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Is Expanded Retrieval Practice a Superior Form of Spaced Retrieval? A Critical Review of the Extant Literature

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Consider the following scenario: You are in the age range of most of the contributors to this volume and are at a neighborhood party. You are introduced to a person named Mark Finglestein. What would be the best procedure to learn this person's name so you are not embarrassed in future chance encounters in the neighborhood? One procedure would be to simply rehearse the name over and over again via massed practice. Of course, as students of learning and memory, we all know that this procedure is doomed to failure. Another procedure would be to space one's retrieval such that after every minute or so one attempts to retrieve the name Mark Finglestein. Because of the well-known benefits of spaced practice, this procedure is much more likely to succeed. A third procedure would be to gradually expand the intervals between the retrieval attempts. For example, you may first retrieve the name after 15 seconds, then 45 seconds, and then 2 minutes. This procedure takes advantage of the benefits of spacing but also maintains relatively high levels of retrieval success. There is evidence suggesting that this procedure may indeed be better than the simple spaced retrieval. In fact, the benefits of expanded retrieval have been at the center of considerable work in both educational and clinical settings.

The present chapter reviews the evidence concerning the benefits of expanded retrieval over equal interval conditions. We will first provide some historical background on the spacing effect, since expanded retrieval may be considered a special case of spacing. We will then critically evaluate the evidence concerning expanded and equal interval retrieval practice. We will conclude with a discussion of some potential limits of expanded retrieval, theoretical implications, and possible avenues for future research.

THE SPACING EFFECT

The spacing effect is one of the most ubiquitous findings in learning and memory. Performance on a variety of tasks is better when the repetition of the to-be-learned information is distributed as opposed to massed in presentation. This observation was first formalized in Jost's law, which states that "if two associations are of equal strength but of different age, a new repetition has a greater value for the older one" (McGeogh, 1943). Spacing effects occur across domains (e.g., learning perceptual motor tasks vs. learning lists of words), across species (e.g., rats, pigeons, and humans), across age groups and individuals with different memory impairments, and across retention intervals of seconds to months (see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Crowder, 1976; Dempster, 1996, for reviews). In this light, it is interesting that spacing effects have not received much attention in Cognitive Psychology textbooks. In fact, in our sampling of seven such textbooks, only one had a section dedicated to this topic, while virtually all cognitive textbooks discussed mnemonic techniques such as the pegword or method of loci. Given the power and simplicity of implementing spaced practice, we clearly hope this changes in the future.

As a sidebar, we felt it was particularly fitting to discuss the spacing effect as part of a book honoring the contributions of Roddy Roediger. Roddy's mentor, Robert Crowder (1976) devoted considerable discussion (over 40 pages) of his classic book, *The Principles of Learning and Memory*, to the effects of spacing on learning and memory. Moreover, Arthur Melton, Roddy's academic grandfather, wrote a definitive piece on this topic in 1970. As noted in Melton's paper, spacing effects, like many things, can be traced back to observations by William James (Roddy's great-great-great grandfather) concerning the benefits of alternating swimming in the summer and skating in the winter. In addition to his academic lineage, spacing effects are also quite consistent with Roddy's functionalist approach in his work and the importance of making a connection between practical implications and basic experimental research. Recently, Roddy has been exploring the application of cognitive principles to educational practice, and has already made important contributions in this domain (see, for example, Roediger & Karpicke, 2006). Expanded retrieval and the spacing effect have been at the center of considerable work in educational settings, and Roddy has been exploring this issue in a number of recent projects (e.g., Karpicke & Roediger, 2005).

