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Individual Differences in Learning Efficiency

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Abstract
Most research on long-term memory uses an experimental approach whereby participants are assigned to different conditions, and condition means are the measures of interest. This approach has demonstrated repeatedly that conditions that slow the rate of learning tend to improve later retention. A neglected question is whether aggregate findings at the level of the group (i.e., slower learning tends to improve retention) translate to the level of individual people. We identify a discrepancy whereby—across people—slower learning tends to coincide with poorer memory. The positive relation between learning rate (speed of learning) and retention (amount remembered after a delay) across people is referred to as *learning efficiency*. A more efficient learner can acquire information faster and remember more of it over time. We discuss potential characteristics of efficient learners and consider future directions for research.

Keywords
learning efficiency, individual differences, memory, learning rate, retention

Modern research on learning and memory has demonstrated that conditions that slow the rate of acquisition tend to promote more durable long-term retention (R. A. Bjork, 1994b). For example, using flash cards to study new vocabulary words is more beneficial than simply rereading to-be-learned information; similarly, groups instructed to use strategies during learning often take longer to learn material but show improvements in retention (e.g., Wang, 1983).

In a recent demonstration of how a slower learning condition can be beneficial, Karpicke and Roediger (2007) asked participants to study a set of unrelated words eight times and after each study period to write down all the words they could remember from the study list (a free-recall test). What varied was whether—after the first study and test phase—all words continued to be restudied and tested. In the standard condition, each study phase contained all 60 words, and participants were instructed to recall as many of those words as possible on each test. In the dropout condition, participants studied only words they had not yet recalled on a prior test and needed to recall only words they had studied in the immediately preceding cycle.

Figure 1 shows the cumulative probability of recall across the eight tests. For example, the data plotted for Test 4 represent the cumulative proportion correct (or the proportion of items recalled at least once on Tests 1–4). As would be expected, both groups improved with repeated encounters, although the dropout group appeared to learn more quickly. Of most interest is memory a week later: Here, we see that the proportion of words recalled in the standard condition (.55) greatly exceeded that in the dropout condition (.21).

Repeated study and recall of words that had already been retrieved (as was done in the standard condition) slowed initial learning (left side of Fig. 1) but enhanced long-term recall (right side of Fig. 1). More generally, "conditions of learning that make performance improve rapidly often fail to support long-term retention and transfer, whereas conditions that create challenges and slow the rate of apparent learning often optimize long-term retention and transfer" (E. L. Bjork & Bjork, 2015, p. 57). R. A. Bjork (1994a) coined the term *desirable difficulty* to describe the general (yet not ubiquitous)

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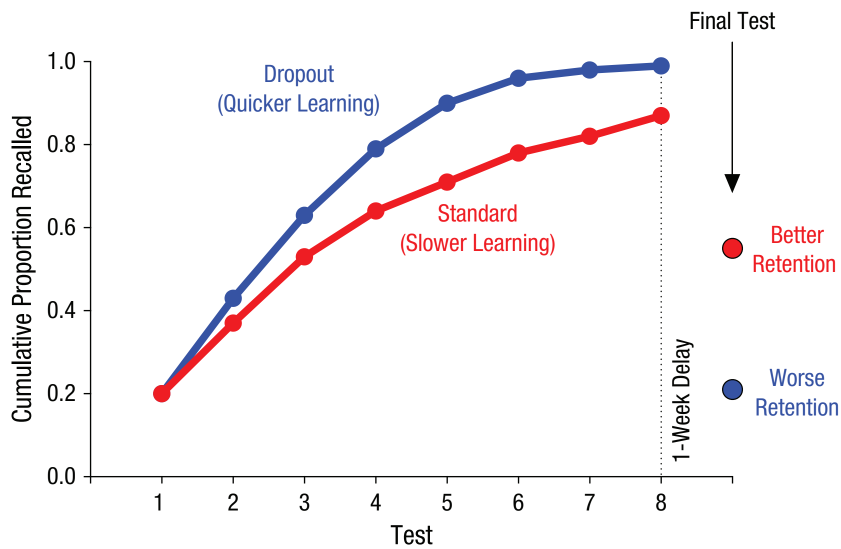

Fig. 1. Data from Karpicke and Roediger (2007) showing the cumulative proportion of recalled words after each of eight tests. Subjects assigned to the condition that learned more slowly (the standard condition) benefitted in the long term by showing better retention on a final test a week later (red dot) relative to subjects assigned to the condition that learned more quickly (the dropout condition; blue dot).

tendency for conditions that slow learning to confer benefits for later memory.

