Retrieval-Based Learning in Neuroanatomy Classes

Ensino Baseado na Evocação do Conhecimento em Aulas de Neuroanatomia

Lia Lira Olivier Sanders[I]
Randal Pompeu Ponte[I]
Antônio Brazil Viana Júnior[II]
Arnaldo Aires Peixoto Junior[I]
Marcos Kubrusly[I]
Antônio Miguel Furtado Leitão[I]

KEY-WORDS

- Anatomy.
- Neuroanatomy.
- Active learning.
- Learning.
- Medical education.

ABSTRACT

Medical schools are continuously challenged to develop teaching modalities that improve understanding and retention of anatomical knowledge. Traditionally, learning has been regarded as the encoding of new knowledge, whereas retrieval has been considered a means for assessing learning. A solid body of research demonstrates that retrieval practice is a way to promote learning that is robust, durable, and transferable to new contexts. It involves having learners set aside the material they are learning and practice actively reconstructing it on their own. A general challenge is to develop ways to implement retrieval-based learning in educational settings. We developed a pedagogical approach that implements retrieval-based learning in practical neuroanatomy classes, which differs from usual neuroanatomy teaching in that it actively engages students through active learning. It requires students to retrieve anatomical knowledge in oral and written form, as well as to identify structures in cadaveric material. Practical anatomy classes have traditionally relied on students' passive exposure to cadaveric material, with the lecturer pointing to and naming anatomical structures. Since August 2014, we have been applying retrieval practice in neuroanatomy classes. A total of 720 students were included in the study. Student performance one week after the practical lesson was higher in the traditional method group than in the retrieval-based learning group ($p < 0.0001$, effect size = 0.60). Four weeks after the intervention, however, the performance of students who learned using a retrieval-based approach was higher than that of students passively exposed to the learning material ($p < 0.0001$, effect size = 0.75). Taken together, our results suggest that retrieval-based learning has a greater effect on long-term retention. Retrieval-based learning is easy to apply and cost-effective. It can be implemented in nearly any educational setting. We hope that our report may inspire educators to adopt retrieval practice approaches and seek ways to apply methods from learning research in actual classrooms.

[I] Centro Universitário Christus, Fortaleza, Ceará, Brasil.
[II] Universidade Federal do Ceará, Fortaleza, Ceará, Brasil.

http://dx.doi.org/10.1590/1981-52712015v43n4RB20180184ingles

PALAVRAS-CHAVE

- Anatomia.
- Neuroanatomia.
- Metodologias ativas.
- Aprendizagem.
- Educação médica.

RESUMO

As faculdades de Medicina são continuamente desafiadas a desenvolver modalidades de ensino que melhorem a compreensão e a retenção do conhecimento anatômico. Tradicionalmente, a aprendizagem tem sido considerada como a codificação de novos conhecimentos, enquanto a evocação tem sido considerada apenas um meio para avaliar a aprendizagem. Pesquisas demonstram que a prática da evocação do conhecimento é uma maneira de promover um aprendizado robusto, durável e transferível para novos contextos. Isso implica que os alunos deixem de lado o material que estão aprendendo e pratiquem ativamente reconstruí-lo por conta própria. Um desafio geral é desenvolver maneiras de implementar a aprendizagem baseada em evocação em ambientes educacionais. Desenvolvemos uma abordagem pedagógica que implementa a aprendizagem baseada em evocação em aulas práticas de neuroanatomia, que difere do ensino usual de neuroanatomia, na medida em que envolve ativamente os alunos na aprendizagem. Requer que os estudantes recuperem conhecimentos anatômicos em forma oral e escrita, bem como identifiquem estruturas em material cadavérico. As aulas práticas de anatomia tradicionalmente se baseiam na exposição passiva dos estudantes ao material de cadáveres, com o professor apontando e nomeando estruturas anatômicas. Desde agosto de 2014, aplicamos a prática da evocação em aulas de neuroanatomia. Um total de 720 alunos foi incluído no estudo. O desempenho dos alunos uma semana após a aula prática foi melhor no grupo submetido ao método de ensino tradicional do que no grupo de aprendizagem baseada em evocação ($p < 0,0001$, tamanho do efeito = 0,60). Quatro semanas após a intervenção, no entanto, o desempenho dos alunos que aprenderam usando uma abordagem baseada na evocação foi melhor do que o dos estudantes passivamente expostos ao material de aprendizagem ($p < 0,0001$, tamanho do efeito = 0,75). Em conjunto, nossos resultados sugerem que o aprendizado baseado em evocação tem um efeito maior na retenção a longo prazo. A aprendizagem baseada em evocação é fácil de aplicar e econômica. Pode ser implementada em praticamente qualquer ambiente educacional. Esperamos que nosso relato possa inspirar os educadores a adotarem abordagens de práticas de aprendizagem por evocação e a buscarem maneiras de aplicar métodos de ensino e aprendizagem derivados da pesquisa sobre educação em salas de aula reais.