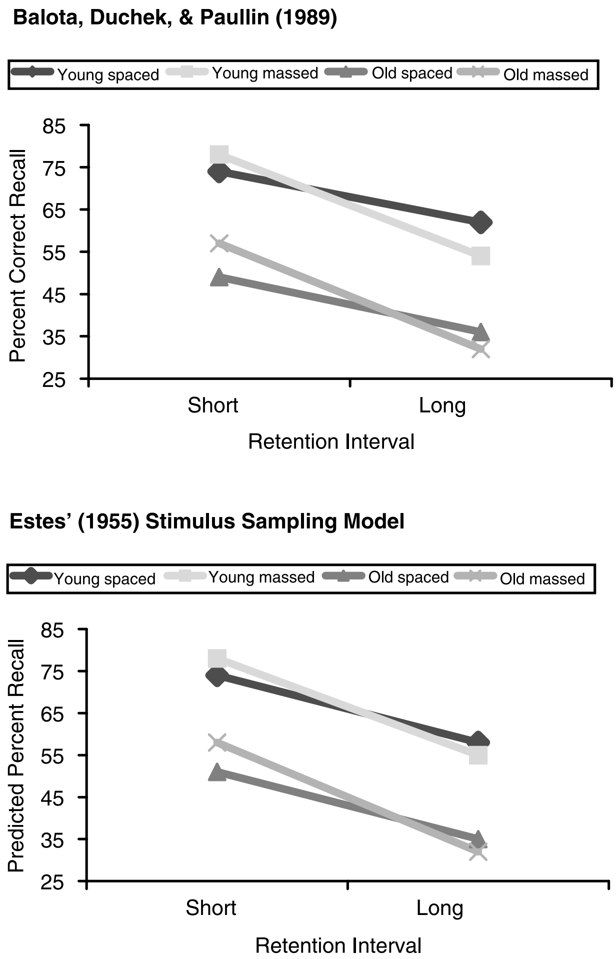
SPACING EFFECTS, POSSIBLE LIMITATIONS, AND THE APPEAL OF EXPANDED RETRIEVAL

Although spaced presentation is clearly beneficial in most situations, as with everything, there are some limitations. For example, there is evidence of a spacing by retention interval interaction. Specifically, massed items are actually better retained after a short retention interval, whereas spaced items are better retained after a long retention interval. This observation was first obtained by Peterson, Wampler, Kirkpatrick, and Saltzman (1963), and was replicated by Glenberg (1977) and Balota, Duchek, and Paullin (1989).

There are numerous theoretical accounts of the spacing effect (see Cepeda et al., 2006, for a review); however, the spacing by retention interval interaction would appear to be most consistent with an encoding variability account. Because of the relevance of this theoretical framework to our discussion of the benefits of expanded retrieval in a later section, we will briefly describe the encoding variability account of the spacing by retention interval interaction. According to encoding variability theory, performance on a memory test is dependent upon the overlap between the contextual information available at the time of test and the contextual information available during encoding. During massed study, there is relatively little time for contextual elements to fluctuate between presentations and so this condition produces the highest performance in an immediate memory test, when the test context strongly overlaps with the same contextual information encoded during both of the massed presentations. In contrast, when there is spacing between the items, there is time for fluctuation to take place between the presentations during study, and hence there is an increased likelihood of having multiple unique contexts encoded. Because a delayed test will also allow fluctuation of context, it is better to have multiple unique contexts encoded, as in the spaced presentation format, as opposed to a single encoded context, as in the massed presentation format.

Because of evidence regarding a contextual encoding deficit in older adults (see Burke & Light, 1981; Duchek, 1984), Balota et al. (1989) investigated the spacing by retention interval interaction in young and older adults, and found that both groups produced clear evidence of the interaction, with older adults being overall lower. More importantly, as suggested in Crowder (1976), Balota et al. fit their data to Estes' (1955) stimulus sampling model (a precursor of encoding variability theory), which was developed to account for aspects of extinction and spontaneous recovery, among other findings, in the animal learning domain. Interestingly, when animals are placed in an environment at varying times after extinction of a response, the response appears to spontaneously recover, even though it had been extinguished earlier. The results of this simple modeling endeavor indicated that older adults were different from younger adults in two parameter values. Specifically, older adults were less likely to store contextual elements in memory and elements also fluctuated between available and unavailable states across time at a slower rate in older adults than younger adults. As shown in Figure 6.1, changes in these two parameters of the Estes' model nicely fit the Balota et al. data (also see Spieler & Balota, 1996, for an extension to an implicit memory task). Thus, the spacing by retention interval interaction nicely extends to individuals with different levels of memory competence, and converges on a particular theoretical account of the spacing effect that emphasizes contextual drift (encoding variability) across time.

The spacing by retention interval interaction indicates that there are limitations to the spacing effect. This tradeoff between lag (the amount of spacing between two events) and retention interval has led some researchers (e.g., Greene, 1992) to speculate that the ratio between spacing and retention interval is the



Changes in Two Parameters

Fluctuation (Young = .76; Old = .54)

Prob. of Storage (Young = .50; Old = .30)

FIGURE 6.1 Percent correct recall as a function of group and retention interval from Balota et al. (1989), along with the predictions from Estes' (1955) stimulus fluctuation model.

critical variable. Although there is some tradeoff between retention interval and spacing, there are probably some limits even here. For example, if one considers a spaced interval of 1 year between two repetitions, one may not expect much benefit even at a very long retention interval, since the initial trace may have either decayed or been completely overwhelmed by interfering material. Of course, this leads us to an important question. Are there ways to maintain the strength of the initial encoding so as to minimize the disruptive effects at long lags? Enter expanded retrieval practice. The goal in this procedure is to gradually increase the lag between retrieval events, thereby maintaining relatively high levels of retrieval success at long lags.

