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THE BENEFITS OF INTERLEAVED PRACTICE FOR LEARNING

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Introduction

Practice is critical to successful learning. Teachers assign homework to give students additional experience with concepts taught in class, students know that they need to review their notes and other course material before an exam, and athletes put in many hours of training to improve and be at the top of their game. Indeed, a single exposure to a fact, concept, or activity will typically not yield effective and long-lasting knowledge or skill acquisition, no matter how attentive or well-intentioned a learner is. The importance of practice is supported by a wealth of anecdotal and scientific evidence (e.g. Ackerman, 2014; Ericsson et al., 2007), and is probably intuitive to most people. What is less obvious, however, is how the practice should be organized or scheduled.

In particular, I am referring to situations in which the learner is presented with multiple examples pertaining to a certain topic or problem type (e.g. in mathematics), or when the learner has the opportunity to engage in repeated practice of a given activity (e.g. golf swing, tennis stroke). Does the sequencing of practice examples or activities within a study or training session affect learning, and, if so, are there ways to schedule or arrange practice so as to optimize this learning?

In this chapter, I shall offer an affirmative answer by reviewing research that has demonstrated that interleaving (or mixing together) different kinds of examples or activities during practice often produces superior learning to that achieved by blocking (or grouping together) the examples or activities by type, across a range of educationally relevant contexts. I shall also examine theoretical accounts of the interleaving advantage, compare how typical pedagogy lines up with the research findings, and discuss the practical implications for educators.

Distributed Practice

Since this chapter deals with the sequencing of practice to optimize learning, it would be remiss of me not to mention the important finding that distributed practice enhances long-term
learning to a greater extent than does massed practice. When the initial study and subsequent review/training opportunities are spaced out over time instead of occurring back to back, learning tends to be more durable (e.g. Cepeda et al., 2006). This phenomenon, often referred to as the spacing effect, has been known by memory researchers for over a century. For instance, in the late nineteenth century, William James in his talks to teachers recommended distributed practice:

You now see why ‘cramming’ must be so poor a mode of study. Cramming seeks to stamp things in by intense application immediately before the ordeal. But a thing thus learned can form but few associations. On the other hand, the same thing recurring on different days, in different contexts, read, recited on, referred to again and again, related to other things and reviewed, gets well-wrought into the mental structure. This is the reason why you should enforce on your pupils habits of continuous application.

(James, 1899/1914, p. 129)

The benefit of spaced or distributed practice has been demonstrated repeatedly with a variety of study materials and learning tasks, and is widely regarded as one of the most robust learning and memory phenomena in the research literature (for a recent review, see Carpenter et al., 2012; also see Chapters 4 and 6 of this volume). There is, however, another study sequencing effect that is related to and yet different from that of spaced practice, and it is the proper focus of this chapter.

Interleaving vs. Blocking

When a teacher sets homework assignments for students or when a sports coach designs practice drills for athletes, the teacher or coach has an important choice to make—either to have the student or athlete work on one kind of component skill many times in a row before moving on to the next skill, or to allow the various kinds of component skills to be mixed together throughout practice. These two alternatives in sequencing practice examples are referred to as blocked (e.g. A1A2A3B1B2B3C1C2C3) and interleaved practice (e.g. A1B1C1B2A2C2B3C3A3), respectively (it is, of course, possible to think of hybrid blocked–interleaved schedules, but for the sake of simplicity I shall focus primarily on the comparison between pure cases).