Recebido em: 25/11/18

Aceito em: 17/12/18

INTRODUCTION

Anatomy is the branch of biology that deals with the study of the structure of organisms and their parts. The complex organization of brain systems poses extra difficulty for educators, who testify students' struggle to master the anatomy of the nervous system[1]. There has been a long-standing call for active pedagogical experiences in medical education[2,3]. Medical schools are particularly challenged to develop teaching modalities that improve understanding and retention of anatomical knowledge[4,5,6].

Initially, learning has been regarded as the encoding of new knowledge, whereas retrieval has been considered a means for assessing learning. Over 100 years of research has shown that practice testing enhances learning and retention[7]. A solid body of research demonstrates that retrieval promotes effective long-term learning. This phenomenon has been called testing effect[8-11], or retrieval-based learning[12], and has been demonstrated across a wide range of test formats, kinds of material, learner ages, outcome measures, and retention intervals[13].

Testing usually corresponds to high-stakes summative assessments, which leads to most students' unfortunate view of exams as an undesirable necessity of education, overshadowing the incremental effect of testing on learning[13]. Every time we retrieve knowledge, we enhance our ability to reconstruct it in the future[14]. When retrieval is successful, knowledge representation is updated to include features of the current context. Future retrieval is enhanced because updated context representations can be used to restrict the search set and hone in on a desired target[15].

Retrieval practice testing involves practicing recall of target information via the use of flashcards, problems or questions. It is a way to promote learning that is robust, durable, and transferable to new contexts[16,17]. It involves having learners actively retrieve knowledge learned in the past and bringing it to mind on their own[15]. A general challenge is to develop ways to implement retrieval-based learning in educational settings.

We developed a pedagogical approach that implements retrieval-based learning in practical neuroanatomy classes. It requires students to retrieve anatomical knowledge in oral and written form, as well as to identify structures in cadaveric material. Our aim was to translate a well-established strategy from learning research to a medical education setting. We compared students' retention of neuroanatomy knowledge before and after introducing retrieval-based learning in neuroanatomy classes. We hypothesized that the retrieval-based approach would enhance neuroanatomy learning. Here we describe our retrieval practice in neuroanatomy classes and report the improvement in medical students' retention of neuroanatomy knowledge after we implemented the new teaching method.

METHODS

This is a cross-sectional study, carried out from November 2016 to April 2017, at a private, higher education institution. Our undergraduate medical curriculum is structured in a hybrid method with active methodology PBL (Problem-Based Learning) and conferences throughout the first eight semesters, followed by four semesters of clerkship. This research followed the ethical aspects established in Resolution 466/2012 of the National Health Council (CNS), which defines the rules of human research. It was approved by the local Research Ethics Committee (approval number: 56341916.6.0000.5049).

