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Desirable Difficulties in Theory and Practice

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The articles in this special issue have triggered memories of the events and research findings that led us to the idea that difficulties can be desirable, but they have also emphasized the complexities and challenges of trying to incorporate such difficulties into teaching and self-regulated learning. Before we go on to comment on the individual papers in this special issue, we provide a bit of history with respect to the considerations that led to the idea that difficulties can be desirable.

Some Reminiscing Re the Desirable Difficulties Idea

In the framework we titled *A New Theory of Disuse* (Bjork & Bjork, 1992), which was written for a Festschrift honoring William K. Estes, we tried to capture what we labelled some "important peculiarities" (p. 36) of human learning and memory. We came up with the somewhat awkward title for our framework by reference to Thorndike's (1914) original *Law of Disuse*, which stated that learned habits, without continued practice, fade or decay from memory with the passage of time. We wanted to give Thorndike credit for emphasizing that *use* is critical for keeping memories accessible, but to also point out that the decay idea, which remains appealing to most people, had been completely discredited by McGeoch (1932) and others. Instead, we wanted to convey that memory representations remain in memory, but can become inaccessible—other than, perhaps, in the presence of rare and unique cues.

In our Festschrift chapter we sought to provide linkages to some of the dynamics that emerged from Estes' stimulus fluctuation theory, especially the "peculiar" idea that forgetting can enable learning. In Estes' theory, which focused on learning by non-human animals, but was extended by Bower (1972) and others to human learning, an animal in a conditioning experiment was assumed to sample "stimulus elements" in the environment and responding was determined by the proportion of sampled elements associated with a given response. Estes assumed that—owing to attentional and other factors—some elements were "available" and others not available at any given time and that forgetting took the form of "conditioned" stimulus elements fluctuating out of the set "available" to an animal—to be replaced by yet-to-be conditioned elements. Such fluctuation would then lead to forgetting (non-responding), but also create the potential for additional conditioning/learning (that is, associating additional stimulus elements to the response in question).

In our framework we assumed that an item in memory can be characterized by two strengths—*storage strength* (how well learned an item is, as defined by how interconnected it is with related items in memory) and *retrieval strength* (the current ease of access to that item given the current cues). Such a distinction was certainly not new with us; it corresponds to Estes' (1955) distinction between *habit strength* and *response strength* and to Hull's (1943) distinction between *habit strength* and *momentary reaction potential*. And more broadly, it corresponds to the time-honored distinction between *performance*, which we can measure at any given point, and *learning*, which can only be measured at a delay—and indirectly by the rate of

loss of retrieval strength or the rate of relearning as measured by the regaining of retrieval strength. Subsequent interactions with motor-skills colleagues, especially Richard Schmidt and Robert Christina, made us aware of linkages to related research on learning versus performance in the motor-skills domain (see Christina & Bjork, 1991; Schmidt & Bjork, 1992; for a review see Soderstrom & Bjork, 2015).

What was "new" about our New Theory of Disuse, versus those precursors, is our specification of how storage strength and retrieval strength interact. In our framework the higher the current level of storage strength the larger the gain in retrieval strength that results from restudying or retrieving, whereas—and much less intuitively—the higher the current level of retrieval strength the smaller the gain in storage strength that results from restudying or retrieving. Thus, forgetting (loss of retrieval strength) can enhance learning (the gain in storage strength), which is why, in the theory, manipulations such as spacing and variation, which reduce retrieval strength, can enhance learning, as measured by performance at a delay.

Metamemory Considerations

The fact that conditions of learning that make performance improve rapidly often fail to support long-term retention and transfer, whereas conditions that create challenges (i.e., difficulties) and slow the rate of apparent learning often optimize long-term retention and transfer, means that learners—and teachers—are vulnerable to mis-assessing whether learning has or has not occurred. Thus, to the extent that we interpret current performance as a valid measure of learning we become susceptible not only to mis-judging whether learning has or has not occurred, but also to preferring poorer conditions of learning over better conditions of learning.

Desirable versus Undesirable Difficulties

The term *desirable difficulty*, coined in 1994 (Bjork 1994a, 1994b), has a nice alliteration, but it has led to our having to emphasize that the word *desirable* is important. Many difficulties are undesirable during instruction and forever after. Desirable difficulties, versus the array of undesirable difficulties, are desirable because they trigger encoding and retrieval processes that support learning, comprehension, and remembering. If, however, the learner does not have the background knowledge or skills to respond to them successfully, they become undesirable difficulties. We entitled a short chapter *Making things hard on yourself, but in a good way: Creating desirable difficulties to enhance learning*[1] to emphasize that the level of difficulty matters (Bjork & Bjork, 2011; 2014).