In the following sections, I shall review studies comparing the relative efficacy of interleaving vs. blocking practice. To foreshadow, research in three broad domains of learning—motor skill acquisition, category learning, and mathematics problem solving—has shown that interleaved practice often yields greater long-term gains. However, learners are typically unaware of the interleaving advantage, and commonly think that blocked practice is more effective for learning. Note that in all the studies described in this chapter the amount of practice or training did not differ between the interleaved and blocked conditions—that is, the number of practice trials or the items or examples presented during training were identical across conditions. The only difference was in how the practice trials or examples were sequenced.
Motor Skill Acquisition

Evidence

The domain of learning that has generated the most research on the sequencing effects of practice trials has been in the area of motor skill acquisition. Shea and Morgan (1979) were the first to demonstrate that interleaved practice led to better motor learning than blocked practice. In their experiment, participants practiced executing three different patterns of movement with their right arms in either an interleaved or blocked sequence of trials. During training, participants in the blocked practice condition exhibited better (i.e. quicker) performance than those in the interleaved condition. However, on a test administered either shortly after or 10 days after training, the participants who underwent interleaved practice displayed faster completion times when executing the movement patterns in which they had been trained. In addition, this group demonstrated faster performance when executing new, unpracticed movement patterns. In other words, interleaving the different kinds of practice trials led to superior retention (memory for the trained behavior) and transfer (the ability to generalize learning to novel contexts).

In a different study that examined the batting skills of collegiate baseball team members, players were given extra batting practice (on top of their usual training) twice a week for 6 weeks. In each practice session, players received 45 pitches (15 each of fastballs, curveballs, and change-ups) either blocked by type or randomly intermixed. On a batting test given after the extra practice sessions, players who had trained in the interleaved condition produced more solid hits than those who had trained in the blocked condition, regardless of whether the pitch type was blocked or random at test (Hall et al., 1994). In a similar study, college students without previous experience of playing racquet sports learned three different badminton serves (short, long, and drive). Participants undertook three sessions of training per week for 3 weeks. In each session, participants performed 36 practice serves. One group practiced only one kind of serve during each training session (e.g. short serve in the first session, long serve in the second session, and drive serve in the third session), while another group practiced all three serves during each training session (i.e. 12 practice trials for each type of serve, randomly sequenced). A test was administered 1 day after the final training session, in which participants had to execute the three different serves. The group that received randomly interleaved training produced more accurate serves (the shuttlecock/birdie was more likely to attain the appropriate height and land within the target area) than the blocked practice group, both when the serves were made from the side of the court that the participants had practiced on (the right) and when the serves were made from the opposite, unpracticed side (the left). Again this demonstrates that interleaved practice led to superior retention and transfer of trained motor skills (Goode & Magill, 1986). Comparable results have been observed in other studies featuring novices learning golf (Porter et al., 2007) and volleyball (Kalkhoran & Shariati, 2012).

In addition to sports, research has found advantages of interleaved practice for a number of other motor skills. For instance, Stambaugh (2011) trained beginning clarinet players (elementary school children) to play three brief series of notes. Over the course of a week, the children participated in three practice sessions, each consisting of 18 practice trials. One group practiced only one series during each session (i.e. they practiced the same series repeatedly 18 times), while a second group practiced all three series of notes during each session (i.e. six practice trials per series, all randomly interleaved). When retention was
assessed 1 day after the final practice for each series, the children who underwent interleaved practice were able to play the series of notes more quickly than those who underwent blocked practice (see also Stambaugh, 2011). In a similar study, participants with previous formal training practiced playing a number of brief melodies on a piano with the goal of improving speed and maintaining accuracy. The melodies were practiced in pairs, with half of the pairs presented in a blocked fashion (repeated practice of one melody before moving on to the next melody) while the remaining pairs were randomly sequenced in an interleaved fashion. On a test administered 2 days after training, melodies that were practiced in the interleaved condition were played more quickly than those that were practiced in the blocked condition (Abushanab & Bishara, 2013).