Participants

To verify whether retrieval practice enhances learning of neuroanatomy content, we compared the performance of 424 students exposed to the *traditional method* (theoretical class + passive work with cadaveric material), from 2011 to the first semester of 2014, with the performance of 296 students who had the opportunity to learn using the *retrieval-based learning* approach (theoretical class + retrieval practice), from the second semester of 2014 to 2016.

Procedure

At our institution, neuroanatomy classes are given during the second semester of Medical School. Students have a theoretical neuroanatomy class, followed by practice in the anatomy lab, two weeks later. We compared two teaching methods in the anatomy lab. The traditional method (see below) consists of a lecturer presenting anatomical structures in embalmed human cadaveric specimens to the students. Retrieval-based learning (our experimental method) differs from the traditional method in that it promotes retrieval practice. In the retrieval-based learning approach, students are requested to identify anatomical structures on their own, using projected and printed structures as well as cadaveric material. Each method is detailed below.

Traditional method

Until the first semester of 2014, the lecturer used cadaveric material in the anatomy lab to show students the anatomical structures, repeating if necessary. For comparison with the new method, we call this approach *traditional method*.

Retrieval-based learning

Since August 2014, we have been applying retrieval practice in neuroanatomy classes. At the beginning of the practical lesson, students are given printed copies of the neuroanatomy illustrations they were shown in the theoretical class. The docent projects these illustrations and presents the anatomical structures to the students. The lecturer then applies the retrieval-based approach, which consists of the following sequential steps:

1. The lecturer points to the projected structures, requesting students to collectively identify them. Students answer aloud. Eventual errors are corrected.
2. Students write down the names of anatomical structures on the printed copies of the neuroanatomy illustrations they received at the beginning of the class and compare their answers in pairs.
3. Each student identifies the anatomical structures in the cadaveric material.

Outcome measures

As learning outcome in each group, we used the scores obtained from two neuroanatomy tests, at one and four weeks after the practical anatomy class. Each test (test 1 and test 2) consists of 12 short answer questions (SAQ) randomly selected from the list of anatomy structures taught. These tests are part of the curriculum; both groups were subjected to them. In both tests the task was the same: students were asked to identify anatomic structures (i.e., write down their names). The first test comprises structures of the telencephalon and diencephalon; the second test, structures of the telencephalon, diencephalon, brainstem, cerebellum, and medulla. Test 1 and test 2 had the same number of questions and were the same through years, which allowed us to compare the performance of the two groups in each test. A direct comparison between the performance of each group in both tests was not possible because test 1 and test 2 were different. Although both tests consisted of 12 questions, the second test comprised structures of more brain structures than the first test.