In an often-cited chapter, Landauer and Bjork (1978) were the first to carefully explore expanded retrieval in two well-controlled experiments. In their first experiment, subjects were presented a deck of cards that included fictitious first and second names of individuals during the acquisition phase. For present purposes, we will focus on the trials in which subjects were first presented both the first and second names intact followed at varying schedules of receiving cards with only the first name of the study pair as a retrieval cue for the second name. For example, in an expanded retrieval schedule, subjects may receive the first name as a retrieval cue at 1, 4, and 10 intervening cards versus an equal interval condition of 5, 5, and 5 intervening cards. A massed condition (study of the name followed by three immediate tests) was used to obtain a baseline estimate of the influence of simple repetition without spacing. The results of a later cued recall test yielded a large benefit for both the expanded and equal interval condition over the massed condition. More importantly, there was a small, but significant effect (approximately a 5% benefit, based on interpolation from their Figure 2) of the expanded condition over the equal interval condition in the final cued recall test.

The Landauer and Bjork (1978) results have been quite influential and would appear to naturally maximize the benefits of spacing. They originally suggested that the benefit of expanded retrieval involves insuring successful retrieval at longer and longer intervals, thereby increasing the difficulty of retrieval, while still yielding success. One could also view these benefits within an encoding variability framework described above. Specifically, with the passage of time and intervening information, there is an increased likelihood of greater fluctuation of context, and hence a greater likelihood of distinct encodings. The notion here is that in a long-term retention test, stimuli that have more distinct encodings, afforded by the longest interval in the expanded condition, would produce a greater benefit compared to stimuli with less distinct encodings due to shorter retention intervals.

Both of the above accounts emphasize the additional benefit beyond successful retrieval in the expanded condition compared to the equal interval condition. In particular, the reason there is an advantage in the expanded condition is that the participants are indeed retrieving items in the face of a longer retention interval during the final retrieval attempt in the expanded compared to the equal interval condition. Importantly, Landauer and Bjork (1978) provided retrieval success data during initial list presentation to directly examine this. Based on interpolation from their Figure 1, Table 6.1 displays performance of an expanded condition compared to an equal interval condition estimated from Landauer and Bjork's first experiment. As shown, there is an initial benefit of expanded retrieval that actually decreases across subsequent retrieval attempts. Hence, the benefit of expanded over equal interval is larger during the acquisition phase than in final

TABLE 6.1 Interpolated Results from Landauer and Bjork (1978)

	Retrieval attempt			**Final recall**
	1	**2**	**3**	
Expanded	.61	.55	.50	.45
Equal interval	.42	.42	.43	.40

recall. This is somewhat counterintuitive because one might expect an advantage of expanding over equal interval schedules above and beyond the retrieval success advantage produced during the acquisition phase. Specifically, at the last retrieval event, the retrieved items have persisted in the face of a longer retention interval and more intervening information in the expanded than in the equal interval condition. On the other hand, the "expanded retrieval effect" may be due to the fact that the first retrieval success occurs soon after study, permitting greater retrieval success in the expanding relative to the equal interval condition, as opposed to greater retrieval efficiency at the longest delays. Of course, this could ultimately overestimate the benefits of expansion. We will return to this possibility later.

The Landauer and Bjork (1978) results are clearly provocative, and the benefits of expanded retrieval have been explored in both educational and clinical settings. Below we will provide a review of the influence of expanded retrieval in these areas. It will become clear that although expanded retrieval is clearly a useful memory aid, there has been relatively little controlled work, akin to Landauer and Bjork's, that attempts to isolate the influence of expansion over comparable equal spaced conditions. Given the potential importance of this procedure, this is surprising.

Before turning to the review of the literature, we believe that it is noteworthy to identify the conditions that are important to make strong inferences regarding the specific role of expanding retrieval, many of which were available in Landuaer and Bjork's seminal study. For example, it is important to include at least three levels of spacing: an expanded condition (e.g., 1, 4, 10), an equal interval condition that matches the average spacing of the expanded condition (e.g., 5, 5, 5), and a massed condition (e.g., 0, 0, 0). With these three levels, one can both measure the influence of expansion with spacing equated (e.g., 1, 4, 10 vs. 5, 5, 5), and also the benefits of spaced (1, 4, 10 and 5, 5, 5) over massed practice (e.g., 0, 0, 0) to insure one obtains a clear spacing effect. In addition, it is useful to measure retrieval success during the initial acquisition phase to obtain an estimate of the original level of learning. As we shall discuss below, it is preferable to include two different delays for the final memory test, because it appears that one can obtain different effects depending upon the delay. Of course, this has some resemblance to the spacing by retention interval interaction. Finally, it would also be useful to include a study alone condition with the same spacing and testing conditions to measure the specific influence of retrieval during study. Unfortunately, as noted, these conditions have rarely been available in the same study to isolate the specific benefits of expanded retrieval.