Explanations

To help to explain the advantage of interleaved over blocked practice for motor skill learning, researchers often point to the role of *contextual interference* (Battig, 1979). The basic idea is that interleaved practice allows for a more variable training context than blocked practice, and that this variability introduces interference. Although increased interference typically slows the acquisition of a novel skill (e.g. Abushanab & Bishara, 2013), it is beneficial for long-term retention and transfer of learning. Although the exact reasons for this improvement remain uncertain, one hypothesis suggests that memory representations for the various motor sequences become more elaborate and distinctive following interleaved practice, because the learner needs to hold multiple motor sequences simultaneously in working memory during practice (thus allowing them to be compared) and use variable information-processing strategies depending on the specific task at hand (Shea & Zimny, 1983; Wright, 1991). Conversely, with blocked practice, the need to vary one’s mental strategies is diminished, and comparisons among the tasks are precluded. Another prominent hypothesis is that during interleaved practice an action plan (or motor program) needs to be reconstructed anew for each trial, due to the interference (or forgetting) caused by intervening trials of varying types. In contrast, during blocked practice the same motor program can be applied on repeated trials. The continual reconstruction of action plans during interleaved practice, while effortful, facilitates future reconstruction and hence retention and transfer (Immink & Wright, 1998; Lee & Magill, 1985).

Metacognitive Considerations

Given that interleaved practice often feels more difficult and the associated performance improvements are usually more gradual (relative to blocked practice), might students perceive that they are not learning as well as they should? Put another way, given that blocked practice often fosters fluent processing, a sense of familiarity with the task, and relatively rapid improvements in performance, would students be misled into thinking that blocked practice leads to relatively greater gains in learning than interleaved practice? There is evidence to suggest that this might indeed be the case. In the above-mentioned study involving piano players, participants were asked during practice to judge how quickly they thought they would be able to play each melody on a test 2 days later. The participants predicted faster playing times for the melodies that were practiced in the blocked condition (despite actual test performance being faster in the interleaved practice condition). Moreover, when asked
after the retention test about their preferences with regard to the two training conditions, the participants indicated that they would choose blocked over interleaved practice when learning melodies in the future (Abushanab & Bishara, 2013). In other words, the pianists were experiencing an illusion of competence, mistakenly believing that blocked practice was superior, when in fact the opposite was true (see also Simon & Bjork, 2001). The metacognitive aspects of training and instruction have important implications for educators, which will be discussed in a later section.

**Category Learning**

**Evidence**

In our everyday lives we encounter innumerable objects. Some of these objects we have encountered before and so they are known to us, some are novel examples of the kinds of things that we are familiar with, while others are entirely unknown to us. Our ability to recognize objects as belonging to particular categories allows us to generalize our knowledge about the categories to new instances (induction).

Although the bulk of research in this area has focused on how categories are learned and represented, recent work has explored how the sequencing of examples during training affects and can improve category learning (Richler & Palmeri, 2014). Intuitively, it would seem that interleaved practice would harm induction, since spacing out examples from a given concept or category might make it more difficult for the learner to notice the common features that define the concept or category (Kurtz & Hovland, 1956; Kornell & Bjork, 2008). Kornell and Bjork (2008) investigated this hypothesis using a task in which participants had to learn to identify the painting style of individual artists. During the training phase, participants viewed six paintings each by 12 artists. The paintings (accompanied by the name of the artist) were presented one at a time in one of two ways—either blocked according to artist (i.e. six paintings by a given artist were presented in a consecutive sequence) or interleaved (i.e. no two paintings by a given artist were presented consecutively). Shortly after training, the participants’ inductive learning was assessed by presenting them with previously unseen paintings by the studied artists and asking them to identify the artist. Across two experiments, participants were better able to correctly classify the new paintings when they studied the artists’ paintings in an interleaved rather than blocked fashion. These findings have since been replicated several times (e.g. Kornell et al., 2010), and with different category stimuli, such as types of birds and butterflies (Birnbaum et al., 2013; Wahlheim et al., 2011).