The level of difficulty that is optimal, therefore, will vary with the degree of a learner's prior learning. In general, for example, it is desirable to have learners generate a skill or some knowledge from memory, rather than simply showing them that skill or presenting that knowledge, but a given learner needs to be equipped by virtue of prior learning to succeed at that generation—or at least succeed in activating relevant aspects of the skill or knowledge, which may then potentiate subsequent practice or study (e.g., Little & Bjork, 2016; Richland, Kornell,

[1] We thank Steve Smith, Texas A&M University, for suggesting the "making things hard on yourself" title.

& Kao, 2009). Guadagnoli and Lee's (2004) "Challenge Point" framework picks up on that idea in the domain of motor skills.

Comments on the Articles in this Forum

The articles the Editor recruited for this special issue illustrate in a compelling way the range of potentially important applications of desirable-difficulties research. The articles also, however, do an excellent job of documenting the challenges that are inherent in trying to introduce desirable difficulties into real-world settings where the necessary changes may well be undesired by learners—and perhaps by teachers as well. The Editor has provided a compelling overview of the articles in this special issue—to which we add a few specific comments on each article.

Enhancing Law School Instruction

In his contribution, Schulze (2020) reports on an effort to upgrade Florida International University's law-school instruction by drawing on the cognitive science of learning and, in particular, by incorporating desirable difficulties. What Shulze and his FIU colleagues have achieved is both amazing and inspiring. That they were able, by revamping FIU's law-school instruction, to increase the rate of FIU students passing the bar exam from about fifth among Florida law schools to first in the majority of recent exams is an amazing achievement. That achievement is truly inspiring because it far exceeds any prediction based on the entering credentials of FIU students, as measured by their LSAT scores and other metrics, versus other Florida law schools. It may be an unwarranted and over-optimistic generalization on our part, but such findings suggest that across education more broadly optimizing instructional practices may act as a kind of leveler.

We found Shulze's comments on testing to be especially interesting. For the two of us and other cognitive scientists, testing is viewed as having multiple pedagogical advantages from both a memory standpoint and meta-memory standpoint: The retrieval processes triggered by testing can enhance later retrieval, reduce the likelihood of recalling competing incorrect information, and provide feedback to learners as to what has and has not been understood and learned. In the law-school climate, though, according to Shulze, "our obsession with summative assessment leads students to believe that testing, or retrieval practice, is meant in all cases only to assess the student's ability, knowledge, and aptitude," and, as a consequence, "students cannot fathom the idea of self-testing unless they are fully prepared for the real exam; and no law student has every felt fully prepared for an exam" (Schulze, 2020).

Spacing Effects in Mathematics Education: Unanswered Questions

There often seems to be skepticism as to whether laboratory findings that seem to have important educational implications will actually transfer to the real world of education—even when the evidence is strong, as in the case of the time-honored finding that long term retention of skills and knowledge benefit from spacing instruction or practice. As a consequence, instructional procedures are often guided by intuition and/or by whatever are standard practices, rather than by experimental research. In a truly important—and in some ways, heroic—project,

Rohrer (2012) took on the challenge of examining the extent to which mathematics education in the real world of schools would profit from spacing (and, hence, interleaving), such as when and how to use the Pythagorean Theorem. He found strong support for the benefits of spacing, a result that is especially important given that most workbooks, as well as classroom exercises, involved blocked, not interleaved, practice.

In the current commentary, Rohrer and Hartwig (2020) list some "unanswered questions" about spaced/interleaved mathematics practice. They point out that it is by no means a given that research-based changes will get into the classroom ("Too often, the classroom is where promising interventions go to die"), given beliefs that students and teachers may hold. One question has to do with the extent to which learners are deterred from adopting interleaving/spacing by the combination of lower performance and greater experienced difficulty when spacing is introduced. Another has to do with whether learners actually believe spaced practice is effective and, relatedly, whether massing and blocking provide an "illusion of mastery" that is difficult to overcome. They also, importantly, summarize evidence that the benefits of interleaving can go beyond the benefits of the spacing that interleaving creates.

Reflections on Teaching Desirably Difficult Learning Strategies

In talking to various audiences over the years, we have often been asked whether we have written some kind of manual on how to incorporate desirable difficulties into one's teaching or self-regulated learning. That question has made us to realize that we have been prone to assuming, unrealistically, that simply telling learners and teachers about relevant research findings is enough. In their contribution, Biwer, De Bruin, Schreurs, and oude Egbrink (2020) discuss their impressive effort to implement a "study smart" program. What they have learned about the opportunities and obstacles in creating a program to make students more effective learners is interesting and important.

The challenges Biwer et al. have confronted are as informative as the successes they have achieved. Among those challenges is that learners bring with them "naïve theories" about learning strategies that need to be "debunked." Another challenge is that what students have been doing has worked—in the sense of getting them to where they are—and what they are doing may also be consistent with what they have been taught earlier in their academic careers.

When and What Difficulties Are Desirable for Children?

