

Interference and Assessment:
How Long Should We Wait to Test Students?

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Assessment is becoming increasingly important in today's educational system. *No Child Left Behind (NCLB)* requires each school to help its students attain a certain level achievement, on which funding is dependent (www.ed.gov, 2003). As each school attempts to meet this challenge and assess its students accordingly, it becomes necessary to evaluate optimal learning situations for our students and how we can best get them to meet the standards set forth by *NCLB*.

Anxiety, interference, forgetting of material and practice all interfere with the optimization of a learning situation (Covington & Omelich, 1987, Campbell, 1987, Fernandes & Moscovitch, 2000, Shebilske et. al, 1999). Today, teachers are hard pressed to teach lessons at even faster paces to cover increasing amounts of material at each grade level. Issues concern whether students should be assessed immediately after learning or at a later time, when new material also will be introduced. Determining which situation elicits optimal performance, both short and long term, is difficult. To begin the process, one must first review how students best learn and retain information and optimal situations for students to retrieve this information. The most important aspect of optimal testing is finding a temporal situation that will allow students to retrieve accurate answers most efficiently.

One often-discussed theory of intrusion in the learning process is that of the interference hypothesis, which states that responses learned within similar situations compete with one another for recall, and that the individual strength of each association determines the outcome (Mensink & Raijmakers, 1988). Responses, however, are acquired independently of one another (McGeogh, 1932). According to McGeogh, perfect recall occurs only when the testing time and situation is identical to when the material was originally stored in memory. As this situation is practically impossible, perfect recall never occurs.

Mensink and Raijmakers (1988) offer a theory that allows for contextual fluctuation and can explain the forgetting of material, or the lower probability of retrieval, at delayed times of assessment. Their search for associative memory (SAM) theory states that a cue is more strongly associated with particular material at Time A than Time B. At Time B, the cue may now have many associations paired with it, not necessarily weakening the strength of the original association, but allowing for different associations of similar or increased strengths between the cue and the newer material. At the time of retrieval, the strongest associative link will yield the answer, potentially in error.

A study conducted by Barnes and Underwood (1959), utilizing their modified modified free recall (MMFR) method, investigated associative strength and interference. The study revealed that in presenting two lists (List 1 followed by List 2), the more List 2 was presented, the greater the decrease in recall of List 1, while the recall strength of List 2 increased. These results demonstrate that part of the Mensink and Raijmakers (1988) SAM theory offering that short-term memory is formed by the discretion of rehearsal.

The more a student engages in rehearsal, the stronger the association. When retrieving the information, the stronger association yields a faster reaction time in the transfer of information than weaker associates, which lead to forgetting. According to Mensink and Raijmakers, forgetting occurs because of an increase in interfering images associated with a particular retrieval cue, or decreases in associative strengths of cues to the image requiring retrieval. However, a strong association can still yield an error.

Campbell (1987) discusses network associative interference and error priming in his research on the learning of multiplication facts among young children. Campbell offers that when solving multiplication problems, students are taught to use procedural operations to complete the process and retrieve the answers, with retrieval eventually becoming automated. However, Svenson (1985) reports that the procedural operations are not replaced by automated retrieval as practice continues, but moreover, procedural operations themselves become more automated, allowing for more facile and swift retrieval of the product. In his research, Campbell hypothesizes that practice with problems using a procedural operation should allow speed and retrieval to be transferred to other problems.

In Campbell's experiment, students were provided with an initial practice session on 36 multiplication problems. Then, 18 of the problems that had been previously designated as part of the interference set (IN) were withdrawn. Problems were designated as part of the interference set if their answers were associated with other multiplication problems or the structure of the problem was similar to another multiplication problem and often resulted in that particular problems' answer, in error. Students continued practice on the remaining 18 problems (PR) for eight additional sessions. On the tenth

and final session, the 18 interference problems were reintroduced among the other 18 problems in random order.

Campbell (1987) found that during the sessions in which the interference set of problems had been withdrawn, the tendency to remit answers to PR problems corresponding to correct IN problem answers decreased greatly. However, when the IN problems were reintroduced to the practice sessions, errors in the PR problems corresponding to a correct answer for IN problems increased again. From these results, Campbell concluded that there was sufficient evidence supporting the claim of a role of associative interference in multiplication.