Beyond visual category learning, the interleaving advantage appears to generalize to a number of different category-based learning scenarios. For instance, across two experiments, Zulkiply et al. (2012) found that analyzing case studies of various mental disorders in an interleaved fashion yielded higher classification accuracy for new test cases than studying the cases in a blocked fashion (i.e. multiple case studies of the same disorder studied consecutively). Also, medical students learning to analyze electrocardiograms for various cardiac disorders (e.g. myocardial infarction, ischemia, pericarditis) exhibited higher diagnostic accuracy on a transfer test featuring novel examples if they undertook interleaved practice and were encouraged to contrast the features of different diagnostic categories, rather than if they undertook blocked practice (Hatala et al., 2003). Another study conducted with nursing students learning auscultation (using a stethoscope to listen to internal sounds of the body)
found a benefit of interleaving for auditory category learning. The students in this study were presented with audio examples of various cardiac and respiratory sounds (e.g. mitral valve prolapse, wheeze) in either an interleaved or blocked manner during training, and were later tested using both old (retention) and new (transfer) examples. Test performance in the interleaved training group was demonstrably superior to that in the blocked training group, especially for the classification of new examples (Chen et al., 2015).

Explanations

Although the findings of Kornell and Bjork (2008) were striking, they did not answer the question of whether the advantage of interleaving was due to the interleaving itself, or to increased temporal spacing between the presentation of paintings by the same artist. In a follow-up study that focused more directly on category induction, Kang and Pashler (2012) found that increasing temporal spacing between paintings while maintaining a presentation sequence that was blocked by artist produced test performances no better than those following typically blocked practice (both of which were worse than performance following interleaved practice). Moreover, presenting paintings by different artists simultaneously resulted in test performance as good as that with interleaved presentation, and better than that with blocked presentation. These results suggest that category learning was enhanced not because of increased temporal spacing per se, but rather because interleaving paintings by different artists facilitated discriminative contrast among the artists’ styles. In other words, the juxtaposition of examples from different categories probably drew learners’ attention to the relevant features that discriminate one category from another and/or promoted greater differentiation on the dimensions on which the categories varied, leading to better induction (e.g. Goldstone & Steyvers, 2001; Nosofsky, 1986). This supposition was supported by a study by Birnbaum et al. (2013), which examined the learning of bird and butterfly species. Interestingly, researchers in the latter study found that having more (rather than fewer) intervening items from different categories between successive presentations of a given category improved inductive learning. This suggests that the interleaving advantage in category learning and the temporal spacing effects need not be mutually exclusive (both could contribute to learning, depending on the particular conditions).

Metacognitive Considerations

There is ample evidence that learners perceive blocked presentation to be more effective for category learning than interleaved presentation. For instance, Kornell and Bjork (2008) found that the vast majority of participants, having experienced both interleaved and blocked presentations of different artists’ paintings, judged that they had learned better in the blocked condition. What is perhaps especially remarkable is that the participants gave their judgments immediately after they had taken a test (with feedback provided!) in which classification accuracy was higher for the artists that had been interleaved (see also Zulkiply et al., 2012; Zulkiply & Burt, 2013). Also, when undergraduate students were presented with a scenario based on the procedure of Kornell and Bjork and asked to predict whether interleaving or blocking would produce better learning, over 90% of them selected the blocked condition (McCabe, 2011). Finally, a study that gave learners control over the sequencing of study examples when learning to categorize types of birds found that the participants overwhelmingly
chose blocked presentation (i.e. they preferred to study multiple examples of a particular bird family before switching to another bird family) (Tauber et al., 2013). The preference for blocking may be driven by the subjective feeling of learning conferred by fluent processing when studying multiple examples of the same kind in a row. Another possibility is that learners simply hold the belief that blocked presentation is a superior method, perhaps due to its common use in instruction. The pedagogical implications of such inaccurate metacognitive monitoring and/or beliefs will be discussed later.