Statistical analyses

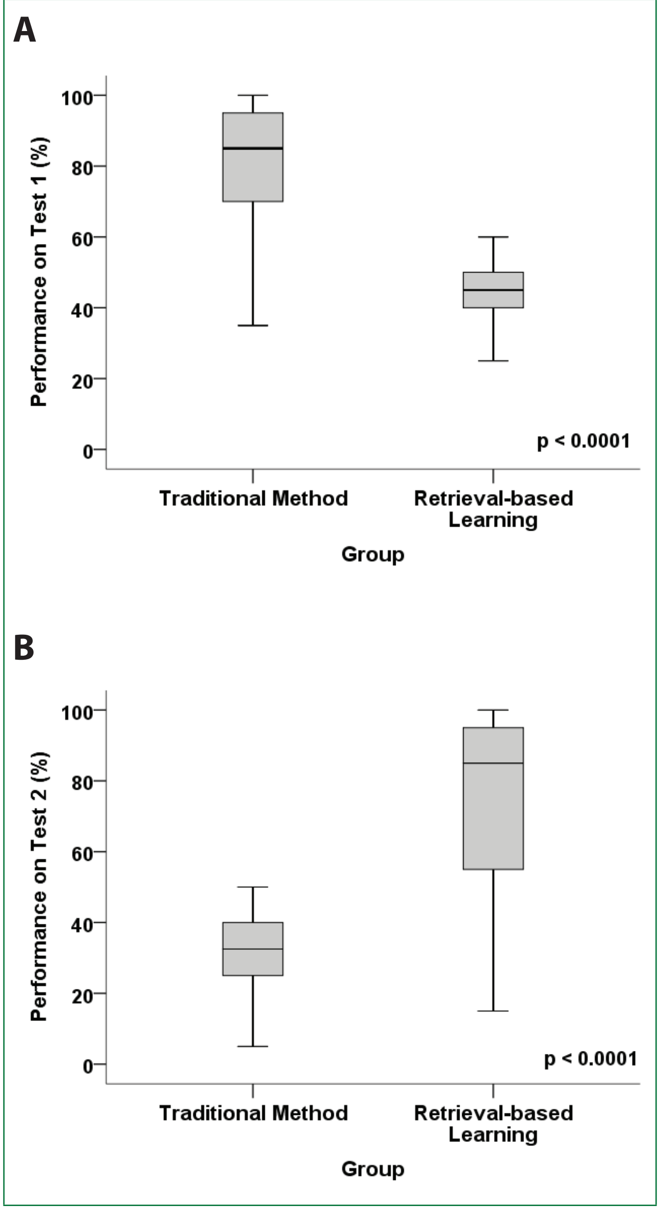
Students' test performance was not normally distributed (test 1: skewness: -1.294, kurtosis: 1,610; test 2: skewness: -0.707, kurtosis: 1.610). Therefore, we used non-parametric statistics (Mann-Whitney two-sample rank-sum test) to test for performance differences between the passive learning and the retrieval-based learning group. All analyses were conducted using the software SPSS 20.0 (Statistical Package for Social Sciences, http://www-01.ibm.com/software/analytics/spss/). The first and the second test were the same through years, but the second test comprised structures of more brain structures than the first test. Therefore, test 1 and test 2 could not be directly compared.

RESULTS

A total of 720 students were included in the study; 300 were male and 420 were female. All students took part in test 1 and test 2 (our method for assessing student learning outcomes). A total of 424 students were subjected to the traditional method; 296, to the retrieval-based learning approach. The groups did not differ in gender composition (traditional method: 173 male, 251 female students; retrieval-based learning: 127 male, 169 female students, chi-square = 0.317, p = 0.573). Students from the traditional method group were slightly older (median = 20 years, 25-75% = 19-22) than students from the retrieval-based learning group (median: 20 years, 25-75% = 19-21, Mann-Whitney U test, p = 0.005). Students' performance in the previous semester, taken as a general measure of academic performance, was higher in the retrieval-based learning group (median = 78.50%, 25-75% = 75.40-81.25% *vs*. 76.00, 25-75% = 72.50-79.25%, Mann-Whitney U test, p < 0.0001). The effect size (r) calculated for the Mann-Whitney U-test ($r = z/(\sqrt{N})$) was 0.22, which, according to Cohen's guidelines for r, is considered a small effect size[18].

Students' performance (%) in test 1 and 2 is plotted in Figure 1. Performance in test 1 (one week after the practical lesson) was higher in the traditional method group than in the retrieval-based learning group (Mann-Whitney U test, p < 0.0001, effect size = 0.60). Test 2 (four weeks after the lesson) showed the opposite pattern: the performance of students who learned using a retrieval-based approach was higher than that of students passively exposed to the learning material (Mann-Whitney U test, p < 0.0001, effect size = 0.75), suggesting a positive impact of the retrieval-based approach on long-term retention. Although academic performance of students from the retrieval-based group was slightly superior than that of students from the traditional method, previous academic performance (effect size of 0.22) does not account for the differential performance in test 2 (effect size of 0.75).

FIGURE 1
Learning outcomes. Group performance (%) A) one week (test 1) and B) four weeks after the lesson (test 2).



