Science of Learning Strategy Series: Article 1, Distributed Practice

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Abstract: Distributed practice is an evidence-based, learning-science strategy that is relevant to the planning and implementation of continuing professional development (CPD). Spacing-out study or practice over time allows the brain multiple opportunities to process new and complex information in an efficient way, thus increasing the likelihood of mastery and memory. Research from cognitive psychology and neuroscience provide the rationale for distributed practice, and examples of its implementation in health professions education have begun to appear in the literature. If used appropriately or extended creatively, some common CPD interventions can fully leverage distributed practice. Through increased understanding, CPD planners can benefit from distributed practice in efforts to improve educational activities, and CPD participants can benefit by making more informed educational choices.

Keywords: science of learning, distributed practice, distributed learning, spacing, continuing education, continuing professional development

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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[2–4] 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 two, evidence-based, learning-science strategies, and to provide some background that might be helpful to CPD stakeholders considering the strategies. One strategy, "retrieval practice," is the focus of the second article of the series, and retrieval practice concerns how one spends time while learning. The other strategy and the focus of this article is "distributed practice," which concerns when one schedules learning sessions. Distributed practice is also known as "distributed learning" and "spacing" and by its benefits, the "spacing effect."

THE ESSENCE OF DISTRIBUTED PRACTICE

The essence of distributed practice is that any significant effort put toward learning or practice is better spread out over time as opposed to massed, as in "massed practice" or "cramming."[5] For example, if one had 6 hours to devote to meaningful learning, time would be better spent in small increments (1–2 hours) on multiple days rather than in one large increment on a single day. Once new information is in working memory, or is activated in our immediate consciousness, additional effort spent with that information offers diminishing returns. In other words, continuing to rehearse or to go over the information at one single time does not provide much of a benefit. Instead, coming back to information repeatedly with cognitive breaks (spaced) between learning sessions—with sleep being the best break[6]—stabilizes the brain network that represents the information. Continuous repetition without cognitive breaks does not activate as much of the brain and does not provide the varied cues (eg, time, place, circumstance, alertness, and mood) associated with different study sessions. For any given effort, distributed practice is superior to massed practice for improving mastery and memory for new information.[5]

A clear example comparing distributed practice and massed practice comes from graduate medical education involving skill acquisition. In a randomized controlled trial, Moulton et al[7] compared two similar groups of surgical residents learning microvascular anastomosis. The massed practice group received four 2-hour training sessions on a single day, whereas the distributed practice group received one 2-hour training session per week for four consecutive weeks. Other than the scheduling difference, the training was the same for both groups. On a retention test using synthetic tissues one month post-training for both groups, the distributed group outperformed the massed group on most outcome measures. More importantly, however, the distributed group outperformed the

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massed group on a "transfer test," ie, applying the skill to vessels in a live, anesthetized animal, a circumstance in which neither group practiced. Despite acknowledging the logistical challenges associated with a multiple-session course versus a single-session course, the authors recommend considering the distributed approach for learning surgical skills in the context of both graduate medical education and CPD.

Classic Research Underlying Distributed Practice

Research on distributed practice and the first experimental study of memory date back to the 19th century, when Ebbinghaus[8] intensively studied his own learning of nonsense syllables over the course of many months. He used nonsense syllables so that he could avoid making connections to meaningful content, as he wanted to learn completely new information. Ebbinghaus is famous for plotting the forgetting curve and showing that over time humans lose access to learned information. The forgetting curve tends to be exponential, such that we lose access to the great amount of information in a relatively short amount of time (hours) and forgetting tapers off but continues in the long-run (days, weeks, or months). In his classic work, Ebbinghaus also found that additional repetitions were effective at slowing the rate of forgetting and that repetitions were effective when they were distributed over time. Since this very early work, countless studies have found similar effects across a wide range of disciplines, learners, and contexts, and there is no shortage of reviews on this topic.[9,10] Furthermore, spacing improves learning in a number of different domains, including verbal learning,[11] problem solving,[12] and skill acquisition.[13] Synthesizing this work, Cepeda et al[5] conducted a large meta-analysis reaffirming that distributing learning over time with at least a 1-day space maximizes long-term retention of that information.