**Problem Solving**

**Evidence**

The final major area of learning in which interleaved practice has been explored is mathematics problem solving. Most of the relevant research on this topic has been undertaken by Doug Rohrer and colleagues, with experiments conducted both in the laboratory and in the classroom. In one laboratory experiment, college students were taught how to calculate the volume of four obscure solids (e.g. spheroid, wedge), after which they had two practice sessions separated by 1 week. During each session, the participants practiced solving four problems pertaining to each type of solid in either a blocked or an interleaved sequence, with corrective feedback provided immediately after each problem (the practice condition was consistent across both sessions for each participant). Performance during practice was higher in the blocked condition than in the interleaved condition. However, on a test containing new volume problems given 1 week after the second practice session, the interleaved group outperformed the blocked group by a wide margin of 63% vs. 20% (Rohrer & Taylor, 2007).

More recently, Rohrer and colleagues extended their research on interleaved practice into actual classrooms (Rohrer et al., 2014, 2015). In their first classroom-based study, the mathematics homework assignments for seventh-grade students in a public middle school were manipulated across 9 weeks. Ten mathematics assignments were given out over that period (each consisting of 12 practice problems). For problem types assigned to blocked practice, all 12 problems in a single assignment would be of that type (and no other assignment would feature that problem type). For problem types assigned to interleaved practice, only the first four problems in the assignment would be of that type; the other eight problems in the assignment would pertain to previously covered topics or types, and the remaining eight practice problems pertaining to the current topic (of the first four problems) would be distributed across future assignments. In other words, the number of practice problems devoted to each type or topic was equal across the blocked and interleaved conditions (12 practice problems per topic), and the only difference was whether all 12 problems of a given type were completed in one assignment or whether they were spread out across multiple assignments (and therefore interleaved with other types of problems). The problem types or topics assigned to the blocked and interleaved practice conditions were counterbalanced among the students. On a test containing novel problems given 2 weeks after the final homework assignment, the students were substantially better at solving the types of problems that had been practiced in an interleaved manner than was the case for those that had undergone blocked practice (72% vs. 38%) (Rohrer et al., 2014).

That study is notable because it was conducted in the context of a regular middle-school curriculum—that is, the mathematics teachers taught their lessons as they normally did, and
apart from designing the homework assignments, the researchers had no control over the type or amount of mathematics-related activities that each student engaged in (inside or outside the classroom). Given the complexities of school-based interventions (e.g. Greene, 2015), the large effect of interleaved practice observed by Rohrer et al. (2014) is particularly impressive.

In the study by Rohrer et al. (2014), the scheduling of the mathematics problems over 9 weeks meant that problem types assigned to the interleaved condition (in which mathematics problems were spread out over multiple homework assignments) were practiced closer in time to the test than those assigned to the blocked condition (in which the problems appeared in a single homework assignment), raising the possibility that a difference in retention interval (the time between the last practice and the test) was responsible for the interleaving advantage. To overcome the retention interval problem, a follow-up study featured a review session of all the topics in class 5 days after the last homework assignment. A test consisting of new problems was administered either 1 day or 30 days after the review session, and the benefit of interleaved practice compared with blocked practice was still very apparent (performance after 1-day delay: 80% vs. 64%; performance after 30-day delay: 74% vs. 42%) (Rohrer et al., 2015).

**Explanations**

Interleaving different kinds of mathematics problems naturally increases temporal spacing between successive presentations of problems of the same kind, and as discussed in the previous section on category learning, it is unclear whether the observed learning benefit is due to spacing or interleaving per se. In order to address this issue, Taylor and Rohrer (2010) asked elementary school children to learn to solve four types of mathematics problems (determining the number of faces, corners, edges, and angles that there are in a prism), with temporal spacing across the interleaved and blocked practice conditions kept constant. A filler task was inserted between practice items in the blocked condition, so that the amount of time between successive encounters with problems of the same type was equivalent to that of the interleaved condition. Performance during practice was higher in the blocked than in the interleaved condition. However, when asked to solve new prism problems 1 day after practice, students in the interleaved practice group performed considerably better than those who received blocked practice (77% vs. 38%). An analysis of the errors revealed that the interleaving advantage was mainly driven by students in the blocked condition using the formulae they had learned for problems that were not appropriate. In other words, they had difficulty discriminating between the different problem types and knowing when to use each learned formula.