DISCUSSION

Practical anatomy classes have traditionally relied on students' passive exposure to cadaveric material, with the lecturer pointing to and naming anatomical structures. Retrieval-based learning in neuroanatomy classes differs from usual neuroanatomy teaching in that it actively engages students through active learning. Students are requested to retrieve anatomical knowledge in oral and written form, as well as to identify structures in cadaveric material. The most crucial factor determining whether a memory is long lasting seems to be how much one thinks about it[19]. An active teaching activity makes students think about the taught content, such as when they try to retrieve anatomical knowledge, be it in written or in oral form.

Retrieval practice has been shown to enhance long-term retention of statistical knowledge in psychology[20] and of anatomy information[21]. Our results suggest that retrieval-based learning has a greater effect on long-term retention. Retrieval-based learning enhanced students' performance in a test 4-weeks after the learning intervention. The traditional method, however, yielded higher grades on a test administered a week later. It has been previously shown that repeated studying produces short-term benefits, whereas repeated testing produces greater benefits in delayed test[22,23]. Studies on the testing effect revealed no difference in retention for tested versus studied items under conditions of immediate testing, but an advantage for tested items under conditions of delayed testing[24]. Dobson and colleagues found a significantly better recall using retrieval-based strategies already one week after the learning phase[21]. In our study, however, this effect was evident only four weeks after the retrieval-based method was applied. Although the memory and learning literature regard four weeks as long-term retention, we acknowledge that neuroanatomy knowledge is expected to last much longer. Four weeks is a relatively short period, which limits our conclusions. It is still not clear why learning conditions that make initial learning more difficult may result in very good long-term retention. Some authors explain the long-term learning effect of retrieval-based learning as desirable difficulties that require more effort from the learner and result in better memory retention[25].

In our study, the tests used to measure students' learning outcome (test 1 and test 2) were different to each other, which made a direct comparison between the two tests impossible. As the classes went on, students learned more anatomical structures. Test 2 comprised the same amount of questions as test 1 but taken from a wider pool of possible neuroanatomy structures. Therefore, we could only compare the performance of the two learning methods (traditional and retrieval-based) in each test. This can also be regarded as a limitation of our study, making an analysis that could consider both time of testing and learning method (such as Anova) impracticable. We can only speculate that a non-gaussian distribution of the test scores would make a parametric statistical analysis still impossible even if test 1 and test 2 were the same.

As a real classroom scenario, we could not control for baseline differences between groups, such as academic performance and previous neuroanatomy knowledge. In fact, the academic performance of students from retrieval-based group was slightly superior to that of students from the traditional method. The magnitude of the effect size of previous academic performance (d = 0.22) was much lower than the effect size of learning method (d = 0.75), suggesting that general academic performance does not fully explain the better performance of the group subjected to the retrieval-based approach. Moreover, the lower performance of the retrieval-based group in test 1 suggests that the long-lasting effect of retrieval practice cannot be explained by differences in student profile.

Although our study adds to the existing evidence in favor of retrieval-based learning, it does not offer a mechanism that explains how retrieval may improve learning. Future research should focus on elucidating the mechanisms by which retrieval processes improve learning. Why does retrieving knowledge produce better long-term retention relative to spending the same time restudying? One possible explanation is that it makes sense to practice retrieving because learners will be required to retrieve knowledge during a final assessment. Although the importance of practice may seem obvious in some skill domains, such as music and sports, retrieval practice is not a widely used strategy in educational settings[26].

Practicing retrieval involves some effort on the part of the learner; so-called "desirable difficulties" strengthen knowledge, increasing the likelihood that it can be accessed in the future[27]. That might explain why retrieval practice can make initial learning slower and more difficult but result in very good long-term knowledge retention. There is also an elaborative retrieval account, according to which subjects activate several semantically related words during the process of retrieval, that are then encoded along with the target knowledge to form a more recallable representation[28]. Karpicke *et al*.[15] proposed an alternative explanation: the episodic context account of retrieval-based learning, according to which people encode information about items and the temporal/episodic context in which those items occurred[29]. During retrieval, people attempt to reinstate the episodic context associated with an item as part of a memory search process[30]. When an item is successfully retrieved, the original context representation is updated to include features of the present test context. When people attempt to retrieve items on a later test, the updated context representations facilitate information recovery, improving memory performance.

