Title: Science of Learning Strategy Series: Article 2, Retrieval Practice

Short Version of Title: Learning-Science Series: Retrieval Practice

Authors
Thomas J. Van Hoof, MD, EdD, Associate Professor, University of Connecticut School of Nursing, Storrs, and Associate Professor, Department of Community Medicine and Health Care, University of Connecticut School of Medicine, Farmington

Megan A. Sumeracki, PhD, Assistant Professor, Department of Psychology, Rhode Island College

Christopher R. Madan, PhD, Assistant Professor, School of Psychology, University of Nottingham

Corresponding Author: Thomas J. Van Hoof, MD, EdD, University of Connecticut, 231
Glenbrook Road, Unit 4026, Storrs, CT 06269-4026; tel: (860) 486-0575; fax: (860) 486 0001; e-mail: tom.vanhoof@uconn.edu

Abstract
Retrieval practice is an evidence-based, science of learning strategy that is relevant to the planning and implementation of continuing professional development (CPD). Retrieval practice requires one to examine long-term memory in order to work with priority information again in working memory. Retrieval practice improves learning in two ways. It improves memory for the information itself (direct benefit), and retrieval practice provides feedback about what needs additional effort (indirect). Both benefits contribute significantly to durable learning. Research from cognitive psychology and neuroscience provide the rationale for retrieval practice, and examples of its implementation in health professions education are increasingly available in the literature. Through appropriate utilization, CPD participants can benefit from retrieval practice by making more-informed educational choices, and CPD planners can benefit in efforts to improve educational activities.

Keywords: Science of learning, retrieval practice, practice testing, test-enhanced learning, selftesting, continuing education, continuing professional development

Funding: None

Conflicts of Interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Acknowledgements: The authors would like to thank the many scholars who have contributed to the science of learning for over a century.

Title: Science of Learning Strategy Series: Article 2, Retrieval Practice

Abstract

Retrieval practice is an evidence-based, science of learning strategy that is relevant to the planning and implementation of continuing professional development (CPD). Retrieval practice requires one to examine long-term memory in order to work with priority information again in working memory. Retrieval practice improves learning in two ways. It improves memory for the information itself (direct benefit), and retrieval practice provides feedback about what needs additional effort (indirect). Both benefits contribute significantly to durable learning. Research from cognitive psychology and neuroscience provide the rationale for retrieval practice, and examples of its implementation in health professions education are increasingly available in the literature. Through appropriate utilization, CPD participants can benefit from retrieval practice by making more-informed educational choices, and CPD planners can benefit in efforts to improve educational activities.

About the Science of Learning Strategy Series

Consistent with a recent *Journal of Continuing Education in the Health Professions'* editorial by Kitto about informing the continuing professional development (CPD) imagination,[1] the emerging and interdisciplinary field of the science of learning (learning science), which concerns itself with how the brain learns and remembers important information, is a compelling but relatively unfamiliar field that stands to inspire CPD participants and planners to think about educational interventions differently. Moreover,

learning science has compiled evidence in support of a set of strategies[2-5] that can help CPD more effectively influence clinician knowledge, skill, attitude, competence, and even performance. The purpose of the series is to bring attention to evidence-based, learning-science strategies, and to provide some background that might be helpful to CPD stakeholders considering the strategies. The first series' article on "distributed practice" focused on *when* one schedules learning sessions, which should be spread-out to allow participants more time and more opportunities to process important information.[6] Here in this second article, the authors focus on *how* one spends time while learning by providing an overview of "retrieval practice." Retrieval practice is known by many terms, such as "practice testing," "test-enhanced learning," and "self-testing," and by its benefits, the "testing effect."

