The Interleaving Effect: Mixing It Up Boosts Learning

Studying related skills or concepts in parallel is a surprisingly effective way to train your brain

Steven C. Pan

This article was originally published by Scientific American. The text in this file is a pre-print version of the final article that was published in the Mind Matters section of Scientific American Mind on August 4, 2015. This document may not exactly replicate the final published version. It is not the copy of record. As of September 3, 2015, the final version is available at: http://www.scientificamerican.com/article/the-interleaving-effect-mixing-it-up-boosts-learning/

We've all heard the adage: practice makes perfect! In other words, acquiring skills takes time and effort. But how exactly does one go about learning a complex subject such as tennis, calculus, or even how to play the violin? An age-old answer is: practice one skill at a time. A beginning pianist might rehearse scales before chords. A young tennis player practices the forehand before the backhand. Learning researchers call this "blocking," and because it is commonsensical and easy to schedule, blocking is dominant in schools, training programs, and other settings.

However another strategy promises improved results. Enter "interleaving," a largely unheard-of technique that is capturing the attention of cognitive psychologists and neuroscientists. Whereas blocking involves practicing one skill at a time before the next (for example, "skill A" before "skill B" and so on, forming the pattern "AAABBBCCC"), in interleaving one mixes, or interleaves, practice on several related skills together (forming for example the pattern "ABCABCABC"). For instance, a pianist alternates practice between scales, chords, and arpeggios, while a tennis player alternates practice between forehands, backhands, and volleys.

Over the past four decades, a small but growing body of research has found that interleaving often outperforms blocking for a variety of subjects, including sports and category learning. Yet there have been almost no studies of the technique in uncontrived, real world settings—until recently. New research in schools finds that interleaving produces dramatic and long-lasting benefits for an essential skill: math. Not only does this finding have the potential to transform how math is taught, it may also change how people learn more generally.

The first signs of interleaving's promise appeared in the domain of motor skills. One early study, published in 1986, involved training students to learn three types of badminton serves. Compared with blocking, interleaving produced better recall of each serve type and better ability to handle new situations, such as serving from the opposite side of the court. Similar results were later reported for baseball, basketball, and other sports. In 2003, one of the first studies to examine interleaving outside of sports found that using it to train medical students produced more accurate electrocardiogram diagnoses than blocking. In 2008, another widely-cited study found a similar benefit for teaching college students to recognize the painting styles of landscape artists. Even critical thinking skills benefit: in a 2011 study, students trained with the technique made more accurate assessments of complex legal scenarios.

Foreign language studies however suggest that the effectiveness of interleaving comes with an important caveat. When native English speakers used the technique to learn an entirely unfamiliar language, such as to generate English-to-Swahili translations, the results were better, the same, or worse than after blocking. These mixed results imply that learners should have some familiarity with subject materials before interleaving begins (or, the materials should be quickly or easily understood). Otherwise, as appears to be the case for foreign languages, interleaving can sometimes be more confusing than helpful.

Given interleaving's promise, it is surprising then that few studies have investigated its utility in everyday applications. However, a new study by cognitive psychologist Doug Rohrer and colleagues at the University of South Florida, recently published in the *Journal of Educational Psychology*, takes a step towards addressing that gap. Rohrer and his team are the first to implement interleaving in actual classrooms. The location: middle schools in Tampa, Florida. The target skills: algebra and geometry.

The three-month study involved teaching 7th graders slope and graph problems. Weekly lessons, given by teachers, were largely unchanged from standard practice. Weekly homework worksheets, however, featured an interleaved or blocked design. When interleaved, both old and new problems of different types were mixed together. Of the nine participating classes, five used interleaving for slope problems and blocking for graph problems; the reverse occurred in the remaining four. Five days after the last lesson, each class held a review session for all students. A surprise final test occurred one day or one month later. The result? When the test was one day later, scores were 25 percent better for problems trained with interleaving; at one month later, the interleaving advantage grew to 76 percent.

These results are important for a host of reasons. First, they show that interleaving works in real-world, extended use. It is highly effective with an almost ubiquitous subject, math. The interleaving effect is long-term—lasting on the order of months—and the advantage over blocking actually increases with the passage of time (in other words, there's less forgetting). The benefit even persists when blocked materials receive additional review. Overall, the interleaving effect can be strong, stable, and long-lasting.

Clearly interleaving does wonders for 7th grade math. Moreover, when combined with prior work showing similar benefits of the technique across a spectrum of topics (algebra, exponents, proportions, prisms, and volumes) and with students at different grade levels (elementary through college), interleaving may turn out to be among the most effective math learning techniques.

Researchers are now working to understand why interleaving yields such impressive results. One prominent explanation is that it improves the brain's ability to tell apart, or discriminate, between concepts. With blocking, once you know what solution to use, or movement to execute, the hard part is over. With interleaving, each practice attempt is different from the last, so rote responses don't work. Instead, your brain must continuously focus on searching for different solutions. That process can improve your ability to learn critical features of skills and concepts, which then better enables you to select and execute the correct response.