The second experiment performed by Campbell provides evidence that reaction times are slowed by the introduction of IN problems. The practice set of problems was divided into 12 problems each: 12 control practice (CP), in which errors were not associated with answers in the IN set, 12 experimental practice (EP), in which errors were frequently associated with answers in the IN set, and 12 IN problems.

Students were tested on all 36 problems in the first session. However, on the second, third, and fourth sessions, only the 24 problems in the CP and EP sets were tested. In the fifth session, the IN problems were again introduced in random order among the other 24 problems. Reaction times for the EP problems decreased more with the withdrawal of the IN problems because the interfering associative strengths were removed from the situation. There was a smaller difference in reaction times in the CP problems since their answers were more weakly associated with those for the IN set of problems. Campbell concluded that these results provided important implications for

understanding how procedural operations in solving multiplication facts relate among problems and how children can be taught basic arithmetic facts effectively.

Another important aspect of interference is whether it is proactive or retroactive. Research has found that retroactive interference occurs when assessment occurs closely to learning material because recently presented information is stronger than older information. However, longer intervals between teaching and testing causes retroactive interference to level off, given that associative links between information become more equivocal in strength (Chandler, 1991). Proactive interference was not found to occur in Chandler's research, and Chandler explained this pattern using his competition hypothesis, stating that the target information was more recent and the associations were stronger as opposed to the association with information preceding the target information. Differences between interference at encoding and retrieval also have been found. Fernandes and Moscovitch (2000) presented verbal representational tasks simultaneously to students which led to a larger interference effect at retrieval than presenting a verbal task alongside a digit-recognition task.

In one experiment, Fernandes and Moscovitch (2000) auditorily presented a list of words to undergraduate students utilizing their full attention span, in other words, students focused only on these words and no other distractions, physical or mental, were offered. Next, students in the divided attention group were asked to participate in either a word-monitoring or digit-monitoring computer task while simultaneously recalling as many words as possible from the list originally presented. Students in the full attention group completed the monitoring task as a distraction task before attempting free recall of the original list of words.

The authors found that those in the divided attention group showed a significantly larger amount of interference during recall than did those students in the full attention group. Also, the divided attention group that participated in the digit-recognition task showed significantly less interference for recall of the originally presented words than those who participated in the word-recognition task. Through other experiments, Fernandes and Moscovitch (2000) found that any type of material presented at encoding diverted a student's attention away from the target material to be eventually recalled and promoted interference that produced significant deficits in recall, as measured by the number of words from the original list recalled.

Fernandes and Moscovitch (2000) concluded that these results indicated that with divided attention, interference effects at retrieval were influenced by material specificity used in the concurrent task. Thus, if the material to be retrieved was of one type of task or representation, it was prudent to delay retrieval while presenting similar material. This will help focus a student on the material to be retrieved, allowing for more facile and accurate retrieval.

When determining the structure of testing for a classroom, one should also consider the anxiety levels of students. Anxiety has been associated with a decrease in performance through interference. A small level of anxiety is appropriate in testing situations, as it promotes arousal in students. However, high anxiety levels can temporarily disrupt normal functioning and divert attention away from the specified task (Covington & Omelich, 1987).

The anxiety-blockage theory, postulated by Covington and Omelich (1987), proposes that anxiety inhibits performance of previously learned responses and does not

inhibit learning itself. If this is indeed the case, the authors hypothesized that less strenuous testing situations should yield larger increases in performance among those students originally exhibiting high levels of anxiety as compared to those who exhibit low levels of anxiety. Additionally, anxiety should increase with more complex problems, in which more incorrect responses compete with the correct answer, which in turn, decreases performance. The degree of interference from anxiety is not dependent upon the initial study effort put forth by a student because according to the author's theory, anxiety causes interference only with the retrieval of information, not with encoding of material. However, studying in test preparation does influence performance on assessments.