The Essence of Retrieval Practice

The essence of retrieval practice is bringing to mind (e.g., as one would during a test) previously studied information. Although one can certainly learn from "high-stakes" tests (e.g., licensing exams) used for summative or judgement purposes, retrieval practice typically refers to "no-stakes" or "low-stakes" tests used for formative or improvement purposes.[7] Examples of no-stakes retrieval practice include activities such as quizzing oneself with flashcards, completing problems or questions at the end of a chapter, and taking old exams.[7] An example of low-stakes retrieval practice might be a quiz that counts for a small number of points or as extra-credit. What seems to be key to testing's benefits is the extent to which it requires additional processing of important information, elaboration of the memory, and thinking back to the initial learning episode.[8,9] The more

a retrieval practice activity reflects priority content, mirrors authentic information use, includes feedback, and is spaced and repeated, the better.[8]

Retrieval practice is thought to provide benefits through direct and indirect mechanisms.[10] The direct benefit refers to ". . . the act of taking a test itself."[10 p.182] Leamnson explains this well: "Intense concentration, under a little pressure, while wrestling with language, cannot but do something to the brain;"[11 p.111] and, he recommends recall-style questions (open-ended or essay) over recognition-style (multiple-choice) ones. However, some research suggests that multiple-choice questions can be just as effective if written well.[12-13] Roediger and Karpicke give examples of the indirect or "mediated" effect of testing as studying continuously throughout a course (i.e., distributed practice using cumulative exams), learning from feedback on practice tests, and using results to direct future study efforts.[10] Moreover, if one experiences significant test anxiety, practice tests can help by desensitizing one to testing conditions, especially if one takes a practice test under time and other exam-related constraints.[11]

In addition to tests being used effectively throughout a learning activity, tests given *before* a learning activity (pretests) offer benefits too,[14] perhaps by "priming students to focus on key information and cognitive activities encountered during study."[15 p.11] Study of pretests specifically in CPD is warranted, but given that pretests can serve as a way to complete a needs assessment, an evidence-based strategy in CPD,[16] issuing

pretests is a defensible action currently, especially in light of their potential learning value, even if only indirect.[17]

Controlling for the benefits of distributed practice, a clear example of comparing repeated testing to repeated studying comes from graduate medical education (GME). In a randomized controlled trial of long-term retention of information, Larsen and colleagues exposed counterbalanced (overlapping) groups of pediatric and emergency medicine residents to an interactive, one-hour teaching session on status epilepticus and myasthenia gravis followed by either repeated studying (review sheets) or by repeated testing (short-answer questions with feedback) immediately following the session, at two weeks, and at four weeks.[18] Despite a relatively small sample size, on the final test about six months after the interactive session, repeated testing resulted in statistically significant results ($p < 0.001$) and educationally significant scores (13% higher) compared to repeated studying.

Classic Research Underlying Retrieval Practice

Like the research on distributed practice, research on the benefits of retrieval date back over 100 years.[19] Since then, considerable research demonstrates the benefits of retrieval practice, both through testing and through other retrieval-based learning activities (e.g., concept mapping from memory).[20] Furthermore, retrieval practice can improve learning of content and its application.[9] In a classic and frequently cited set of experiments, Roediger and Karpicke demonstrated the direct benefits of retrieval on learning.[21] In one experiment, college students engaged in learning conditions that

required they study a text passage for five minutes and then either continue studying or recall what they could from memory (Figure). In one condition, students studied a passage four times in a row (SSSS). In a second condition, students studied three times and recalled what they could once (SSSR). Finally, in a third condition, students studied once and recalled three times (SRRR). Learning was measured through a final test either five minutes or one week after learning. After five minutes, those in the SSSS group performed best, while those in the SRRR group performed worst. However, after one week, significant learning benefits of retrieval practice were observed. Final test scores of students in the SRRR group were 20% higher than those of students in the SSSS group, with the SSSR group falling in-between. Importantly, students in the SRRR and SSSR groups never saw the passage again after recall, demonstrating long-term, direct effects of retrieval on learning, even in the absence of feedback.