A second explanation is that interleaving strengthens memory associations. With blocking, a single strategy, temporarily held in short-term memory, is sufficient. That's not the case with interleaving—the correct solution changes from one practice attempt to the next. As a result, your brain is continually engaged at retrieving different responses and bringing them into short-term memory. Repeating that process can reinforce neural connections between different tasks and correct responses, which enhances learning.

Both of these accounts imply that increased effort during training, either to discriminate correct responses or to strengthen them, is needed when interleaving is used. This corresponds to a potential drawback of the technique, namely that the learning process often feels more gradual and difficult at the outset. However, that added effort can generate better, longer-lasting results.

In modern society there is tremendous interest in ways to enhance learning and memory: brain training, learning apps, and so on. Interleaving has the benefit of scientific evidence in favor of its use across a range of circumstances. It also has the practical advantage of requiring no extra training, extra time, or special equipment to work. Only more careful planning is required, and possibly some extra effort at the outset.

Despite these relative advantages, interleaving remains mostly unknown and unused. Consider the example of grade school math. Out of all the math textbooks used in the U.S. today, all but one type—the Saxon series—uses blocked practice. One can only speculate on what would happen if interleaving were widely used in classrooms and in textbooks. The differences in academic achievement could be substantial.

As interleaving research progresses, we stand to learn much more about the technique: other areas where it works, or doesn't, and what other limitations it might have. Yet that doesn't preclude us from putting it to the test right now. For instance, are you studying statistics? Learning to play an instrument? Taking up a new sport? In all of these areas, you are faced with a series of skills or concepts to learn. The typical response would be to practice each of these, one at a time, over and over. Another option would be to mix it up. As it turns out, your brain may prefer doing exactly that. ■

References

Carpenter, S. K., & Mueller, F. E. (2013). The effects of interleaving versus blocking on foreign language pronunciation learning. *Memory & Cognition*, *41*(5), 671-682.

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*(1), 4-58.

Goode, S., & Magill, R. A. (1986). Contextual interference effects in learning three badminton serves. *Research Quarterly for Exercise and Sport*, *57*(4), 308-314.

Hambrick, D. Z. (2014). Brain training doesn't make you smarter. In G. Cook (Ed.), *Scientific American Mind, Mind Matters*. Available at: https://www.scientificamerican.com/article/brain-training-doesn-t-make-you-smarter/

Helsdingen, A., van Gog, T., & van Merriënboer, J. (2011). The effects of practice schedule and critical thinking prompts on learning and transfer of a complex judgment task. *Journal of Educational Psychology*, *103*(2), 383.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"?. *Psychological Science*, *19*(6), 585-592.

Landin, D. K., Hebert, E. P., & Fairweather, M. (1993). The effects of variable practice on the performance of a basketball skill. *Research Quarterly for Exercise and Sport*, *64*(2), 232-237.

Mayfield, K. H., & Chase, P. N. (2002). The effects of cumulative practice on mathematics problem solving. *Journal of Applied Behavior Analysis*, *35*(2), 105-123.

Richland, L. E., Finley, J. R., & Bjork, R. A. (2004). Differentiating the contextual interference effect from the spacing effect. *Proceedings of the 26th Annual Conference of the Cognitive Science Society*. Chicago, IL: Cognitive Science Society.

Rohrer, D., Dedrick, R. F., & Burgess, K. (2014). The benefit of interleaved mathematics practice is not limited to superficially similar kinds of problems. *Psychonomic Bulletin & Review*, *21*(5), 1323-1330.

Rohrer, D., Dedrick, R. F., & Stershic, S. (2015). Interleaved practice improves mathematics learning. *Journal of Educational Psychology*, *107*(3), 900-908.

Rohrer, D., & Taylor, K. (2007). The shuffling of mathematics problems improves learning. *Instructional Science*, *35*(6), 481-498.

Schneider, V. I., Healy, A. F., & Bourne Jr, L. E. (2002). What is learned under difficult conditions is hard to forget: Contextual interference effects in foreign vocabulary acquisition, retention, and transfer. *Journal of Memory and Language*, *46*(2), 419-440.

Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. *Applied Cognitive Psychology*, *24*(6), 837-848.

About the Author

Steven C. Pan is a National Science Foundation Graduate Research Fellow and doctoral candidate at the University of California, San Diego. His research involves using the tools of cognitive psychology and neuroscience to enhance human learning, memory, and performance. This article was drafted at the 2015 ComSciCon workshop, held at the Microsoft NERD Center and sponsored by Harvard University and MIT.

Please address correspondence to Steven C. Pan, Department of Psychology, University of California, San Diego. 9500 Gilman Drive, La Jolla, CA, USA, 92093-0109. Email: stevencpan@ucsd.edu