Just as we saw in the case of category learning, interleaved practice seems to help learners to differentiate between the types of problems they are learning to solve. When learning mathematics, it is not sufficient to learn how to execute a strategy—one must also know when a particular strategy is appropriate (VanderStoep & Seifert, 1994). After all, there are problems that appear similar on the surface but which require different strategies (e.g. in statistics, independent versus repeated measures t-test). Moreover, with word problems there is often no explicit mention of the target mathematical concept or appropriate strategy, and it is left to the student to infer the type of problem that they are trying to solve (Rohrer, 2009). It is therefore not too surprising why blocked practice is less than ideal—the learner often already
knows what strategy is required without even reading or analyzing the problem, and there is little need to figure out what kind of problem they are dealing with. In other words, the grouping together of problems of the same kind short-circuits learning to discriminate between the various problem types. As a result, less attention is paid to features of the problem that indicate what type of problem it is.

In the classroom study by Rohrer et al. (2014), the types of problems that the middle-school students were learning to solve were actually quite different (e.g. linear equations, determining the slope of lines, word problems involving proportions). When students’ errors on the test were analyzed, there were very few instances in which students had used the wrong strategy, which was appropriate for a different kind of problem (and the rate of these discrimination errors did not differ between the interleaved and blocked practice conditions). This suggests that enhanced discrimination is not the only explanation for the interleaving advantage. Rohrer et al. propose that in addition to discrimination (i.e. learning to recognize the type of problem), association of a given problem type with an appropriate strategy is critical for successful problem solving. With blocked practice, the learner need only focus on executing a strategy (in repeated succession), without associating the problem with its strategy, whereas with interleaved practice, the switching between different problem types and strategies strengthens the association between a problem type and its strategy.

Is Blocked Practice Ever Helpful?

The research discussed in the preceding sections of this chapter clearly shows that interleaved practice is more effective than blocked practice across diverse forms of learning. However, to say that interleaving is always better, or that blocking is never useful, would be to oversimplify matters. After all, even in the above-mentioned studies by Rohrer et al. (2014, 2015), the homework assignments in the interleaved condition began with a mini-block of four mathematics problems on a given topic. Indeed, research in motor and category learning has revealed some boundary conditions with regard to the superiority of interleaved practice.

When one considers the theoretical explanation as to why interleaving enhances motor learning (i.e. increased contextual interference), one could perhaps anticipate that in certain situations the interference would be excessive and possibly overwhelm the learner, leading to either no benefit of interleaving (relative to blocked practice) or even a reduction in learning. One factor that has been shown to modulate the interleaving advantage is the complexity of the motor task. A meta-analysis of published studies found that the average effect size (the benefit of interleaved over blocked practice in terms of standard deviations) was larger in laboratory studies, which tend to feature simpler motor tasks, than in field studies, which tend to examine more complex, ecologically valid, sports-related motor skills (0.57 vs. 0.19) (Brady, 2004). With complex motor tasks, the level of expertise of the learner and the amount of practice also seem to matter. Although some of the studies mentioned in the earlier section on motor skill learning featured novices (e.g. learning badminton, volleyball), there are other studies that failed to find a benefit of interleaving for novices and young children (Magill & Hall, 1990). Also, a benefit of interleaved practice may emerge only after extensive practice (Shea et al., 1990). When dealing with beginners who are trying to learn a complex motor skill, a hybrid approach may be optimal—that is, starting with blocked practice and gradually transitioning to randomly interleaved practice (Porter & Magill, 2010).
For inductive learning of categories, the dominant explanation as to why interleaving is beneficial is that it facilitates discriminative contrast among the various categories (e.g. Kang & Pashler, 2012). If this is the case, interleaving should be advantageous for learning categories that are hard to tell apart (i.e. those which have high inter-category similarity), and indeed the research cited earlier which showed that interleaved presentation improved category learning generally featured categories that were highly similar (e.g. different kinds of birds or butterflies). However, when the members within each category share very few features in common (i.e. there is low intra-category similarity), there is evidence that learning of such categories is better with blocked than with interleaved presentation (Carvalho & Goldstone, 2014). Blocking the categories promotes the noticing of commonalities within each category (Kurtz & Hovland, 1956), which is especially useful when category members are of low similarity.