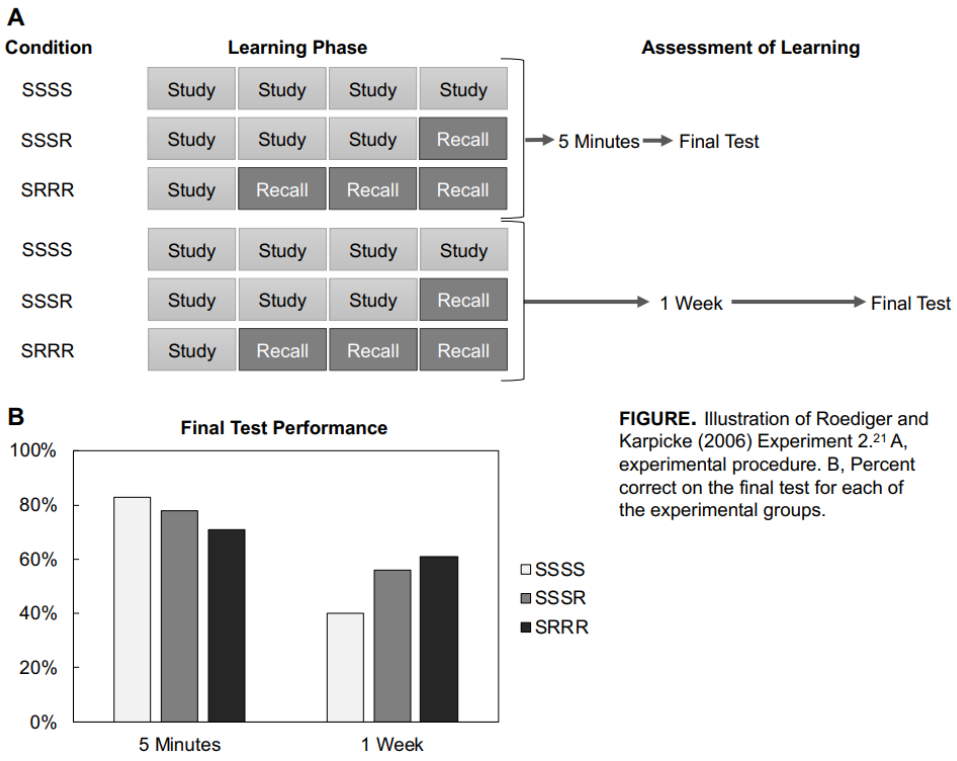

FIGURE. Illustration of Roediger and Karpicke (2006) Experiment 2.[21] A, experimental procedure. B, Percent correct on the final test for each of the experimental groups.

Neuroscience Underpinnings of Retrieval Practice

Given the significant effects of retrieval practice on learning, several studies have examined how retrieval practice occurs within the brain. Of particular interest are studies that have used functional magnetic resonance imaging (fMRI) to examine how differences in regional brain activity may underlie the differences between repeated study and retrieval practice during learning. Wing and colleagues examined brain activity during learning, with participants being asked to learn weakly-associated word pairings (e.g., study: TUSK—HORN, test: TUSK—?).[22] After initially studying sets of word pairs while in the MRI scanner, half of the word pairs were shown next as a retrieval test (without feedback), with the remaining word pairs shown again for re-study. The word pairs were then presented in a study block again, followed by a second retrieval test or by re-study. Rather than being compared to a control group consisting of different participants, each participant had some word pairs that they studied four times (SSSS) and some alternating between study and recall (SRSR). Twenty-four hours later, the participants returned and had the final memory test (outside of the MRI scanner), which was the critical test of interest. Replicating and extending the behavior-only studies described in the classic research section, participants had better memory retrieval for the word pairings that were in the retrieval practice condition (SRSR) than those that they merely re-studied (SSSS). Two particular brain regions (anterior cingulate cortex and inferior frontal gyrus) often associated with effortful learning were more involved in retrieval practice than in re-studying. Another study conducted by Eriksson and colleagues used a procedure with two major differences: (1) there was no restudy-only condition, and (2) the procedure included up to eight memory tests (eight

iterations of “SR”), but items were dropped from restudy (S trials) after successful recall.[23] Nonetheless, these researchers also found that activation of one brain region (anterior cingulate cortex) was associated with more retrieval practice. Several other studies with other procedural differences have come to similar conclusions.