Here, we consider whether the pattern of slower, more gradual learning is advantageous when it occurs naturally across people. That is, experimentally induced conditions that slow the rate of learning can promote memory; but within a single group of people treated identically, do the slower learners exhibit more durable memories?

Individual Differences: Do Slower Learners Benefit From Slower Learning?

In an effort to address this question, Zerr and colleagues (2018; see also Nelson et al., 2016) adopted a learning protocol similar to that used by Karpicke and Roediger (2007). Because the goal was to classify differences across people (and not to examine means across experimental conditions), many more participants were needed for this design than in a typical experimental study. Specifically, 281 participants studied 45 Lithuanian–English word pairs (Zerr et al., 2018, Study 1). As depicted in Figure 2, after studying the pairs, participants took a cued-recall test with immediate correct-answer feedback. That is, they were given the Lithuanian cue and asked to provide the English equivalent. They then took repeated tests only on the items previously missed. That is, Test 2 included only word pairs that had not been recalled on Test 1, and Test 3 included only word pairs not recalled on Tests 1 or 2. Each participant took tests until each of the pairs had been recalled exactly once. They then restudied all 45 pairs once before taking a final cued-recall test covering all items.

The three dependent measures were initial (Test 1) performance, the number of tests a person took until all items had been recalled (tests to criterion), and final-test performance at the end of the study. The finding of most interest was the presence of a strong relation between the number of tests to criterion (an index of a person's speed of learning) and performance on the final test. Specifically, after a short delay, faster learners (i.e., those who required fewer tests before they had recalled each item once) tended to recall more, as shown in Figure 3 ($r = -.57$). A similar pattern was also seen in a smaller sample ($r = -.71$; Nelson et al., 2016). Quicker learners do not pay a price for their quick learning; instead, they tend to retain more (Kyllonen & Tirre, 1988; Nelson et al., 2016; Zerr et al., 2018). This pattern occurs despite the fact that slower learners have many more encounters with the materials; the fastest learners required only 5.06 test cycles (on average) before completing their initial learning phase, whereas the slowest learners took 12.26 test cycles.

Figure 4 presents the data in a simplified way, binned into quartiles according to learning speed (defined by the number of tests required to reach criterion). Faster learners tend to start out performing better (on Test 1), reach criterion more quickly (by definition, as this was how fast learners were defined), and—importantly—retain the newly learned information better than the slower learners, as can be seen in the final-test performance (Zerr et al.,

