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How to Learn Effectively in Medical School: Test Yourself, Learn Actively, and Repeat in Intervals

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Students in medical school often feel overwhelmed by the excessive amount of factual knowledge they are obliged to learn. Although a large body of research on effective learning methods is published, scientifically based learning strategies are not a standard part of the curriculum in medical school. Students are largely unaware of how to learn successfully and improve memory. This review outlines three fundamental methods that benefit learning: the testing effect, active recall, and spaced repetition. The review summarizes practical learning strategies to learn effectively and optimize long-term retention of factual knowledge.

Learning in medical school can be divided into two forms of knowledge: factual and procedural knowledge. Factual knowledge is the theoretical background of medical education, e.g., learning the adverse effects of beta-blockers, muscles of the lower extremity, or the definition of the systemic inflammatory response syndrome. Procedural knowledge is the practical part of medicine, e.g., how to perform the insertion of a central line, draw blood, or conduct a clinical exam on a patient with acute respiratory distress. Factual or conceptual knowledge covers “what” information, whereas procedural knowledge covers “how” and “why” information [1].

While the latter can be learned by means of simulation and practice, factual knowledge is more difficult to obtain by means of reading, summarizing, testing, and restudying. The majority of time in medical school is spent on acquiring factual knowledge in the various specialties that is subsequently tested in exams to prove that learning was successful. Usually, students feel overwhelmed and stressed by

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the sheer amount of facts that medical school obliges them to learn [2]. Students also experience that long-term retention of factual knowledge is mediocre at best and forgetting is the unpleasant side of learning something new [3].

Surprisingly, scientific knowledge of how to learn and acquire factual knowledge is not a standard part of the curriculum in medical school [4]. This article reviews main scientific findings on how to successfully learn and retain factual knowledge.

**HOW CAN YOU IMPROVE LEARNING IN MEDICAL SCHOOL?**

How do students learn factual knowledge? The process of learning can be exemplified by the above-mentioned adverse effects of beta-blockers. In pharmacology, medical students learn about the different substances in the group of beta-blockers, their indications, pharmacodynamics, adverse effects, and conditions when not to prescribe them to patients. Adverse effects of beta-blockers can be summarized to several facts such as bradycardia, bronchoconstriction, claudication, hyperlipidemia, and reduced sensitivity to hypoglycemia. These facts can be learned by means of reading, building mnemonics, or simple repetition. Therefore, learning is successful when these five adverse effects can be named on free recall or by knowing that a patient with diabetes should not be treated with beta-blockers due to the adverse effect of reduced sensitivity to hypoglycemia. In our memory, we build links between the topic beta-blocker and these five adverse effects.

Forgetting is the process of losing this information in memory or not being able to retrieve it even though the information is still stored. The links between beta-blocker and single adverse effects are missing. The German psychologist Hermann Ebbinghaus hypothesized that the process of forgetting follows a curve when experimenting with the memorization of nonsense syllables and subsequent testing of the retention of these syllables [5]. Ebbinghaus found that as time passed, his memory of these syllables faded likewise. Thus, new factual knowledge that we acquire is destined to be forgotten if it is learned just once.

A different experiment revealed the impressive capacity of memory. The Swedish psychologist K. Anders Ericsson and his team published a paper in *Science* in 1980 that describes an experiment involving an undergraduate with average intelligence and memory abilities [6]. The student engaged in a task that involved recalling the sequence of random digits that were read at the rate of one digit per second. For more than 20 months, the student engaged in this activity about 1 hour a day, 3 to 5 times per week. Starting with a digit span of seven, the undergraduate reached a digit span of almost 80 after 20 months or 230 hours of practice. These results show that the memory skill can be improved by practice even with abstract information.

These two experiments show the effect practice has on memory. Without practice, learned information is quickly lost down the path of Ebbinghaus’ forgetting curve. With practice, the memory can be trained comparable to the training of a muscle. Yet which methods are the most suitable in order to learn and practice what is learned based on scientific findings? This section will cover three topics of effective learning: the testing effect, active recall, and spaced repetition.

**THE TESTING EFFECT**

The testing effect concerns a paradox in the life of every student in medical school. When learning pharmacology and the five main adverse effects of beta-blockers, students read the facts, they summarize them, restudy, or memorize them for a considerable amount of time and are then tested once in a written or oral exam. Testing in the mind of the average student is a means to assess knowledge and not part of learning.

Testing as an active element of learning is more effective than studying the factual knowledge repeatedly [7]. A considerable number of experiments were conducted to study this testing effect. One example cited in the aforementioned paper is a study by
Hogan and Kintsch from 1971 [8]. One group of students studied a list of 40 words four times with short breaks between the study time. A second group of students studied the list only once and took three free recall tests afterward. Two days later, both groups underwent a final test. The first group that studied the list four times recalled about 15 percent of the words. The second group, which studied once and then took three free recall tests, recalled about 20 percent of the words. Studying a list of words just once and then testing yourself by free recall led to significantly better results than studying the identical content four times.