Examples of CPD Studies Involving Retrieval Practice

Often in conjunction with distributed practice, a strategy addressed in the first article of the series,[6] the authors found a variety of CPD studies of retrieval practice in the literature from different countries and involving multiple health care professions and specialties. While not all studies that involved comparisons demonstrated a benefit of retrieval practice in outcomes measured (see, for example, McConnell et al. 2018), the vast majority casts a favorable light on the strategy. In fact, a recent systematic review of test-enhanced learning (a common synonym for retrieval practice) in the health professions found that retrieval practice “. . . demonstrates consistent and robust effects across different health professions, learner levels [including CPD], [testing] formats, and learning outcomes.”[2 p.337] The systematic review authors recommend that health professions educators use tests, especially ones that require “production” (or recall) of information, in a repeated and spaced way, and that educators provide learners with feedback on test results.[2] Reflecting some diversity of published research to date, the authors of this article chose three examples to illustrate the strategy of retrieval practice in the context of CPD.

Kerfoot and colleagues evaluated an online, spaced, educational game among primary care clinicians to improve knowledge of hypertension management and blood pressure control of patients receiving care in eight US Veterans Affairs' medical centers.[25] The intervention group received the "game," which consisted of emailed multiple-choice questions (with explanations) every three days for 52 weeks, with performance relative to peers offered to generate friendly competition. Until answered consecutively twice correctly, participants received repeat questions every 12 days (if incorrectly answered) or 24 days (if correctly answered). The control group received identical educational content through online posts.

Christopher and colleagues evaluated the first of a 5-year "stepwise skill reinforcement model" that included CPD as a way to improve important outcomes for Medicaid enrollees living in urban communities in Chicago.[26] The CPD component included a needs assessment, which inquired about knowledge and skill with motivational interviewing, followed by a live CPD activity, an immediate assessment (commitment to change format with barriers anticipated), and another assessment 6-8 weeks later (about competence and performance). Participants (physicians and other professionals serving a variety of roles) then received five monthly "testlets" (each with a case scenario, multiple-choice question, immediate feedback, and access to additional information) to measure outcomes and to reinforce the application of skills to practice.

As a final example, Feldman and colleagues conducted a pragmatic randomized controlled trial to improve knowledge retention and self-reported learning behaviors of

Canadian pediatricians attending a 4-day annual conference featuring 15 workshops.[27] The control group consisted of participants attending a conference workshop only. The intervention group consisted of participants attending a conference workshop but also completing a pretest (multiple-choice without feedback) one week prior to the conference and a posttest (multiple-choice with feedback) 14 days after the conference.

Recommendations for CPD Participants and Planners

What can CPD participants do to leverage the benefits of retrieval practice?

For CPD *participants* considering educational options to make significant improvements in knowledge, skill, attitude, and other important outcomes, taking advantage of a needs assessment, especially one that takes the form of a recall-style pretest, is likely superior to starting an educational activity without any advanced consideration of priority content. As a large-scale example of a pretest, the National Certification Corporation requires that nurses and nurse practitioners, who are beginning a new maintenance-of-certification cycle in a particular specialty or subspecialty, complete a 125-item assessment, the results of which drive an “individual education plan” (number of hours and focus of content) for that certification period.[28] Akin to taking a pretest, taking one or more posttests is a way to reinforce important information and to identify remaining gaps that might require additional effort. If spaced in time (≥1 day), each test requires a cycle that involves retrieval (accessing what is currently stored in long-term memory), encoding (considering information again in working memory), and consolidation (re-storing information in long-term memory). This learning cycle is critical to mastery and memory (Appendix). If a pre or posttest is not available for an activity, participants can

identify a recent, representative case and reflect on what is known and unknown with respect to evidence. Discussing the case with a colleague to identify challenging questions would prepare one to learn more effectively through the activity or to follow up with questions after an activity. Test questions might also be available through specialty societies. Even if such questions are recognition-style, a participant can think about the answer before looking at response options, effectively searching long-term memory for the information.

What can CPD planners do to leverage the benefits of retrieval practice?