EXPANDED RETRIEVAL PRACTICE IN EDUCATIONAL SETTINGS

The additional benefit of expanded retrieval over equal interval spacing obviously has important implications for educational settings. Although Landauer and Bjork's (1978) work sparked considerable interest in applying expanded retrieval to educational settings, Roddy informed us of relevant work nearly 40 years before Landauer and Bjork's study. Specifically, Spitzer (1939) incorporated a form of expanded retrieval in a study designed to assess the ability of sixth graders to learn science facts. Impressively, Spitzer tested over 3600 students in Iowa—the entire sixth-grade population of 91 elementary schools at the time. The students read two articles, one on peanuts and the other on bamboo, and were given a 25-item multiple choice test to assess their knowledge (such as "To which family of plants does bamboo belong?"). Spitzer tested a total of nine groups, manipulating both the timing of the test (administered immediately or after various delays) and the number of identical tests students received (one to three). Spitzer did not incorporate massed or equal interval retrieval conditions, but he had at least two groups that were tested on an expanding schedule of retrieval, in which the intervals between tests were separated by the passage of time (in days) rather than by intervening to-be-learned information. For example, in one of the groups, the first test was given immediately, the second test was given seven days after the first test, and the third test was given 63 days after the second test. Thus, in essence, this group was tested on a 0-7-63 day expanding retrieval schedule. Spitzer compared performance of the expanded retrieval group to a group given a single test 63 days after reading the original article. On the first (immediate) test, the expanded retrieval group correctly answered 53% of the questions. After 63 days and two previous tests, their score was still an impressive 43%. The single test group correctly answered only 25% of the original items after 63 days, giving the expanded retrieval group an 18% retention advantage. This is quite impressive, given that this large benefit remained after a 63-day retention interval. Similar beneficial effects were found in a group tested on a 0-1-21 day expanded retrieval schedule compared to a group given a single test after 21 days. Of course, this study does not decouple the effects of testing from spacing or expansion, but the results do clearly indicate considerable learning and retention using the expanded repeated testing procedure. Spitzer concluded that ". . . examinations are *learning devices* and should not be considered only as tools for measuring achievement of pupils" (p. 656, italics added), and we are sure Roddy would agree (see Roediger & Karpicke, 2006).

Since Spitzer (1939), there was very little work was published on expanded retrieval using educationally-relevant materials for 45 years until Rea and Modigliani (1985) tested the effectiveness of expanded retrieval in a third-grade classroom setting. In separate conditions, students were given new multiplication problems or spelling words to learn. The problem or word was presented audiovisually once and then tested on either a massed retrieval schedule of 0-0-0-0 or an expanding schedule of 0-1-2-4, in which the intervals involved being tested on old items or learning new items. After each test trial for a given item, the item was re-presented in its entirety so students received feedback on what they were learning. Performance during the learning phase was at 100% for both spelling words and multiplication facts. On an immediate final retention test, Rea and Modigliani found a performance advantage for all items—math and spelling—practiced on an expanding schedule compared to the massed retrieval schedule. They suggested, as have others, that spacing combined with the high success rate inherent in the expanded retrieval schedule produced better retention than massed retrieval practice. However, as in Spitzer's study, Rea and Modigliani did not test an appropriate equal interval spacing condition. Hence, their finding that expanded retrieval is superior to massed retrieval in third graders could simply reflect the superiority of spaced versus massed rehearsal—in other words, the spacing effect.

More recently, Cull (2000) compared expanded retrieval to equal interval spaced retrieval in a series of four experiments designed to mimic typical teaching or study strategies encountered by students. He examined the role of testing versus simply restudying the material, feedback, and various retention intervals on final test performance. Paired associates (an uncommon word paired with a common word, such as *bairn–print*) were presented in a manner similar to the flash-card techniques students often use to learn vocabulary words. The intervals between retrieval attempts of to-be-learned information ranged from minutes in some experiments to days in others. Interestingly, across four experiments, Cull did not find any evidence of an advantage of an expanded condition over a uniform spaced condition (i.e., no significant expanded retrieval effect), although both conditions consistently produced large advantages over massed presentations. He concluded that distributed testing of any kind, expanded or equal interval, can be an effective learning aid for teachers to provide for their students.

Karpicke (2004) investigated the effectiveness of using expanded retrieval to learn material commonly encountered by students—prose passages. Participants were given 7 minutes to read an encyclopedia article and practice free recalling the article on an expanding or equal interval schedule. An important feature of Karpicke's study was that he matched the timing of the first recall attempt in the acquisition phase in the expanded and equal interval conditions. As noted, in most expanded retrieval studies, the first practice for the expanded items comes sooner than practice for the equal interval items. Hence, in Karpicke's study, the first recall attempt for both equal and expanded conditions was either immediate (given just after reading the article) or delayed (given after 7 minutes of a distractor task). He tested a total of four recall schedules in the acquisition phase: 0-2-4, 0-2-2, 2-2-4, 2-2-2. The final free recall test was given 1 week later. In both the immediate and delayed practice conditions, Karpicke found no difference in memory performance when expanded and equal interval schedules were matched on the timing of the first retrieval attempt. This was true in the acquisition phase as well as the final free recall test. However, one might compare the 0-2-4 condition to the 2-2-2 conditions to investigate the expanded retrieval effect.