The essay by Knabe and Vlach (2020) draws our attention to the fact that while the desirable difficulty of spacing, rather than massing, practice is one of the most reliable and extensively studied phenomena in the field of learning, it remains the case that little research has been focused on the potential of spaced practice to improve children's learning, particularly their learning in a classroom setting. While pointing out the need to investigate the promise of this strategy for children's learning more fully, they also provide an important warning—namely, that for such studies to be meaningful, they must be conducted in ways that take into account the potential effects of the many individual differences among children in the early years of their living and learning.

They predict, for example, that individual differences in visual attention, memory capacity, prior knowledge, and metamemory abilities—all of which are rapidly developing, but at different rates, during the early years of life—will play a major role in determining whether the learning of an individual child or age group can profit from a spaced versus a massed schedule of study. Such developmental differences will clearly present K-12 instructors with a very difficult task of deciding when the learning of a given child would or would not profit from spaced versus massed study schedules, which makes the need for careful research on the limitations and boundary conditions of the spacing effect in early education a critical need.

The Role of Cognitive Effort in Motor Skill Learning

Hodges and Lohse provide a thought-provoking analysis of three areas within motor learning where they argue that our thinking about desirable difficulties needs to be refined. Their analysis focuses on three intriguing questions: (a) If, in general, learners feel they are learning less well when faced with desirable difficulties, how can that finding be reconciled with those in the field of motor learning showing that learning is enhanced when individuals feel they are succeeding?; (b) can the concepts or assumptions about desirable difficulties, the role played by errors in learning, and cognitive effort be reconciled with findings obtained in the area of implicit motor learning?; and (c) can partners serve as a desirable difficulty under conditions of shared practice? Their comments regarding possible answers to these questions are insightful and suggest avenues for future research that may prove quite productive.

Also provided is an insightful discussion of the need to identify desirable difficulties prospectively, highlighting that such difficulties be task relevant, novel (i.e. not something the learner is already doing), and potentially solvable by the learner. This latter criterion is one we frequently find we must emphasize when speaking with educators and creators of instructional materials: Namely, that for difficulties to be desirable—that is, promote learning—they must present challenges to the learner but not be of such difficulty that the learner cannot eventually meet or overcome them. Use of "adaptive" learning schedules where levels of difficulty are tailored to an individual's past successes represent good instantiations of this necessary feature. Also, of value is the discussion of the role of making errors, often considered something to be avoided, in optimizing learning. Indeed, from the standpoint of the desirable difficulty framework learners should interpret errors as opportunities for enhanced learning, but that is much easier said than done.

Interactions of Motivation and Cognition in Self-Regulated Learning

Finn (2020) provides a convincing case that bringing desirable difficulties into the real world of education requires addressing the motivational factors she sketches in her essay. The two of us have actually been quite guilty of ignoring such factors, the importance of which comes through, if less explicitly, in some of the other articles in this forum as well. If one's goal is to have students replace less-effective learning activities—activities that may have become habitual and may even have been encouraged by teachers—with more effective activities, the issues of motivation mentioned in Finn's essay must be addressed.

Among other important observations, Finn points out that students' memories of their past academic experiences—and achievements, or lack thereof—provide a basis for their expectations and goals. Such expectations and goals, in turn, can heavily influence both students' effort to learn and their selection of learning procedures. From that standpoint, as she argues, research of achievement motivation and on judgment and decision making becomes highly relevant.

Strategies to Motivate Students to Embrace Desirable Difficulties

Zepeda, Martin, and Butler (2020) focus on a challenge that appears explicitly or implicitly in a number of the other essays in this special issue: How to get learners to embrace and employ desirable difficulties in managing their own learning. Years ago, we thought—somewhat naively—that simply showing the benefits of incorporating desirable difficulties would be enough for students and others to introduce such difficulties into their own learning. Desirable difficulties *are,* however, difficulties, and any benefits are long-term benefits, whereas the short-term consequences are typically poorer performance, so it seems obvious at this point that convincing learners to introduce desirable difficulties is a major challenge.

In their scholarly analysis of how learners might be motivated to incorporate desirable difficulties Zepeda et al. review relevant research in the broader domain of psychological research on motivation. More specifically, they provide brief reviews of five approaches that may provide insights into how learners can be motivated to introduce desirable difficulties into the management of their own real-world learning. That there is important research to be carried out on how motivational factors influence and interact with learning strategies comes through very clearly from their analysis.

Concluding Comments

The commentaries in this special issue have made us look both backward and forward with respect to the real-world applications and implications of desirable difficulties findings. Looking back, it is surprising from the current vantage point that it took us a while to realize that the dynamics we viewed as theoretically interesting actually had real-world importance for teaching and self-regulated learning as well. Looking forward, the commentaries in this issue have, if anything, increased our estimation of the potential to enhance teaching and self-regulated learning by introducing desirable difficulties, but have also opened our eyes with respect to the challenges that remain if that potential is to be realized.

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