Neuroscience Underpinnings of Distributed Practice

When a person processes information for the first time, their brain activity is more extensive, that is, engages more parts of the brain. For example, initial processing involves the hippocampus, part of the temporal lobe that coordinates processing of information (Figure 1) and many regions of the cerebral cortex depending on the senses involved and the information's meaning to the learner. If repetition occurs during the initial session, the brain will process the information less exhaustively and less extensively[15,16] and diminish the involvement of the hippocampus in that processing. However, if spacing of several days or weeks exists between repeated attempts (ie, distributed practice across a relatively brief period), each session is more like the initial one in the sense that the brain is extensively activated[17] and continues to involve the hippocampus. In other words, by distributing practice over a period of days or weeks, it becomes easier to reactivate a memory of previous information and to continue to engage extensive brain regions.

Over longer time periods (eg, months or years), distributed practice can result in information becoming available more as a fact (semantic memory) than as an experience (episodic memory). In this circumstance, the role of the hippocampus becomes less critical in retrieving the information (Figure 2). For example, Sommer[18] demonstrated this point in a longitudinal study. On a computer screen, participants learned arbitrary associations between pictures and locations and were repeatedly presented and tested over the course of approximately 300 days. During presentation and

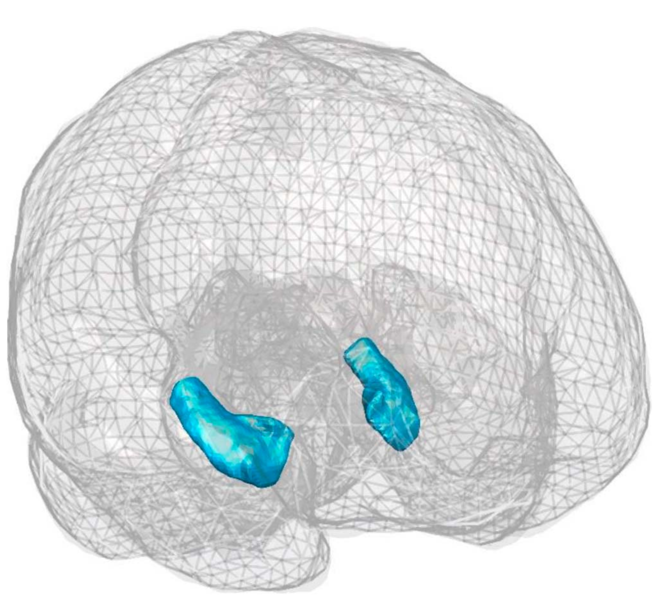

FIGURE 1. Illustration of the hippocampus structure within a transparent three-dimensional brain outline. Reprinted with permission.[14]