In Covington and Omelich's (1987) experiment, a multiple-choice quiz was administered to undergraduate psychology students, with some questions defined as easy and others as difficult. Students also completed an effective study skills questionnaire rating their study skills for the quiz. The following day, the same students were administered the same quiz items. However, this time, students were told that the quiz was part of an experiment and that the results of the second quiz would have no effect on their class grade. The scientific value and the role of the student as a participant were emphasized to further decrease students' anxiety levels. After, students rated their anxiety levels as compared to the assessment situation the previous day.

Covington and Omelich (1987) discovered that a majority of students reported feeling less anxious on the retest, and high-anxiety students experienced a greater reduction in their anxiety level than did students with low-anxiety levels. There was no improvement found on difficult items, but there was a significant effect found for easy

items among anxiety-prone students, though it was dependent upon an individual's test preparation. Specifically, students who were anxiety-prone, yet had effective study skills, showed the most improvement in performance when a lower anxiety assessment situation was introduced. Optimal testing conditions already existed for those students with low-anxiety levels and effective study skills and as such, gained little from the experimentally-induced situation. Students who exhibited either high-anxiety or low-anxiety levels, but ineffective study skills, showed little gain.

Thus, Covington and Omelich's (1987) hypothesis was tentatively supported. If a student was well prepared for an exam and was prone to anxiety, he/she would benefit from a situation that reduced their perceived anxiety. However, those students who are not initially prepared would not benefit greatly from this change in assessment conditions.

The structure of rehearsal should be considered when assessing students such that top levels of performance result. According to Hull's (1943) drive theory, prolonged activity on a task suppresses performance and promotes interference by inducing fatigue and reducing an individual's motivation to perform. A break allows a reminiscence effect, which increases performance again.

According to Shebilske, Goettl, Corrington, & Day (1999), massing lessons together increases a student's fatigue and decreases their arousal. Fatigue is found to be highest on those tasks that a student finds either extremely simple or extremely complex. The consolidated theory states that REM sleep allows neurotransmitters to be replenished and strengthens the connections among neurons, reinforcing the belief that breaks between lessons is beneficial. These findings would suggest that a scaffolding

environment, where the teacher directs learning to where the student can handle the material on his own with sufficient teacher guidance.

The meta-cognitive theory of Bjork (1994) and Green (1989) provides that massed practice might promote immediate increases in performance such that overconfidence results as well as a possibility of less elaborate processing of material. Given the overconfidence and possible lack of elaborate processing, students may not have the ability to transfer knowledge to other content areas, and long-term retention may not occur. Thus, testing at a later date might yield decreased performance levels for some students. Also, because a base of sufficient knowledge is necessary to scaffold a student's thinking into more complex domains, a poor base may reflect inadequate resources available to increase student's knowledge. Bjork also suggests that providing a break between lessons may introduce short-term difficulties for students, facilitating the strengthening of associations, which improves long-term performance.

It is important to remember that when testing a student, a situation must be provided that will yield optimal performance. The reviewed research provides evidence that low-anxiety testing situations are most favorable and that students should not be introduced to related materials when retrieval of a specific material is requested. When encoding specific material, students should have their attentional resources entirely devoted to that material. Finally, material should promote deep processing, which will allow for the contextual transfer of information and increased flexibility of the learner.

On the basis of this small portion of research, it is impossible to recommend a best-case scenario for testing students. However, future research can build from these studies to create a suitable assessment situation. For instance, future research should

examine how distributed practice, which results in more elaborate knowledge structures than massed practice, can be most effective in elementary classrooms without promoting associative interference. Elementary students should be examined as they spend most of their day within one classroom focusing on many different content areas without structured breaks or class switching, as middle and high school students do.

One should also consider how in-class preparation relates to anxiety levels of students and if structured practice can decrease a student's anxiety to the point where optimal performance can be achieved. For example, if practice is initially massed, then distributed to promote elaborate thinking processes and the strengthening of associative links, and finally, massed again to increase a student's confidence level, will the student be less anxious about an upcoming exam on that material? Classroom lessons can be structured in this manner: the introduction to new material can be massed, followed by a distribution of more elaborate thinking processes in practice for a few lessons, and finally a mass of review sessions that will promote the facile retrieval among students as well as increase confidence levels. This research has the possibility for implications about how a class lesson in a certain content area should be structured.

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