations and tests was fast-paced and demanding. Even the occasional subject who might have known something about traditional mnemonic techniques would not have had the time to employ such techniques effectively, nor did subjects claim to have used any semantic-encoding devices in those experiments. It also does not seem tenable to argue that a test at a longer delay involves more semantic elaboration than does a test at a shorter delay. The fact that expanding retrieval practice is a non-semantic mnemonic technique questions our typical characterization of storage in long-term memory.

Retrieval Capacity as a Limited Resource. I have stressed herein that retrieving information from memory facilitates subsequent retrieval of that information. The converse, however, is also true: without being accessed periodically, information in memory--however well learned--eventually becomes inaccessible. Phone numbers, names, and other items of information that were once accessible without apparent effort eventually become non-retrievable with disuse. Elsewhere in this volume, E. Bjork and R. Bjork argue that the loss of access to information in memory with disuse has an adaptive role in the overall functioning of the human memory system. The loss of retrieval access to older, out-of-date, information facilitates the retrieval of newer, relevant, information--in terms of both speed and accuracy. Such a conceptualization requires, however, that there is a kind of capacity limitation on the retrieval process. Given that storage in long-term memory is essentially unlimited, such a limitation on the retrieval side may be adaptive.

The Importance of "Rote" Learning. If one accepts the notion that retrieval practice is central to developing and maintaining reliable access to information in memory, then rote

learning, treated with disdain by psychologists and educators alike, deserves more respect. It is a fact of life that much of what we need to learn to function efficiently are arbitrary assignments of labels, symbols, and numbers. For many tasks, such as name learning, precious little understanding can be brought to bear on the problem: The task is essentially rote. Complex intellectual skills such as language and chess are undergirded by prodigious amounts of rote memorization. Rather than regarding such learning as inferior, we should recognize that it is essential, and we should get on with the job of making such learning as efficient and painless as possible.

REFERENCES

Bahrick, H.P., Bahrick, P.O., & Wittlinger, R. D. (1975). "Fifty years of memory for names and faces: A cross sectional approach," Journal of Experimental Psychology: General, 104, 54-75.

Bjork, R.A. (1975). "Retrieval as a memory modifier," in Information Processing and Cognition: The Loyola Symposium (Ed. R. Solso), pp. 123-144.

Gardiner, J.M., Craik, F.I.M., & Bleasdale, F.A. (1973). "Retrieval difficulty and subsequent recall," Memory & Cognition, 1, 213-216.

Gelfand, H., Bjork, R.A., & Kovacs, K.E. (1983, November). "Retrieval as a recognition-memory modifier: A distribution-based theory." Paper presented at the meeting of the Psychonomic Society, San Diego, CA.

Landauer, T.K, & Bjork, R.A. (1978) "Optimal rehearsal patterns and name learning," in Practical Aspects of Memory (Eds. M.M. Gruneberg, P.E. Morris, & R.N. Sykes). pp. 625-632, Academic Press, London.

Rea, C.P., & Modigliani, V. (1985). "The effect of expanded versus massed practice on the retention of multiplication facts and spelling lists," Human Learning, 4, 11-18.

Roediger, H.L., & Neely, J.H. (1982). "Recall as a self-limiting process," Memory & Cognition, 6, 54-63.

Schacter, D.L., Rich, S.A., & Stampp, M.S. (1985). "Remediation of memory disorders: Experimental evaluation of the spaced retrieval technique," Journal of Clinical Neuropsychology, 7, 79-96.

Wagenaar, W.A. (1986). "My memory: A study of autobiographical memory over six years," Cognitive Psychology, 18, 225-252.

Whitten, W.B., & Leonard, J.M. (1979). "Learning from tests: Facilitation of delayed recall by initial recognition alternatives," Journal of Experimental Psychology: Human Learning and Memory, 6, 127-134.