Interestingly, Karpicke (2004) did find an advantage for the expanded condition in both the acquisition phase as well as the final free recall test, similar to

Landauer and Bjork (1978). Because there was no delay in the first retrieval event in the immediate retrieval conditions in this study, and the 0-2-4 and 0-2-2 produced equivalent and better performance than the 2-2-2 and the 2-2-4, Karpicke points out that it is difficult to isolate the influence of expansion from the immediacy of the first recall event. In this light, it would have been useful to have 0-1-2-3 and 0-2-2-2 conditions for comparison. In any case, Karpicke's findings support the notion that any expanded retrieval effect at a final test is strongly linked to greater retrieval success for the expanded condition compared to the equal interval condition during the first acquisition phase. When these two conditions were matched in performance during the acquisition phase, the expanded retrieval effect did not emerge.

Researchers have also attempted to extend the utility of expanded retrieval to other "real world" settings such as in our original example of learning the name Mark Finglestein (remember Mark?) at a neighborhood party. Morris and Fritz (2000; see also Morris & Fritz, 2002; Morris, Fritz, & Buck, 2004) modified the expanded retrieval technique to create a "name game" to help individuals learn the names of members in their group. In the name game, an individual introduces herself, while a group leader writes their name on a board and then erases it once the other group members had read it. A second individual then repeats the first person's name aloud and introduces himself to the group. The third individual then repeats the names of the first and second individuals (in that order) and adds her name, etc. This technique of repeating previous names (starting with the first person's name) then adding a new name to the group is followed until all group members are introduced. Thus, the interval between hearing a given name progressively expands as each new person is introduced. In the Morris and Fritz (2000) study, participants were given a final recall test on the names after 30 minutes and again after 2 weeks and 11 months. Performance in the name game condition was compared to a condition in which individuals were simply paired with another group member and then asked to introduce their partners aloud to the group. In two experiments, participants recalled significantly more full names from the name game condition than the partner condition, even after 11 months. This condition also produced superior performance compared to when the group leader simply read the previous names back after each new introduction without ever asking individuals to retrieve the names. In a follow-up study, Morris and Fritz (2002) found that a reversed version of the name game, in which names were recalled in reverse chronological order, produced better performance than the original version used in the previous study. They noted that the reversed name game more closely mimics the technique originally employed by Landauer and Bjork (1978), and it was more effective than the original name game because there was less chance of forgetting a new name when the delay between learning and retrieval was reduced. Although the name game clearly does work, there is again no comparable equal interval condition to examine if the schedule is the critical dimension or the spacing.

The studies reviewed above specifically cited a desire to apply the expanded retrieval technique to nonlaboratory settings and explored its applications to a variety of learning situations (science and multiplication facts, spelling words, and first and last names). The studies found an advantage for expanded retrieval compared to information that is simply repeated or reread (Cull, 2000; Morris & Fritz, 2000, 2002), tested only once (Spitzer, 1939), or tested on a massed retrieval schedule (Cull, 2000; Rea & Modigliani, 1985). In addition, Karpicke (2004) provides intriguing evidence that provides support for the utility of expansion for text materials, but overall his results primarily show the importance of the immediacy of a first testing session. Only Cull (2000) directly compared the utility of expanded retrieval to other schedules of spaced retrieval and this study did not obtain any benefits of expanded retrieval over an equal interval schedule. In a later section, we will further discuss the Cull study and other studies that have attempted to decouple the influence of spacing from expansion in more traditional laboratory settings.

EXPANDED RETRIEVAL PRACTICE IN COGNITIVELY IMPAIRED POPULATIONS

Another area where expanded retrieval has been viewed as having considerable potential is as a cognitive rehabilitation technique for various memory-impaired populations. This area has been very active. The specific appeal of expanded retrieval is that the benefits of expanded retrieval are relatively automatic and nonstrategic, as opposed to teaching memory impaired individuals mnemonic techniques such as the pegword method or method of loci, which demand considerable strategic/attentional control processes.

Schacter, Rich, and Stampp (1985) utilized the expanded retrieval procedure to improve memory performance in four patients with cognitive impairment due to a variety of etiologies. In this study, subjects first studied faces and associated characteristics (i.e., names, hometowns, occupations, hobbies) and then utilizing the face cue, engaged in retrieval practice for the associated characteristics at expanded time intervals. Initially subjects were given a verbal prompt to engage in retrieval practice and over time the verbal prompt was removed to see if subjects would engage in expanded retrieval practice on their own. The results indicated that memory performance for the associated characteristics improved after expanded retrieval practice relative to baseline performance as measured prior to the introduction of the expanded retrieval strategy. Importantly, two out of the four subjects were relatively successful in spontaneously using expanded retrieval practice without prompts. Thus, Schacter et al. concluded that expanded retrieval practice might be a particularly effective strategy for memory enhancement in cognitively impaired populations.