Retrieval has long been regarded as a means for assessing learning, but there is compelling evidence from cognitive sciences that retrieval also produces direct effects on learning[17]. Although flexibility is required to translate such strategies to specific learning settings, results replicated in real-life settings, with actual educational materials, provide strong support to studies conducted in learning labs.

Our results confirm previous evidence showing that retrieval practice enhances learning and long-term memory. Moreover, it shows that it is possible to adapt laboratory-developed methods to classrooms. Strategies that lead students to retrieve learning are more effective than passive exposure to classroom material. Retrieval-based learning in anatomy classes is easy to apply and cost-effective. It can be implemented in nearly any educational setting. Retrieval-based learning requires lecturers to change their teaching methods, planning and preparing retrieval practices. We can imagine that such a paradigm change, which implies more time to prepare the lecture and puts the learner at the center of the learning process, may face resistance from some traditional lecturers. Considering that the final goal of medical education goes way beyond four weeks, it would be very interesting to see how long the benefits of retrieval practice last. Future studies may investigate longer knowledge retention periods. Nevertheless, we hope that our report may inspire educators to translate methods from learning research into actual classroom practice.

REFERENCES

1. Kennedy S. Using case studies as a semester-long tool to teach neuroanatomy and structure-function relationships to undergraduates. J Undergrad Neurosci Educ [Internet]. 2013;12(1):A18-22. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3852866&tool=pmcentrez&rendertype=abstract
2. Flexner A. Medical Education in the United States and Canada Bulletin Number Four (The Flexner Report). Carnegie Bulletin. 1910. p. 364.
3. Cox M, Irby DM, Cooke M, Sullivan W, Ludmerer KM. Medical Education American Medical Education 100 Years after the Flexner Report. N Engl J Med. 2006;13355:1339–44.
4. Turney BW. Anatomy in a modern medical curriculum. Ann R Coll Surg Engl. 2007;89(2):104–7.
5. Bergman EM, Prince KJ a H, Drukker J, van der Vleuten CPM, Scherpbier AJJA. How much anatomy is enough? Anat Sci Educ [Internet]. 2008;1(4):184–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19177406%5Cnhttp://onlinelibrary.wiley.com/doi/10.1002/ase.35/abstract%5Cnfiles/78/abstract.html
6. Sugand K, Abrahams P, Khurana A. The anatomy of anatomy: a review for its modernization. Anat Sci Educ. 2010;3(2):83–93.
7. Rawson KA, Dunlosky J. Optimizing schedules of retrieval practice for durable and efficient learning: How much is enough? J Exp Psychol Gen. 2011;140(3):283–302.
8. Carrier M, Pashler H. The influence of retrieval on retention. Mem Cognit. 1992;20(6):633–42.
9. Ho AM-H, Critchley LAH, Leung JYC, Kan PKY, Au SS, Ng SK, et al. Introducing Final-Year Medical Students to Pocket-Sized Ultrasound Imaging: Teaching Transthoracic Echocardiography on a 2-Week Anesthesia Rotation. Teach Learn Med [Internet]. 2015;27(3):307–13. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26158333
10. Wheeler, Mark A.; Roediger III HL. Research Report. Psychol Sci. 1992;3(4):240–5.
11. Chan JCK, McDermott KB, Roediger HL. Retrieval-induced facilitation: Initially nontested material can benefit from prior testing of related material. J Exp Psychol Gen. 2006;135(4):553–71.
12. Karpicke JD, Blunt JR, Smith MA, Karpicke SS. Retrieval-based learning: The need for guided retrieval in elementary school children. J Appl Res Mem Cogn [Internet]. 2012;3(3):198–206. Available from: http://dx.doi.org/10.1016/j.jarmac.2014.07.008
13. Dunlosky J, Rawson KA, Marsh EJ, Nathan MJ, Willingham DT. Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. Psychol Sci Public Interes Suppl. 2013;14(1):4–58.
14. Yong PZ, Lim SWH. Observing the testing effect using Coursera video-recorded lectures: A preliminary study. Front Psychol. 2016;6(JAN):1–5.
15. Karpicke JD, Lehman M, Aue WR. Retrieval-Based Learning. An Episodic Context Account. Vol. 61, Psychology of Learning and Motivation - Advances in Research and Theory. 2014. 237-284 p.
16. Carpenter SK. Testing Enhances the Transfer of Learning. Curr Dir Psychol Sci. 2012;21(5):279–83.
17. Karpicke JD. Retrieval-Based Learning: Active Retrieval Promotes Meaningful Learning. Curr Dir Psychol Sci. 2012;21(3):157–63.

18. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. J Exp Psychol Gen [Internet]. 2012;141(1):2–18. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21823805
19. Willingham DT. Ask the Cognitive Scientist: What Will Improve a Student's Memory? Am Educ. Winter:17–25.
20. Lim SWH, Ng GJP, Wong GQH. Learning psychological research and statistical concepts using retrieval-based practice. Front Psychol. 2015;6(OCT):5–7.
21. Dobson JL, Perez J, Linderholm T. Distributed retrieval practice promotes superior recall of anatomy information. Anat Sci Educ. 2017;10(4):339–47.
22. Roediger HL, Karpicke JD. Test-enhanced learning: Taking memory tests imporves long-term retention. Psychol Sci. 2006;17(3):249–55.
23. Karpicke JD, Bauernschmidt A. Spaced retrieval: Absolute spacing enhances learning regardless of relative spacing. J Exp Psychol Learn Mem Cogn. 2011;37(5):1250–7.
24. Carpenter SK, DeLosh EL. Application of the testing and spacing effects to name learning. Appl Cogn Psychol. 2005;19(5):619–36.
25. Soderstrom NC, Bjork RA. Learning Versus Performance: An Integrative Review. Perspect Psychol Sci. 2015;10(2):176–199.
26. Karpicke JD. Metacognitive Control and Strategy Selection: Deciding to Practice Retrieval During Learning. J Exp Psychol Gen. 2009;
27. Bjork EL, Bjork RA. Making things hard on yourself, but in a good way: creating desirable difficulties to enhance learning. In: Gernsbacher MA, Pew RW, Hough LM, Pomerantz JR, editors. Psychology and the Real World: Essays Illustrating Fundamental Contributions to Society. New York, NY: Worth Publishers; 2011. p. 56–64.
28. Carpenter SK. Semantic Information Activated During Retrieval Contributes to Later Retention: Support for the Mediator Effectiveness Hypothesis of the Testing Effect. J Exp Psychol Learn Mem Cogn. 2011;37(6):1547–1552.
29. Howard MW, Kahana MJ. A distributed representation of temporal context. J Math Psychol. 2002;46(3):269–299.
30. Lehman M, Malmberg KJ. A buffer model of memory encoding and temporal correlations in retrieval. Psychol Rev. 2013;120(1):155–189.

CONTRIBUTIONS

A.M.F.L. conceived the original idea and carried out the experiments. L.L.O.S., R.P.P. and A.B.V.J. analysed the data. L.L.O.S. wrote the manuscript with support from A.A.P.J., M.K. and A.M.F.L. A.M.F.L. and L.L.O.S. supervised the project.

CONFLICT OF INTERESTS

The author(s) declare(s) that there is no conflict of interest regarding the publication of this article.

POSTAL ADDRESS

Lia Lira Olivier Sanders
Centro Universitário Christus (Unichristus) – Escola de Medicina
Rua João Adolfo Gurgel, 133 – Fortaleza
CEP 60192-345 – CE – Brazil
E-mail: lia_sanders@hotmail.com