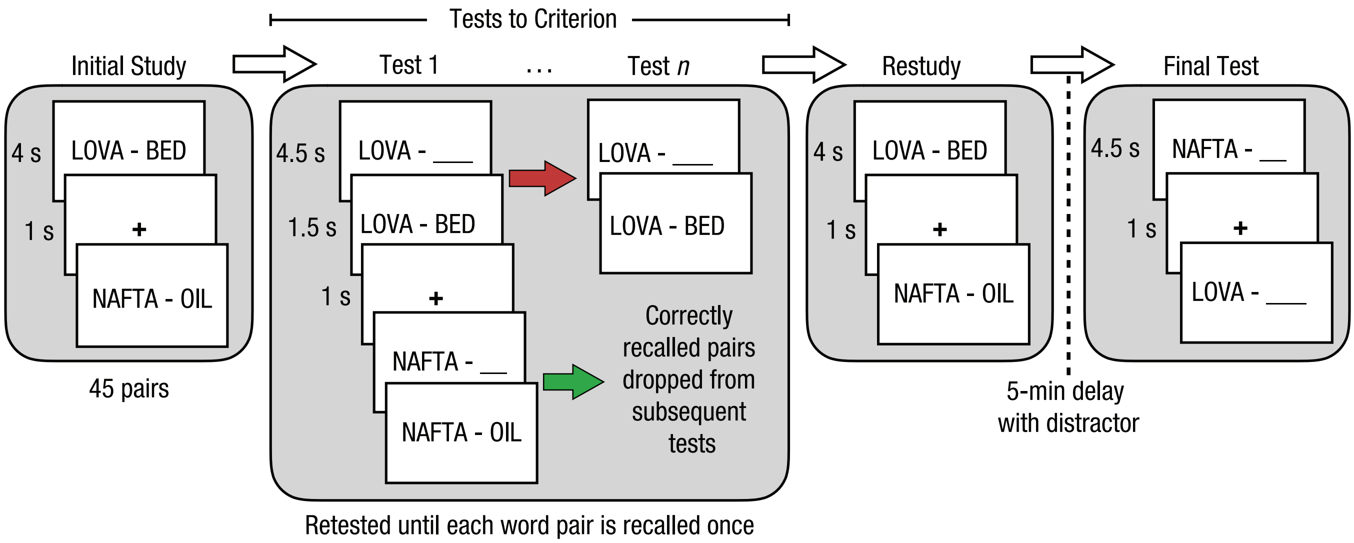

Fig. 2. Overview of the learning-efficiency task used by Zerr et al. (2018). Participants first studied 45 Lithuanian–English word pairs for 4 s each (initial study) before taking an initial cued-recall test on all of the word pairs (Test 1). Items that were correctly recalled were "dropped out" and not tested again, whereas incorrect items were tested again until recalled. This process was repeated until all 45 items had been recalled exactly once by participants (tests to criterion), demonstrating that they had learned the material. All 45 items were then studied once more (restudy) before a final cued-recall test on all 45 items (final test). Figure reprinted with permission from Zerr et al. (2018).

2018). This advantage in long-term retention for fast learners has been seen not only when a final test is given the same day as initial learning but also when learners are tested after a delay of 2 days (Nelson et al., 2016) and 1 week (Zerr, 2017).

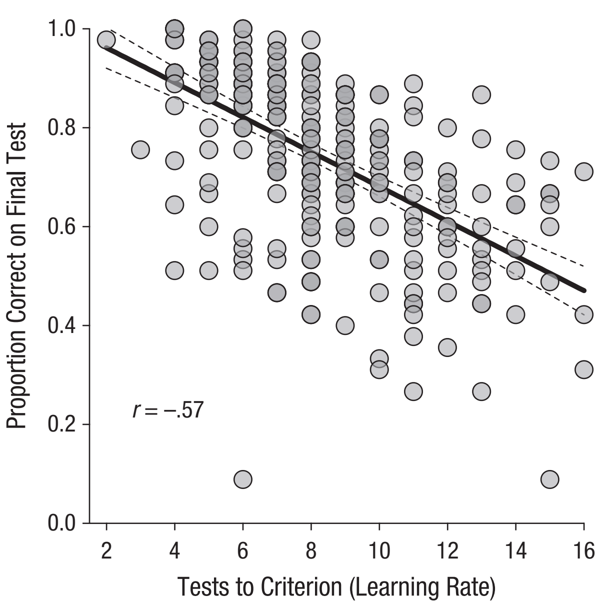

Fig. 3. Data from Zerr et al. (2018) showing the relation between the number of tests to criterion and the proportion of correct responses on the final test across individuals within a condition. Participants who learned the items more quickly (fewer tests to criterion) tended to have better retention (higher final test scores). The solid line shows the best-fitting regression; dashed lines indicate 95% confidence intervals.

Because of the strong intercorrelations among Test 1 recall, tests to criterion, and final-test performance, we created a composite score for each person by standardizing these three individual scores (reverse-scoring tests to criterion because fewer is better) and averaging the scores. People with higher composite scores exhibited *efficient learning* (i.e., quick, durable learning). Because learning efficiency as a construct is a new concept, and because learning and memory studies with healthy adults rarely examine reliability of measures or stability of performance over time, we examined whether a person's learning efficiency is stable when assessed at two time points. Learning-efficiency scores from one day to the next were quite consistent across 281 participants (r = .68; Zerr et al., 2018, Study 1). Impressively, when a group of 46 participants underwent this procedure twice across an average span of 3 years, learning-efficiency scores were again highly consistent (r = .70; Zerr et al., 2018, Study 2), suggesting that learning efficiency is stable within people across time.

The juxtaposition of person-level and condition-level effects of slow learning highlights an important reason for the study of individual differences in the field of learning and memory: Reliable findings at the level of the condition and the group may not maintain a one-to-one correspondence to findings obtained from individual-differences approaches (Fisher, Medaglia, & Jeronimus, 2018). Before we can make statements about how memory operates, findings on the aggregate must complement findings across individuals. When a learner is choosing how to study, conditions that lead to more