CPD *planners* can enhance the educational value of an activity by offering questions, ideally open-ended ones tied to challenging cases, as pretests and posttests. The expert recruited for the activity might identify or help to develop cases for these purposes, and even construct responses that can serve as feedback to address inaccuracies and misperceptions. Another resource about cases for discussion and testing is *MedEdPORTAL*, an open-access journal of teaching and learning resources in the health professions.[29] Published activities include educational materials and evaluation instruments. During the activity itself, such as a meeting, the expert-discussant could deliver an unfolding case rather than make a presentation, asking questions that would force participants to query their long-term memory for information. An unfolding case might be more engaging and interactive than a presentation, especially if the participants generated the case based on an adverse outcome. In 2012, the American Academy of Neurology (AAN) effectively utilized a pretest and multiple posttests to enhance learning associated with its annual conference.[30] The AAN's

approach represents a combination of distributed practice and retrieval practice, but the optimal frequency of tests and the interval between them depends on a variety of factors.[5] Generally speaking, repeated retrieval attempts that are spaced are particularly effective.[8,9]

Conclusion

Retrieval practice involves using tests and related activities that challenge long-term memory in order to improve important educational outcomes in CPD. Cognitive psychology research in support of retrieval practice dates back over a century, and the field of neuroscience has begun to offer biological explanations that explain the strategy's effectiveness. Although people typically associate tests with high-stakes judgement, use of retrieval practice as a learning tool is appearing in the literature with increasing frequency, and retrieval practice's benefits have clear implications for participants and planners alike. Participants of CPD should seek activities that involve pre and post testing, and planners should supplement CPD activities with questions or cases that force learners to examine their long-term memory throughout the activity. Planners of CPD activities should design activities with practice questions and cases that are meaningful components of the activity itself, along with pre and post options. Furthermore, rather than recruit experts to make presentations, educators planning CPD activities should utilize experts to engage and to interact with the audience, through unfolding case discussions that include challenging questions before, during, and after the activity proper. Retrieval practice can inform the collective imagination of participants and planners, and, in so doing, improve the effectiveness of CPD activities.

Lessons for Practice

- Retrieval practice is an evidence-based strategy that supports learning and memory by requiring learners to scrutinize their long-term memory for important information and to undertake a challenge that can reinforce and extend expertise.

- Retrieval practice provides learners with an opportunity to test their memory for information not yet fully mastered and remembered, with opportunities for improvement that arise guiding additional CPD decisions and efforts.

- CPD planners and participants should utilize tests to enhance learning outcomes, considering open-ended and case-based questions to prepare, engage, and reinforce priority content.

References

1. Kitto S. Opening up the CPD imagination. *J Contin Educ Health Prof*. 2019;39:159-160.

2. Green ML, Moeller JJ, Spak JM. Test-enhanced learning in health professions education: A systematic review: BEME Guide No. 48. *Med Teach.* 2018;40:337-350. DOI 10.1080/0142159X.2018.1430354

3. Phillips JL, Heneka N, Bhattarai P, Fraser C, Shaw T. Effectiveness of the spaced education pedagogy for clinicians' continuing professional development: A systematic review. *Med Educ.* 2019 Sep;53:886-902. DOI 10.1111/medu.13895

4. Van Hoof TJ, Doyle TJ. Learning science as a potential new source of understanding and improvement for continuing education and continuing professional development. *Med Teach*. 2018;40:880-885. DOI 10.1080/0142159X.2018.1425546

5. Weinstein Y, Madan CR, Sumeracki MA. Teaching the science of learning. *Cogn Research.* 2018;3:2-17. DOI 10.1186/s41235-017-0087-y

6. Author 1, Author 2, Author 3. Science of Learning Strategy Series: Article 1, Distributed Practice. *JCEHP* (in press).

7. 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 Interest*. 2013;14:4-58.

8. Larsen DP, Butler AC. Test-enhanced learning (Chapter 38). In Walsh K (Ed.). *Oxford Textbook of Medical Education*. Oxford University Press: New York, NY; 2013. DOI: 10.1093/med/9780199652679.001.0001

9. Karpicke, J. D. (2017). Retrieval-based learning: A decade of progress. In J. T. Wixted (Ed.), *Cognitive psychology of memory, Vol. 2 of Learning and memory: A comprehensive reference* (J. H. Byrne, Series Ed.) (pp. 487-514). Oxford: Academic Press.

10. Roediger HL, Karpicke JD. The power of testing memory: Basic research and implications for educational practice. *Perspect Psychol Sci.* 2006;1:181-210.

11. Leamnson R. Thinking about Teaching and Learning: Developing Habits of Learning with First Year College and University Students. Sterling, VA: Stylus, 1999.