The vast majority of the work employing the use of expanded retrieval in clinical populations has been conduced by Camp and his colleagues, with individuals in various stages of Alzheimer's disease (AD; for a review, see Camp, Bird, & Cherry, 2000). Given that memory loss is the hallmark symptom of Alzheimer's disease, targeting this population with such a behavioral intervention could prove quite beneficial to both patients and caregivers. In an effort to apply Landauer and Bjork's (1978) expanded retrieval practice to the AD population, Camp and colleagues adopted a clinical protocol for teaching AD patients new information using spaced retrieval practice (Camp, 1989; Camp & McKitrick, 1992). In this procedure, subjects are first given one piece of information to remember (e.g., the name of a staff person) and are then tested for immediate recall. If this immediate recall attempt is successful, then the next retrieval attempt is queried after 5 s, and then expanded to 10 s, 20 s, 40 s, 60 s. After successful retention of the item for 60 s, intervals are increased by 30 s (90 s, 120 s, etc.). If a person does not successfully retrieve the information, he/she is given the correct response, asked to immediately repeat the correct response, and then is tested at the last successful interval. Expanded retrieval attempts are again initiated from that point forward on successful retrieval events.

As Camp, Foss, Stevens, and O'Hanlon (1996) describe, there are some key features of this spaced retrieval strategy that promote success in memory-impaired patients. First, the expansion of retrieval attempts occurs over time, not over intervening to-be-remembered items. Thus, the time intervals are typically filled with social conversation or other non-related activities. Hence, as Camp and Mattern (1999) argue, the expanded retrieval training can be efficiently used within a therapy session wherein the intervening time intervals can be used for other therapeutic activities. Second, this technique is analogous to a shaping procedure wherein an association is formed between a stimulus (i.e., the retrieval query) and a single response (i.e., the name). Because the learning occurs very gradually over time, the initial retrieval attempts are likely to be successful, even for individuals in the moderate stages of AD. Third, the expanded retrieval strategy incorporates the neurorehabilitation technique of errorless learning (Wilson, Baddeley, Evans, & Shiel, 1994). Wilson and colleagues have argued that memory-impaired populations show better long-term retention for information when they are not allowed to make errors during training (Baddeley & Wilson, 1994; Wilson & Evans, 1996). The notion is that explicit memory is necessary for error recognition and elimination during learning. When the explicit system is deficient, then errors may be implicitly incorporated into the learning and thus each repetition of an erroneous response may serve to further strengthen that incorrect response, thereby hindering the retention of the correct information. Thus, the expanded retrieval procedure used by Camp and colleagues requires that when there is a failure of retrieval, the correct response be given immediately and repeated by the subject. Finally, the implementation of the expanded retrieval strategy requires little cognitive effort and/or resources on the part of the learner. Camp and colleagues have argued that expanded retrieval training makes use of implicit memory, which is relatively spared even in the later stages of AD (e.g., Balota & Ferraro, 1996; Camp et al., 2000; Faust, Balota, & Spieler, 2001). Thus, it is ideally suited for memory-impaired patients.

Indeed there have been numerous reports in the literature of the successful use of expanded retrieval practice in teaching new information to individuals in the relatively advanced stages of AD. Specifically, Camp and colleagues have used this technique to teach AD individuals various types of information, such as names of common objects (e.g., McKitrick & Camp, 1993), face-name associations (e.g., Camp & Schaller, 1989), object-location associations (e.g., Camp & Stevens, 1990), and even prospectively remembering to perform a task (e.g., McKitrick, Camp, & Black, 1992). Moreover, long-term retention of information has been demonstrated over several days in some cases (e.g., Camp et al., 1996). For example, in the latter study, Camp et al. employed an expanding retrieval strategy to train 23 individuals with mild to moderate AD to refer to a daily calendar as a cue to remember to perform various personal activities (e.g., take medication). Following a baseline phase to determine whether subjects would spontaneously use the calendar, spaced retrieval training was implemented by repeatedly asking the subject the question, "How are you going to remember what to do each day?" at expanding time intervals. The results indicated that 20/23 subjects did learn the strategy (i.e., to look at the calendar) and retained it over a 1-week period.

