Improving Learning Efficiency of Factual Knowledge in Medical Education

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OBJECTIVE: The purpose of this review is to synthesize recent literature relating to factual knowledge acquisition and retention and to explore its applications to medical education.

RESULTS: Distributing, or spacing, practice is superior to massed practice (i.e. cramming). Testing, compared to re-study, produces better learning and knowledge retention, especially if tested as retrieval format (short answer) rather than recognition format (multiple choice). Feedback is important to solidify the testing effect.

CONCLUSIONS: Learning basic factual knowledge is often overlooked and under-appreciated in medical education. Implications for applying these concepts to smartphones are discussed; smartphones are owned by the majority of medical trainees and can be used to deploy evidence-based educational methods to greatly enhance learning of factual knowledge. (J Surg Ed 72:882-889. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: medical education, testing effect, distributive practice, feedback, smartphones

COMPETENCIES: Medical Knowledge

INTRODUCTION

With recent interest in clinical simulation and higher order reasoning, learning basic factual knowledge is often overlooked and underappreciated in medical education. Yet without a solid knowledge base, the practice of medicine would not be possible. The sheer volume of information encountered by medical trainees is enormous. In addition to learning the jargon of medical terminology (comparable to learning a foreign language), students must learn and retain a body of factual knowledge in both basic and applied sciences. Unfortunately, without repeated rehearsal, most of this knowledge is subsequently forgotten shortly after graduation.[1-3] This is true for both basic sciences and clinically relevant knowledge.[4,5] In the United States, the first 2 years of medical education are generally spent in the classroom setting (preclinical), whereas starting from the third year, students are immersed in the hospital environment. While working full time in the clinical setting, students are expected to independently continue reading and learning new material. With less time for formal didactic instruction, more emphasis is placed on self-directed learning. This expectation is further amplified during residency, when "protected" educational time is minimal and work demands are maximal. Postresidency, physicians are required to continually learn and master new material to maintain proficiency and certification.

To gain acceptance into a medical school and to match in a surgical residency requires a high level of achievement, intelligence, and effort. Yet, learners are often uninformed regarding the optimal methods of study. Metacognition, defined as "knowing about knowing," is used to describe a learner's awareness of his/her own knowledge strengths and deficits. It underlies the choices a learner makes in deciding what to study, when to study, how much to study, and when to stop studying. Research demonstrates that up through the university level, learners have an inaccurate understanding of how learning works. In a survey of college students, respondents were 8 times more likely to use inferior study strategies, with only 1% using the best strategy.[6] The most frequently chosen method continues to be rereading of prior lecture notes and textbook chapters, a highly inefficient and nondurable strategy.[6,7] Left on their own, some adult learners will restudy material up to 7 times longer than their colleagues with minimal gain in accuracy, an effect termed *labor-in-vain*.[8]

In the past 2 decades, there have been great strides in education research and advances in the understanding of how learners acquire and retain new knowledge. Most of these experiments have been performed in a laboratory setting under highly controlled and artificial conditions.

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However, recent translational studies under real world settings (including in medical education) have replicated and extended these findings. The purpose of this review is to synthesize recent literature relating to factual knowledge acquisition and retention and explore its applications to medical education. Specifically, we will discuss how the spacing effect, the testing effect, the choice of test format, and the provision of feedback all contribute to dramatic gains in learning.

THE SPACING EFFECT

The *spacing effect* describes the phenomenon whereby for an equal amount of cumulative study time, spacing or distributing the study sessions with intervening time gaps (or inter-study interval [ISI]) results in superior knowledge acquisition and long-term retention compared with massing the study sessions together. The final examination is given after a retention interval (RI). Descriptions of the spacing effect stretch back as far as the classic Ebbinghaus experiments of 1885, and there are hundreds of reports confirming this effect in applications ranging from learning a new language, to mathematical concepts, to surgical skills training, and in subjects ranging from rats to young children, to cognitively impaired adults, to physicians.[9-12] Yet, despite the long history and oft-replicated results, the spacing effect is rarely used intentionally in real world settings as a form of strategic studying.[13] Massed repetition (i.e., "cramming") is still by far the dominant strategy, chosen because of flawed metacognitive judgments based on feelings of fluency or illusions of competency.[14,15] In actuality, such strategies that maximize performance early in the learning process are associated with faster forgetting; conversely, strategies resulting in slower early knowledge or skill acquisition are associated with longer retention.[16]

A theory for why the spacing effect exists is the *encoding* or *contextual variability theory*.[17,18] In this account, when an item is learned or studied, a memory trace representing the learning context is also stored. Thus, multiple learning sessions will produce varied memory traces and a richer set of paths or cues allowing the learner more chances to recall the item. An alternative theory is the *deficient processing theory*.[19] In this theory, subsequent item presentations after the initial learning session are treated with less attention (because of fatigue, boredom, or overconfidence) and thus the repeated sessions are reduced in quality. Congruent with this theory is the concept of *desired difficulty*.[16] Within this paradigm, memory has 2 characteristics: storage strength and retrieval strength. The former represents a permanent property of the item, i.e., long-term retention, and the latter refers to the immediate accessibility of the item. According to this theory, the 2 strengths are negatively correlated during initial learning. Less effortful immediate retrieval produces smaller increments in storage strength, and conversely, more difficult retrieval (lower retrieval strength) results in higher gains in storage strength.

Up until recently, most research on the spacing effect was conducted in the laboratory setting with very short gaps (minutes), short RIs (minutes to hours), and no long-term follow-up. For longer RIs in real world settings, recent studies provide empirical evidence to help decide how long the ISI should be. In a large randomized study of 1354 subjects (mean age 34 y, standard deviation = 11; 72% were woman), Cepeda et al. presented the subjects with 32 obscure, but true trivia facts (e.g., "What European nation consumes the most spicy Mexican food?" Answer: "Norway"). Using 26 combinations of ISIs and RIs, these investigators reported that the optimal ratio for maximal retention varies as a function of RI.[20] To quote the authors, "if you want to know the optimal distribution of your study time, you need to decide how long you wish to remember something." As the RI increases from 1 week to 1 year, optimal ISI in absolute terms increases, but as a percent of RI, the optimal ISI decreases from 20% to 40%, to 5% to 10%.[20,21] All else being equal, simply restudying material at the optimal time can retain *more than double* the amount retained. The Cepeda study also demonstrated that the costs of too-short spacing were greater than those of too-long spacing. Put another way, the benefits of spacing may override the costs of increasing error rates associated with increasing the ISI.[22]

In a study of dental students taking a theoretical radiological science course, subjects were randomized to usual practice or spaced testing (test questions were delivered by email 14 d after the lecture). Nkenke et al. found that subjects in the spaced education group actually spent far more time (216 min vs 58 min, $p < 0.001$) engaged in the learning context. Using a validated questionnaire, the authors found that the spaced education group rated the didactics significantly better (mean 4.9 out of 6 vs 4.1, $p = 0.034$), and felt that their learning needs were better fulfilled (4.6 vs 1.4, $p = 0.02$).[23] These findings are significant and meaningful when considering that amount of time spent studying is directly correlated with scores on the American Board of Surgery In-Training Exam (ABSITE) and that most of the surveyed residents were dissatisfied with traditional study methods.[24]

THE TESTING EFFECT

It was previously believed that learning occurred only during active study; testing was regarded as formative assessment, measuring learning that had previously occurred but itself contributing little, if any, to learning. Thus, it is a common practice for a learner to study and test a topic until an item is successfully recalled, and then drop that item from future study and testing. It seems intuitively obvious that once an item is mastered, attention should be focused