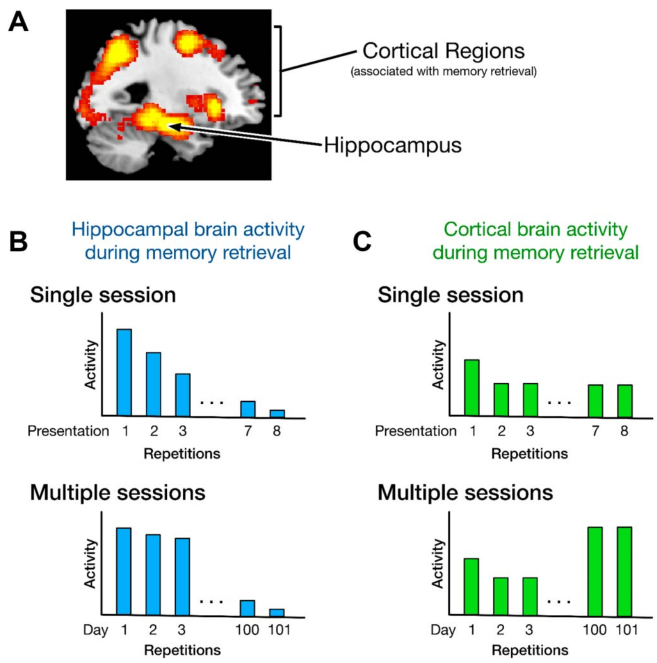

FIGURE 2. Brain regions and activations related to memory retrieval over different time scales. A, Brain regions associated with memory retrieval, in particular, the hippocampus along with regions of the cerebral cortex. Brain activity is shown as regional activations from fMRI data, overlaid on a structural MRI. B and C, illustrate brain activity in the (B) hippocampus and (C) cortical regions associated with memory retrieval over multiple repetitions that are either within a single experimental session or across multiple sessions. Within a single session, the hippocampal activity will be attenuated with each subsequent presentation, whereas activation in cortical regions is slightly reduced on the second presentation and is maintained at this level for later presentations. However, across multiple sessions, the hippocampal activity will reach nearly the same level and will diminish much more gradually. In this case, the activity in cortical regions will be relatively low in early sessions and later become higher after distributed practice. In this way, the cortical activity becomes decoupled from the hippocampal activity, as the information transitions from episodic memory to semantic memory.

testing, the study measured brain activity using functional magnetic resonance imaging (fMRI) at days 1 and 2, at several sessions around day 100, and at several sessions around day 300. In the first sessions (days 1 and 2), retrieval of the learned associations engaged the hippocampus; however, the hippocampal engagement diminished in later sessions (around days 100 and 300). By contrast, activity in regions of the cerebral cortex increased in later sessions, corresponding to the gradual acquisition of knowledge (creation of semantic memory) without the need for their accompanying experiences (episodic memory). In other words, through longer-term distributed practice, information became less reliant on the episodic memory system and more reliant on the semantic one, enhancing expertise in the newly learned domain.

Examples of CPD Studies Involving Distributed Practice

Often in conjunction with retrieval practice, a strategy to be described in the second article of the series, the authors found a variety of CPD studies of distributed practice in the literature from different countries and involving multiple health care professions and specialties. Although not all studies that involved comparisons demonstrated a benefit to distributed practice in outcomes measured,[19] the majority casts a favorable light on the strategy. In fact, a recent systematic review of distributed practice in CPD specifically found that spaced activities (mostly online) can be effective in improving clinician knowledge, skill, attitude (confidence), behavior (including performance), and possibly patient outcomes.[3] Based on published research, the authors chose three examples to illustrate the strategy of distributed practice in the context of CPD.

As the first example, in an effort to decrease inappropriate prostate-specific antigen testing among primary care providers (nurse practitioners, physicians, and physician assistants) working in a region of the US Veterans Affairs system, Kerfoot et al[20] published a randomized controlled trial comparing a control group (no intervention) with a "spaced education" cohort, which received four cycles of nine emails (0–2 emails per week) over a 36-week intervention period. Each email consisted of a clinical scenario with a question about whether a prostate-specific antigen test was appropriate, and participants received immediate feedback (the answer with explanation reflecting clinical practice guidelines) after responding.

As a second example, in a prospective longitudinal study of a course (fundamentals of laparoscopic surgery) to develop minimally invasive surgical skills among 57 practicing surgeons in Brazil, Nakata et al[21] demonstrated that an in-person, simulator-based, long-term course (three sessions spread evenly—every four months—over a 1-year period) is a feasible alternative to the single, intensive (weekend) short-term course that typifies post-training options.

As a third example, Robinson et al[22] report quantitative and qualitative results of a pilot study of a brief "spaced education" program to impact the knowledge and referral patterns of Australian health care providers (ie, primary care physicians, nurses, medical oncologists, and gynecology–oncology fellows) to reflect guideline updates on genetic assessment and testing for women with particular types of cancer. On spaced (every 5 or 8 days) and repeated intervals (until participants answered each question correctly twice), participants received emails with a case, question, choices, and following a response, the results (with peer comparison), a take-home message, detailed explanation, and reference.