A randomized controlled trial confirmed these findings and discovered that repeated testing resulted in significantly higher long-term retention than repeated studying [9]. This study involved a didactic conference for pediatric and emergency medicine residents. There were two counterbalanced groups. One group took tests on the topic of status epilepticus and studied a review sheet on myasthenia gravis. The second group studied a review sheet on status epilepticus and took tests on myasthenia gravis. Testing and studying sessions were held immediately after teaching and on two additional time intervals of about 2 weeks. Each time, feedback was given to the participants. A final test after 6 months completed the study. Six months after the initial teaching session, repeated testing resulted in final test scores that were on average 13 percent higher than in the group of repeated studying [9].

A significant contributor to the testing effect is initial feedback to teach the student whether an answer was correct or incorrect. Interestingly, feedback enhances learning, but even testing without feedback is beneficial [10]. The study by Roediger et al. presents an experiment in which four groups of students read a text passage. One group remained passive after reading, and three groups underwent a multiple-choice test. Of these three groups, one was tested without feedback, another received immediate feedback after each question, and a third received delayed feedback for all questions after the entire test. One week after the initial reading session, all four groups underwent a final test. The group that took no test showed 11 percent correct answers. Those participants who were tested without feedback presented 33 percent correct answers, immediate feedback resulted in 43 percent, and delayed feedback in 54 percent correct answers. Therefore, testing even without feedback tripled the score in a test 1 week after initial studying. Best results were obtained by delayed feedback, which hints at the positive contribution of spaced representation of learning content that will be discussed in one of the following sections.

Despite the various studies that found retesting to be more effective than restudying, students seem to be largely unaware of testing superiority in supporting short-term retention [11]. When students use testing in a learning context, they apply it to assess knowledge and do not see it as a technique to intensify learning. In particular, students do not seem to be aware of the superiority of testing compared to studying.

**ACTIVE RECALL**

Whenever new information is repeated, an emphasis should be put on active methods of repetition such as free recall. In the example of the adverse effects of beta-blockers, simple rereading or summarizing of the facts is often applied. However, active recall (e.g., write down or name the five main adverse effect of beta-blockers) is a significantly more effective learning strategy than passive restudying of the facts. Testing as described in the previous section is a form of active recall. However, testing can also be performed by passive presentation of information such as in multiple-choice tests. This section regards active recall methods, meaning the effort to consciously reproduce information that was learned before without using cues.

Active learning methods engage the mind and do not necessarily need to be instantly successful. It has been demonstrated that even unsuccessful attempts to retrieve information from memory that were accom-
panied by feedback enhanced learning [12], and even quizzing about learning content that was never presented before enhanced learning of that very content. In a study by Kornell et al., two groups studied fictional history questions [12]. One group read the question for 8 seconds and was demanded to immediately type the answer. After 8 seconds, the answer was presented for 5 seconds. The second group simply studied the question and answer together for 13 seconds without the instruction to give an answer. Although the second group had more than double the time to study the fictional fact, both groups showed comparable results without significant difference. The attempt to retrieve fictional information, which was inevitably unsuccessful due to the fictional history facts presented, resulted in comparable learning success compared to a group that had more than double the time to study the learning content. Therefore, quizzing is superior to learning because an equivalent learning success can be reached in less than half of the time. It is understandable that challenging tests are thought of as discouraging for students. Yet the experiment conducted by Kornell et al. showed that difficult tests, which at first result in high error rates, actually stimulate subsequent learning.

Another experiment performed by Morris et al. demonstrated the superiority of active retrieval practice compared to passive representation of the content [13]. The experiment simulated a real-life experience of learning names when meeting new people at a party. One group experienced representation of names, and another group applied retrieval practice. On average, the group experiencing representation of the name of a newly met person recalled 5.8 names at the final test. The retrieval practice group recalled 11.5 names on average. Consequently, trying to remember actively the name of a person you have just met is a more effective learning strategy than merely hearing the person’s name repeatedly.

**SPACED REPETITIONS**

The mentioned experiment by Morris et al. also supported the positive effect of spaced repetition. Participants were asked to try to recall the name of the person shortly after they had just met him or her and then again after a longer interval [13]. Instead of trying to recall the name every 30 minutes, it is advisable to space out the repetition and recall the name after 5 minutes, 30 minutes, and then after 2 hours.