From the Laboratory to the Classroom

There is ample research evidence to support the benefit of interleaved practice for a variety of learning domains that are relevant both inside and outside the classroom. Of course, the complete picture regarding the relative utility of interleaved versus blocked practice is not as simple or straightforward as one would perhaps like (as the immediately preceding section has made clear). However, the existence of boundary conditions does not throw a spanner in the works when it comes to practical advice for educators. It just means that the recommendations must be nuanced and qualified at times. Let us first consider two major obstacles that stand in the way of teachers implementing interleaved practice.

There is evidence from the motor skill and category learning domains that learners, after having experienced both interleaved and blocked practice, tend to think that the latter is more effective, in direct contradiction to their actual learning demonstrated on a later test (e.g. Abushanab & Bishara, 2013; Kornell & Bjork, 2008; Zulkiply et al., 2012). The consecutive repetition of the same kinds of examples or motor actions one gets in blocked practice probably engenders a sense of relative fluency, which leads one to assume that great gains in learning have occurred. Another explanation for the discrepancy between subjective judgments and more objective measures of learning has to do with learners’ beliefs or intuitions that blocking is more helpful than interleaving (e.g. McCabe, 2011). It should be noted that teachers are by no means immune from erroneous metacognitive beliefs. In a study conducted at a public university in Colorado, college instructors were just as likely as students to rate blocked presentation of paintings as being more effective than interleaved presentation for learning to recognize individual artists’ styles (Morehead et al., 2016).

These erroneous metacognitive beliefs may pose a particular challenge to a teacher’s intention to incorporate interleaved practice. During training or practice, interleaving sometimes yields poorer performance than blocking, giving the impression that the latter is more effective. Not only might the teacher question whether interleaved practice was the right strategy to adopt, but also the students might be unhappy about using this approach. A New York Times article on the study by Rohrer et al. (2014) stated that “The math students at Liberty Middle School were not happy. The seventh graders’ homework was harder and more time-consuming at first, and many of the problems seemed stale” (Carey, 2013).

Later on in the article, though, the journalist mentions how the students eventually got used to the interleaving of different problem types in their homework assignments, and
felt that it was easier to study for subsequent tests because all of the topics had recently been practiced. In other words, interleaved practice requires perseverance. The results may not be immediately apparent, but with some persistence the benefits to learning will become clear.

The second major barrier to the wider use of interleaving is convention. Traditional instructional practice typically favors a blocked approach. Inside the classroom, teaching materials and aids (textbooks, worksheets, etc.) are usually organized in a modular way, which promotes blocked practice. After presenting a new topic in class, it is common for teachers to give students practice with the topic via a homework assignment or worksheet. However, apart from that block of practice shortly after the introduction of a topic, there is usually no further practice until a review session prior to a major test. What this means for teachers who have decided to incorporate interleaved practice in their classrooms is that some planning is required. The classroom studies by Rohrer et al. (2014, 2015) described earlier demonstrate how a small tweak in homework assignments—switching from having the practice problems in a given assignment devoted to just a single topic to having a mix of problems pertaining to various topics appearing in each assignment—can produce impressive improvements in mathematics learning. Apart from rearranging the problems in the homework assignments and presenting the correct answers to the assignments in class (corrective feedback is important, because students tend to make more errors during interleaved practice), the mathematics classes were conducted in the same way as in the past. There was no increase in class time spent on mathematics instruction, no disruption to the regular teaching of mathematics topics, and the number of practice problems that students received for homework remained the same.