There have been numerous other studies utilizing this protocol of expanded retrieval practice to induce memory-impaired patients to learn clinically relevant behaviors. For example, this technique has been employed to teach a demented client with dysphagia (i.e., a swallowing disorder) to use a compensatory strategy of alternating bites of food with sips of liquid to prevent aspiration (Brush & Camp, 1998a). Expanded retrieval training has been applied to attaining goals during speech therapy sessions (Brush & Camp, 1998b) with demonstrated retention over a 4-week period in demented clients. Patients with dementia associated with Parkinson's disease have successfully learned new motor tasks (Hayden & Camp, 1995) and patients with dementia associated with HIV have been trained in the use of external aids (Lee & Camp, 2001) with expanded retrieval practice. Likewise, a client with AD was able to learn the names of 11 members of his social group with a combined intervention of errorless learning and expanded retrieval (Clare et al., 2000). There has even been a case report of an individual in the early stages of AD who trained himself to spontaneously use expanded retrieval practice to remember new information (Riley, 1992). Thus, the benefits of expanded retrieval have been widely documented in the literature across various targeted behaviors and clinical populations.

What is somewhat surprising in reviewing all of these studies is that there has been no attempt to systematically compare expanded retrieval practice with other schedules of spaced retrieval practice, such as equal interval spacing or even massed spacing of retrieval practice. In most of these studies, performance after expanded retrieval practice is simply compared relative to baseline performance (e.g., Camp et al., 1996; Cherry, Simmons, & Camp, 1999). More recently, Bourgeois et al. (2003) compared expanded retrieval training with a modified cued hierarchy training in teaching demented individuals to use various external memory aids. The modified cued hierarchy training is initiated in a similar way as the expanded retrieval training in that patients are first given the target information (e.g., when you want to know what activity to perform today—look at your activity list) and then immediately queried for that information. If patients cannot immediately give the correct response or give an incorrect response, they are given a hierarchy of cues in the following order until the correct response is given: semantic ("Something to look at"), phonemic (the first syllable of "activity list"), visual (point to list), tactile (touch list), imitation ("I look at my activity list"). No cues are given in the expanded retrieval training. The results indicated that both strategies improved usage of external aids, but the expanded retrieval strategy was more effective. Of course, the latter study simply indicates that spaced retrieval practice leads to better retention than providing a hierarchy of cues. It did not address the question of which specific pattern of spacing leads to the greatest benefit in long-term retention.

This issue of isolating which component of expanded retrieval is critical with a clinical sample was more systematically addressed in a recent study by Hochhalter, Overmier, Gasper, Bakke, and Holub (2005). Individuals with AD were presented pill names (Exp. 1; *n* = 10) under five different schedules of retrieval practice: massed, uniform distributed (i.e., equal interval), spaced/expanded adjusted based on performance (similar to the Camp protocol), expanded without adjustment, and random. The results indicated that only 6/10 individuals showed long-term retention for at least one pill name and there was no difference in the number of "learners" across the different schedules of retrieval practice. Thus the spaced/expanded retrieval condition did not show a benefit relative to any of the other schedules of practice. If anything, more subjects showed long-term retention in the random condition (*n* = 5) than the spaced/expanded condition (*n* = 3) and also had fewer errors during training.

The Hochhalter et al. (2005) study is clearly informative, but the relatively small number of subjects and more variable applied therapeutic setting makes it difficult to draw any firm conclusions. However, as described below, Balota, Duchek, Sergent-Marshall, and Roediger (2005) provide a study comparing equal interval and expanded practice in a laboratory context with a large set of healthy young, older adults, and individuals with early stage Alzheimer's disease and come to a very similar conclusion as the Hochhalter et al. study regarding comparisons of equal interval and expanded retrieval.

It is interesting to note that in their initial study, Schacter et al. (1985) acknowledged that it was unclear whether it was the actual expanding pattern of retrieval that led to the performance benefit in their study or whether it was merely due to the simple repetition of retrieval attempts. They argued that to some extent the latter question is not really clinically important given that expanded retrieval practice does indeed work for memory-impaired patients. Clearly, one would agree with this statement on an individual patient basis, where the goal of treatment is to enhance memory for important personal information. It is evident from the literature that having memory-impaired individuals engage in an expanded retrieval strategy does improve memory performance under a variety of situations, at least relative to baseline (no treatment) performance (Camp, Bird, & Cherry, 2000). Furthermore, one can see how the gradual expansion of recall attempts with the initial accompanying retrieval success would be relatively easy to implement in a clinical setting or in a home setting by caregivers (McKitrick & Camp, 1993). However, from a theoretical perspective, it is also critical to examine the properties of the most effective spacing of retrieval practice to enhance long-term retention. This research could also provide evidence for designing the best intervention strategies for memory-impaired individuals.

RE-EXAMINATION OF THE EVIDENCE FOR THE BENEFITS OF EXPANDED RETRIEVAL OVER EQUAL SPACED RETRIEVAL: BACK TO THE LABORATORY

As reviewed in the previous two sections, there is clear evidence that expanded retrieval practice has considerable potential in both educational and applied settings. The question that we will now turn to is an examination of how much of this evidence is specific to "expanded" retrieval. This of course depends on what is the appropriate baseline. As in Landauer and Bjork's (1978) original paper, we believe the appropriate baseline to be a comparably matched equal interval schedule. In this way, one can directly investigate if there is an additional benefit of expansion over mere spacing. For these studies, we are forced to return to the laboratory where more control of critical variables is available.