Recommendations for CPD Participants and Planners

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

For CPD participants considering educational options to make significant improvements in knowledge, skill, attitude, and other important outcomes, selecting a longitudinal activity that meets relatively briefly but multiple times with some space ($\geq$1 day) between sessions is a better strategy than a single event. Multiple interactions over time reflect the brain's need for iterative cycles of encoding (considering information in working memory), consolidation (storing information in long-term memory), and retrieval (accessing what is stored for additional consideration) that are critical to mastery and memory (Appendix, Supplemental Digital Content 1, http://links.lww.com/JCEHP/A96). However, participants can transform a single, educational event into a spaced one by taking advantage of event preactivities, such as pretests or needs assessments, and event postactivities, such as post-tests and clinician reminders. Participants can also create their own preactivities and postactivities by reviewing performance measurement and feedback reports that are increasingly available from health plans, talking with colleagues and patients about barriers to care, and/or reflecting on a challenging case that raises questions about opportunities for improvement. Turning any learning opportunity into a process rather than an event can increase its learning value by distributing practice.

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

CPD planners can enhance the educational value of an activity by offering multiple sessions spread-out over time. Some common CPD structures, such as grand rounds, performance improvement, educational outreach, and practice facilitation lend themselves to the advantages of distributed practice, as they involve (or can involve) repeated, brief interactions over time. If an event (eg, national conference) is still necessary or desirable for other reasons, such as networking and collaboration, planners can engage learners before and after the conference through meaningful virtual interactions. Emails with links to poignant examples can predispose learners to content that the conference will address, and challenging cases can generate cognitive dissonance regarding relevant content. After the conference, planners can reinforce important content through post-tests, electronic health record tools (clinician reminders and documentation prompts), patient-mediated interventions (patient reminders), and follow-up on commitments to change made at the conference. Specialty societies (state chapters) and other organizations can offer complementary activities, such as quality improvement collaboratives, which build on a conference theme.

As one example of a national conference that offered preactivities and postactivities to improve long-term retention of knowledge, the American Academy of Neurology's 2012 conference conducted a study of four topics (ie, epilepsy, multiple sclerosis, headache, and child neurology), each addressed through an in-person short course offered as part of the conference.[23] All recruited participants completed a pretest before the conference and experienced each of the courses during the conference. The control group received no follow-up, but two intervention groups received virtual follow-up, one through repeated quizzing and the other through repeated studying. Finally, 5.5 months after the conference, all participants completed a knowledge post-test, which was identical to the pretest. Although the study's details are beyond the scope of this article, the authors reported that the repeated quizzing group demonstrated significantly better long-term knowledge retention compared with the repeated study and control groups. Through repeated testing (another term for retrieval practice), the study provides an example of a way to accomplish distributed practice in a traditional educational event such as a conference.

CONCLUSION

Distributed practice is the act of spreading-out or spacing study to improve important educational and patient-care outcomes in CPD. Cognitive psychology research in support of distributed practice dates back over a century, and the field of neuroscience has begun to offer biological explanations to support the strategy's effectiveness. Although some logistical challenges exist, examples from CPD specifically and health professions education generally have begun to appear in the literature, and these examples have clear implications for participants and planners alike. Participants of CPD should seek activities that reflect a process similar to learning itself. Through needs assessment, pretests and post-tests, and performance measurement and feedback of patient care data, participants can transform one-time events into more effective mechanisms for learning and change. Educators planning CPD activities should offer longitudinal programs that are necessarily distributed, or planners should extend a single event through one or more educational and quality improvement interventions to accomplish spacing. Distributed practice can inform the collective imagination of participants and planners and, in doing so, improve the effectiveness of CPD activities.

Lessons for Practice

- Distributed practice or spacing is an evidence-based strategy that supports learning and memory through multiple study or practice sessions separated by cognitive breaks.
- Participants of CPD events can transform nonspaced activities into distributed ones through needs assessments, pretests and post-tests, and performance measurement and feedback of patient care data.
- Educators planning continuing professional activities can accomplish distributed practice by offering longitudinal programs that pair events with one or more educational or quality improvement interventions that occur before and/or after the event.

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