In an experiment that tested steady against expanding retrieval practice, 250 students studied 30 immunology and reproductive physiology concepts [14]. The students were divided into five groups. Two groups recalled the concepts actively at a steady interval without (days 1, 10, 20) or with a delay of 7 days (days 8, 15, 22). Another two groups recalled the concepts actively at expanding intervals again without (days 1, 6, 16) or with a delay, in this case of 1 day (days 2, 7, 17). The fifth group served as a control group. All of the groups underwent a test at day 29 to assess the final score; consequently, the end point for all groups was the same. It was found that expanding retrieval practice led to a significantly greater recall of facts at day 29 than recalling at steady intervals [14]. Longer delay between initial learning and recalling facts was associated with poorer retention rate. Therefore, the group that learned with expanding retrieval practice and no delay preceding the first assessment proved to have the best learning strategy.

Generally, the four groups with retrieval practice performed twice as well as the control group did, thus emphasizing the positive effect of active retrieval practice independent of specific retrieval strategy. In comparison, the two groups that applied expanding retrieval performed significantly better than the two groups that recalled the concepts at steady intervals. The combined mean of the first groups (42.57, SD 1.8) was significantly higher than that of the two with steady intervals (34.1, SD 1.36) [14]. In comparison to the control group (21.26, SD 1.4), there was a general beneficial effect of retrieval independent, whether it was at steady or at expanding interval. Thus, two findings stand out: Retrieval practice after initial learning is a main contributor to suc-
cessful learning, confirming the findings stated above about active recall and the testing effect, and retrieval practice should be performed on expanding intervals to further enhance learning.

Additional insight into the benefit of expanding retrieval practice was presented in another study [15]. The authors found that the positive impact of retrieval practice depends on the degree to which the to-be-learned information is vulnerable to forgetting. It is especially helpful when the learning content consists of several units that may interfere with each other. In one experiment, 30 participants studied an educational text about Antarctica. They were then instructed to free recall information about Antarctica at 4 time intervals of either 0, 3, 7, and 18 or after 7, 7, 7, and 7 minutes. Between these intervals, the participants read text passages about 10 additional regions (e.g., Greenland, Africa) similar to the initial Antarctica text. Consequently, this intervening activity led to interference with the facts that were initially learned.

In a final test 1 week later, the group that learned at expanding time intervals performed significantly better than the group learning with steady intervals, outperforming the latter group by a 2-to-1 margin [15]. The authors conclude that expanding retrieval practice is best used when the learning material is vulnerable to being forgotten. In this case, expanding retrieval practice improves long term retention of correct information and prevents from learning incorrect information.

CONCLUSIONS

How do these studies impact learning in medical school? Whenever students learn factual knowledge, they should test themselves while learning, actively recall information, and retest the facts at expanding time intervals to make learning in medical school most effective. These learning strategies help students learn the most in the least amount of time. Studying according to scientific findings on the testing effect, active recall, and expanding repetition intervals assures optimal long-term retention of factual knowledge. It has to be emphasized that despite the obvious positive effects of these learning strategies on students’ performance, learning how to learn is not a standard part of the curriculum in medical school [4,16]. This lack is questionable.

Obviously, medical knowledge is growing. Despite an increase in depth and complexity of medical knowledge in the past decades, the length of medical education remains constant. Time is scarce in the medical curriculum and never sufficient to teach the whole body of medical knowledge. Providing time to teach medical students how to learn is difficult.

It is, however, even more difficult for students to provide time to learn in an ineffective way in medical school, to learn factual knowledge, forget, and relearn it. It takes modest time for medical schools to teach the above-mentioned concepts that enable students to save time and effort. Eventually, students’ final scores and patient care may improve — a result that satisfies medical faculties and students equally.

How should medical schools implement programs to convey these learning strategies? The author proposes that a program based on these concepts should be taught in medical school at an early stage. The program should be based, obviously, on the concepts it conveys. This means that the program should be taught actively by posing questions and quizzing students, provide tests to foster learning, and repeat the learning strategies in spaced intervals. A basis module of this program may consist of several hours to present the concepts and the scientific background. Shorter modules serving as repetition and application of the learning strategies should be taught in expanding time intervals so that students learn the concepts at the start of the term and restudy them, e.g., 7, 15, 30, and 60 days later. Therefore, a basis module combined with several short follow-up modules would suffice to teach the basic scientific findings on effective learning strategies.

Additional scientific concepts apart from the three that were presented in this
paper may be added to the program. A module presented in year 1 of medical school may focus on learning factual knowledge, whereas a module in year 3 may shift toward factual and procedural knowledge to prepare for effective learning in clerkships. The modules may be adapted flexibly to the students’ needs. However, the content of the modules may not be the most important issue. The key is to create a constructive atmosphere and to raise awareness about the process of learning in medical school. Before students start to learn, they should be taught how to learn. This idea should become an essential part of the medical curriculum.

The presented learning strategies provide a starting point to enable students to learn more effectively in medical school. Research is conducted concerning the larger picture of how to combine scientific evidence in cognitive neuroscience with medical education [17]. The author proposes this program as a first step to explore concepts that improve learning in medical school.

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