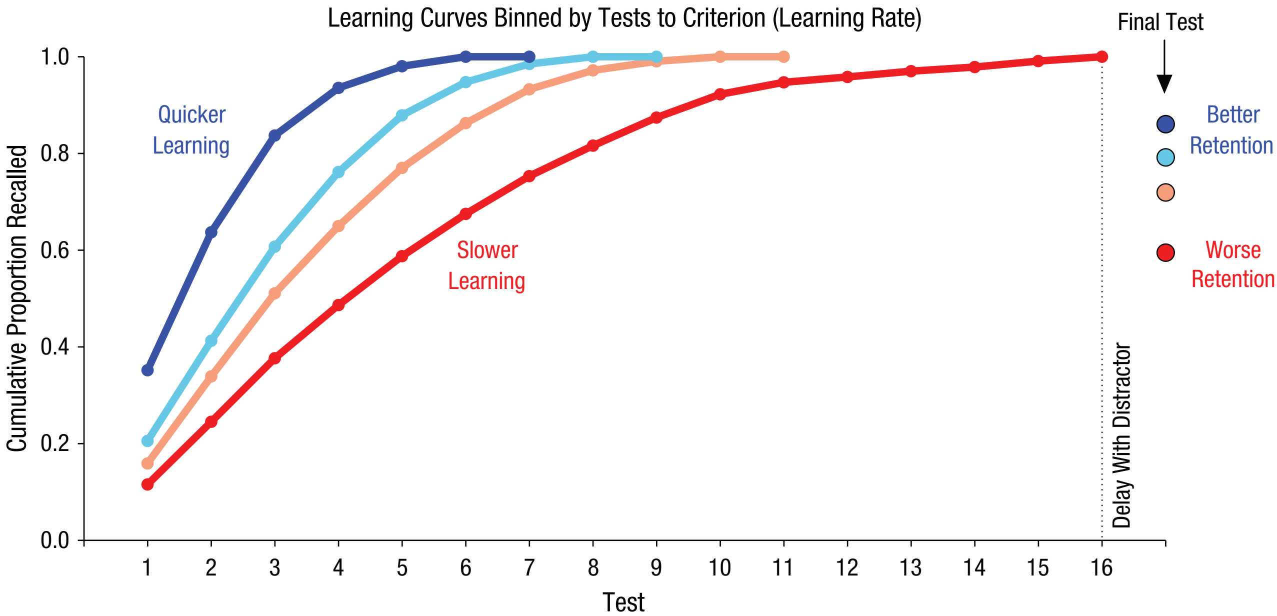

Fig. 4. Data from Zerr et al. (2018) showing the cumulative proportion of correctly recalled word pairs after each of 16 tests, binned into four equal quartiles according to performance. The fastest learners (top 25%, blue line) had higher final-test performance after a 5-min delay with a distractor (blue dot) relative to the other groups. Contrast this pattern with that in Figure 1 to see the discrepancy in group-level (Fig. 1) and individual-level (Figs. 3 and 4) effects between learning rate and retention. Figure adapted with permission from Zerr et al. (2018).

gradual acquisition (e.g., retrieval practice, strategy usage) usually aid learning. Across participants, however, being a slower learner is less advantageous than being a quicker learner.

Contrasts with experimental conditions aside, one might view the finding that faster learners tend to retain well as not being terribly surprising. We suggest, however, that the procedures are biased in favor of slow learners. Consider the extremes, in which the 25% fastest learners reached criterion after an average of 5.06 test trials (or 100.34 total items tested), and the 25% slowest learners required 12.26 test trials (or 236.53 total items tested). It is well established that repetition, spaced practice, and retrieval practice all help memory; repeated spaced retrieval practice is especially beneficial. Yet here is a case in which many more trials of spaced retrieval practice (with feedback) resulted in inferior retention. One might reasonably have predicted that slower learners might have benefitted from the enhanced practice and exhibited superior retention.

Indeed, Ebbinghaus (1885/2011) considered it an axiom that quicker learners retain less: "The foregoing sketch of our knowledge concerning memory makes no claim to completeness. To it might be added such a series of propositions known to psychology as the following: 'He who learns quickly also forgets quickly'" (p. 4). Going back to the time of ancient Greece, Plato, in *Theaetetus*, claimed in his wax-tablet metaphor of memory that "Persons in whom the wax is soft are quick to learn but quick to forget; when the wax is hard, the opposite happens" (Plato, 1997, p. 215).

Characteristics of Efficient Learners

Why are faster learners able to acquire information in less time with fewer exposures yet still demonstrate better memory for what was learned? That is, aside from speed of learning, how do quicker learners differ from slower learners? Zerr et al. (2018) reported that more efficient learners had higher intelligence scores, faster processing speed, and better performance on a variety of cognitive tasks. These observations offer some understanding, but by no means did these measures account for all the variance across people. Are faster learners more likely to adopt or implement strategies—or more effective strategies—to bind the word pairs together? Do they simply possess more general knowledge or perhaps employ their general knowledge more successfully? Or perhaps they differ in certain cognitive processes, such as better allocating their attention while learning. A complete understanding awaits future work, but here we consider some evidence bearing on these questions.