For optimal implementation of interleaved practice, a few practical issues need to be considered. First, of all the knowledge or skills that a student is expected to learn, which (sub)topics should one attempt to interleave during a given practice session? For instance, should topics from science, history, English, and mathematics be interleaved when a student is practicing using flashcards? In this instance, there is unlikely to be any benefit from interleaving of such disparate topics (Hausman & Kornell, 2014). Research findings suggest that interleaving helps students to notice the differences between categories or concepts (e.g. Birnbaum et al., 2013; Kang & Pashler, 2012), which means that when the categories or concepts that have to be learned are, to some extent, similar or confusable, interleaving should be particularly useful. Within a given academic discipline (e.g. mathematics, physics), often the concepts that are being learned have some degree of similarity or overlap, and therefore the concepts within a discipline would be prime targets for interleaved practice. However, topics between disciplines (e.g. between history and chemistry) are probably too dissimilar to confer any benefit of cross-subject interleaving. This might be convenient, as any attempt at interleaving would probably remain within a single class or subject, which means that there would be no real need to coordinate multiple teachers across different subjects.

A second issue is the degree of interleaving during practice. Does practice have to be purely interleaved (i.e. with no blocking whatsoever) in order for a benefit to be obtained? There is evidence that blocked practice is helpful for novices, especially initially (e.g. Shea et al., 1990). Also, grouping items of the same kind or topic together helps students to detect the commonalities across the items, which is useful when intra-category similarity is low (Carvalho & Goldstone, 2014). What this means is that taking interleaving to an extreme is probably not optimal in all situations. Teachers might consider providing a certain amount of
blocked practice after introducing a new topic or concept, and perhaps feature practice items that appear to be quite different yet tap the same underlying concept. For instance, in mathematics, understanding of a given solution strategy or formula can be assessed or practiced in a variety of ways (e.g. problems containing diagrams, algebraic equations, word problems describing different scenarios), and it is important for students to figure out what these different forms share in common. Another potential advantage of blocked initial practice is that performance improvements tend to be more rapid, which might reduce learner anxiety and/or increase self-efficacy (e.g. Schunk, 1991). Of course, these performance gains are usually short term, and practicing the same kinds of items repeatedly could lull students into a state of complacency. Beyond blocked practice in the initial stages, therefore, the goal should be to transition to interleaved practice.

Current educational norms are heavily oriented towards blocked practice. Blocked practice feels effective, instructors are accustomed to it, and instructional materials generally facilitate it. However, there is a substantial body of evidence in favor of increasing the degree of interleaving during practice. Across a variety of learning domains, studies have found an advantage of interleaved over blocked practice. Some of these studies have examined the learning of ecologically valid material in educationally relevant contexts, increasing our confidence that the findings will apply to students in everyday classrooms. Whether you are an art history instructor teaching students to recognize the differences in style between various Impressionist painters (e.g. Manet vs. Monet), a biology instructor teaching students how to differentiate between various crocodilian species (e.g. alligators vs. crocodiles), or a mathematics instructor teaching students how to solve different calculus problems (e.g. integration by parts vs. substitution), you have a choice in terms of how you present examples in class and also how practice problems are sequenced in assignments. Although making a decision to increase the level of interleaving will require some effort and planning (because it is a departure from the default blocked practice), it need not entail a radical overhaul of one’s teaching practices. Something as simple as shuffling the problems that appear in homework assignments—without significant changes to classroom instruction or the amount of homework—can produce great gains in learning (Rohrer et al., 2014, 2015). Also, with the increasing use of computers in instruction (e.g. computer-assisted tutoring tools), it is likely that introducing interleaved practice will become easier (for an example implemented in a college classroom, see Kirchoff et al., 2014). My hope is that educators reading this chapter will think of creative ways to ensure that their students are exposed to a variety of examples or problem types during practice, which more closely approximates the situation that they will face during a test (or in real life). Indeed, the benefits of interleaving are most apparent for learning that is inductive or that can be generalized to new situations or problems—precisely the kind of learning that is a primary goal of education!

NOTE

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Interleaved Practice for Learning