12. Little JL, Bjork EL, Bjork RA, Angello G. Multiple-choice tests exonerated, at least of some charges: Fostering test-induced learning and avoiding test-induced forgetting. *Psych Sci*. 2012;23:1337-1344. DOI 10.1177/0956797612443370

13. Smith MA, Karpicke JD. Retrieval practice with short-answer, multiple-choice, and hybrid tests. *Memory*. 2014;22:784-802. DOI 10.1080/09658211.2013.831454

14. Little JL, Bjork EL. Pretesting with multiple-choice questions facilitates learning. Conference Paper. August 2011. Accessed April 13, 2020. https://cogsci.mindmodeling.org/2011/papers/0058/paper0058.pdf

15. Brame CJ, Biel R. Test-enhanced learning: The potential for testing to promote greater learning in undergraduate science courses. *CBE Life Sci Edu*. 2015;14:1-12. DOI:10.1187/cbe.14-11-0208

16. Mazmanian PE, Davis DA. Continuing medical education and the physician as a learner: Guide to the evidence. *JAMA*. 2002;288(9):1057-1060.

17. Roediger, H. L., Putnam, A. L., & Smith, M. A. (2011). Ten benefits of testing and their applications to educational practice. In J. Mestre & B. Ross (Eds.), *Psychology of learning and motivation: Cognition in education* (pp. 1-36). Oxford: Elsevier.

18. Larsen DP, Butler AC, Roediger HL. Repeated testing improves long-term retention relative to repeated study: A randomized controlled trial. *Med Educ.* 2009;43:1174-1181.

19. Abbott EE. On the analysis of the factors of recall in the learning process. *The Psychol Rev: Monograph Supplements*. 1909; 11:159-177. DOI 10.1037/h0093018

20. Blunt JR, Karpicke JD. Learning with retrieval-based concept mapping. *J Educ Psychol.* 2014; 106:849-858. DOI 10.1037/a0035934

21. Roediger HL, Karpicke JD. Test-enhanced learning: Taking memory tests improves long-term retention. *Psych Sci*. 2006;17:249-255. DOI 10.1111/j.1467-9280.2006.01693.x

22. Wing EA, Marsh EJ, Cabeza R. Neural correlates of retrieval-based memory enhancement: An fMRI study of the testing effect. *Neuropsychologia*. 2013;51(12):2360-70. DOI 10.1016/j.neuropsychologia.2013.04.004

23. Eriksson J, Kalpouzos G, Nyberg L. Rewiring the brain with repeated retrieval: A parametric fMRI study of the testing effect. *Neurosci. Lett*. 2011;505(1):36-40. DOI 10.1016/j.neulet.2011.08.061

24. McConnell M, Hou C, Panju M, Panju A, Azzam K. Does testing enhance learning in continuing medical education? *Can Med Educ J*. 2018;9:e83-e88.

25. Kerfoot BP, Turchin A, Breydo E, Gagnon D, Conlin PR. An online spaced-education game among clinicians improves their patients' time to blood pressure control: A randomized controlled trial. *Circ Cardiovasc Qual Outcomes*. 2014;7:468-474. DOI: 10.1161/CIRCOUTCOMES.113.000814

26. Christopher B, Grantner M, Coke LA, Wideman M. Better care teams: A stepwise skill reinforcement model. *J Contin Educ Health Prof.* 2016;47:283-288.

27. Feldman M, Fernando S, Wan M, Martimianakis MA, Kulasegaram K. Test-enhanced continuing medical education: A randomized controlled trial. *Acad Med*. 2018;93:S30-S36.

28. Bissinger R, Burns B. Third-party assessment and targeted continuing education for maintenance of certification. *J Nurs Regul*. 2018;9:53-58.

29. Association of American Medical Colleges. MedEdPORTAL. https://www.mededportal.org/about/journalinformation/. Accessed April 9, 2020.

30. Larsen DP, Butler AC, Aung WY, Corboy JR, Friedman DI, Sperling MR. The effects of test-enhanced learning on long-term retention in AAN annual meeting courses. *Neurology*. 2015;84:748-754.