Learning-strategy differences

Effective strategies during learning improve memory (for a review, see Unsworth, 2019). In paired-associates learning, a learner has to devise a way to associate two items so that one can be recalled when the other is shown. The most obvious approach is for learners to generate a link (or mediator) between the items—this link could be another word, an image, a story, a physical description, and so forth. Faster learners generate more mediators while learning, and these mediators tend to be both implemented earlier in the learning process and more effective in aiding memory (Wang, 1983). In addition, a new group of participants who were provided with mediators generated by faster learners learned more quickly on average than a group supplied with mediators generated by slower learners (Wang, 1983, Experiment 3). Although strategies may slow the average rate of learning at the overall condition level compared with a condition that does not implement strategies, *within* a condition, participants who implement strategies more quickly remember better.

Might instructing learners on strategies beforehand improve learning efficiency overall and perhaps even close the performance gap? Little evidence on this exists, and it is mixed. When fast and slow learners were instructed with respect to strategies prior to learning, the effects depended on the specific instructional strategies used (Shuell, 1983). Specifically, when instructions asked learners to organize the to-be-learned list of words alphabetically, the groups accrued the same benefit. When instructions asked learners to organize the words according to categorical memberships, the slower learners gained more from the strategies. In short, the literature is mixed with respect to whether strategy training might be used to close the gap between slower and faster learners.

Prior-knowledge differences

Memory researchers often try to mitigate confounding effects of prior knowledge by using either unfamiliar material or material low in meaning, with the goal of leveling the playing field across learners. However, prior knowledge (or crystallized intelligence) may still promote integration of new information into existing knowledge and improve the efficacy of learning strategies—the more knowledge someone possesses, the richer the set of potential mediators. In a large study of Air Force enlistees ($N = 396$), individuals with greater vocabulary knowledge learned word pairs more quickly and were better at recognizing them later (Kyllonen, Tirre, & Christal, 1991; see also Kyllonen & Tirre, 1988). In their review chapter on individual differences in long-term memory, Bors and MacLeod (1996) concluded that individuals "who know more learn better, whether the knowledge and learning are in a specific domain or more global" (p. 432).

Attentional-control differences

Attentional control is the ability to allocate and guide attention to goal-relevant information. People who are better able to focus their attention are less susceptible to interfering information; further, they more quickly search long-term memory when retrieving information (Unsworth & Spillers, 2010).

Neuroimaging evidence suggests that the ability to control one's attention is a potential driver of efficient learning. During the initial study of unfamiliar material (in this case, Lithuanian–English word pairs), more-efficient learners display greater suppression of the brain's default mode network (DMN) relative to less-efficient learners (Nelson et al., 2016). The DMN is engaged (or active) much of the time, as it appears to be tied to our typical "default mode" of thought—for example, while daydreaming or thinking about goals or feelings. Alternatively, DMN activity is hypothesized to be disengaged (or suppressed) when focused attention to the external environment is required, such as when a difficult, attention-demanding task is being performed (Raichle et al., 2001). Because Nelson and colleagues demonstrated that efficient learners suppress DMN activity more than inefficient learners do, they concluded that efficient learners may be better able to focus their attention to accomplish the task at hand.

The ability to control one's attention is also thought to be a major determinant of working memory capacity and fluid intelligence (Engle, 2018), two constructs that predict performance on a wide variety of real-world cognitive tasks. Individuals with higher working memory capacity, in turn, implement more effective knowledge-based strategies during learning, whereas those with lower working memory capacity frequently fail to use any particular strategy (Unsworth, Brewer, & Spillers, 2013). Each of these factors presumably aids in making learning more efficient, and the factors likely interact to allow efficient learners to both acquire information more quickly and remember it more successfully.

Future Directions

There are a number of open questions concerning the construct of efficient learning, predominantly in terms of durability and domain generality. For how long do faster learners maintain their retentive advantage? How generalizable is efficient learning across different materials (e.g., verbal and nonverbal stimuli)? Does efficient learning depend on the type of memory test used (e.g., cued recall, free recall, recognition), or does faster learning relate to better memory regardless of how memory is tested?

Summary

Jenkins (1961) remarked, "In the learning area especially, I believe we neglect individual differences. We have given a great deal of attention to the conditions and contents of learning experiments but very little to the attributes of subjects" (p. 147). We have highlighted the differences in conclusions drawn from experimental work (in which slower learning is often desirable for long-term retention) and the individual-differences approach (in which faster learners have an advantage in retention). The dynamic interplay between the person and learning conditions is ripe for investigation, as is the question of what person-level characteristics contribute to learning efficiency.

Recommended Reading

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Declaration of Conflicting Interests

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