In one of the most comprehensive studies in this area, Cull, Shaughnessy, and Zechmeister (1996) explored the benefits of expanded retrieval over uniform spacing in a series of five experiments. They compared the expanded schedules of 1-5-9, with the equal interval schedule of 5-5-5, and included a 0-0-0 massed presentation condition, as a baseline to measure the benefit of spacing on a later final recall test. As shown in Table 6.2, the results generally support the benefit of expanded retrieval over equal interval conditions. Experiments 1 and 4 produced reliable expanded retrieval benefits compared to an equal interval condition, whereas the results from Experiments 2 and 3 were in the same direction, but did not reach significance. Experiment 5 produced near ceiling effects in both spaced conditions. Somewhat surprisingly, the comparison of the equal interval condition to the massed condition did not consistently produce spacing effects. A test for the spacing effect was not directly provided for Experiments 1 and 2, and in Experiments 3 and 4, these two conditions produced identical performance. Only, their fifth experiment provided strong evidence for a spacing effect, but this experiment did not provide evidence for an expanded retrieval effect, because of ceiling problems.

Cull (2000, Exp. 1) provided a direct follow-up study to the initial Cull et al.

TABLE 6.2 Results from Cull et al. (1996), and Cull (2000) Studies

Experiment	**Presentation schedule**		
	1-5-9	**5-5-5**	**0-0-0**
Cull et al. (1996)			
1. Test only	.33	.23	.17
2. Test only	.27	.18	.11
3. Test only	.34	.28	.28
4. Test only	.72	.59	.59
5. Test–study	.91	.91	.62
Cull (2000, Exp. 1)			
Test only	.38	.34	.18
Study only	.27	.29	.14
Test–study	.48	.49	.19

(1996) study. He included the same three spacing schedules used in the earlier Cull et al. study, along with three different types of study. In essence, his first experiment included three different experiments, as these conditions were between participant manipulations. In the study-only condition, the cue and response item of a paired associate were both presented on each repetition for 8 s. In the test-only condition, the cue for retrieval was presented on each occasion for 8 s. In the study–test condition, the cue was presented for 6 s for retrieval, followed by the response item for 2 s. As shown in Table 6.2, Cull did not obtain an advantage for the expanded over the equal interval condition in any of these conditions. As noted earlier, Cull also explored more educationally relevant manipulations in three additional experiments. None of these experiments afforded any benefit of expanded retrieval over a comparable equal interval condition.

Carpenter and DeLosh (2005, Exp. 2) have recently investigated face-name learning under massed, expanded (1-3-5), and equal interval (3-3-3) conditions. This study also involved study and study and test procedures during the acquisition phase. Carpenter and DeLosh found a large effect of spacing, but no evidence of a benefit of expanded over equal interval practice. In fact, Carpenter and DeLosh reported a reliable benefit of the equal interval condition over the expanded retrieval condition. Although Carpenter and DeLosh did report a reliable (20%) benefit of expanded retrieval during the acquisition phase, they did not break this down by each retrieval event to determine the size of the difference at the last retrieval event in the expanded condition.

In addition to studies with healthy young adults, there have been two recent studies that have explored the benefits of expanded retrieval with healthy older adults and early stage Alzheimer's disease. Balota et al. (2005) compared a massed presentation condition (0-0-0-0-0-0) with an equal interval (0-0-3-3-3) and an expanded retrieval schedule (0-0-1-3-5). Because this study included healthy young adults, older adults, and individuals with Alzheimer's disease, who have quite a wide range of memory ability, Balota et al. had subjects engage in two massed retrieval attempts before each of the three schedules to insure all groups were off the floor in their final recall performance. The results of performance during the acquisition phase are shown in Figure 6.2. Here one can see that the expanded retrieval condition indeed produces a benefit over the equal interval condition that persists until the last retrieval event for all groups of participants. Hence, because performance on the last retrieval event reflects longer maintenance of the memory in the 0-0-1-3-5 condition than the 0-0-3-3-3 condition, one would expect a benefit to persist in the final cued recall tests. This was not what the results indicated. Specifically, as shown in Figure 6.3, all three groups produced large spacing effects in a final cued recall test; however, there was no evidence of a reliable difference between the expanded and equal interval conditions for any of the groups. Moreover, the lack of a difference in final recall between the expanded and equal interval condition was replicated in two subsequent experiments, in which corrective feedback was given to participants. Hence, the Balota et al. results converge nicely with the recent Cull (2000) and Carpenter and DeLosh (2005) studies and extends this pattern to both healthy older adults and individuals with early stage Alzheimer's disease.

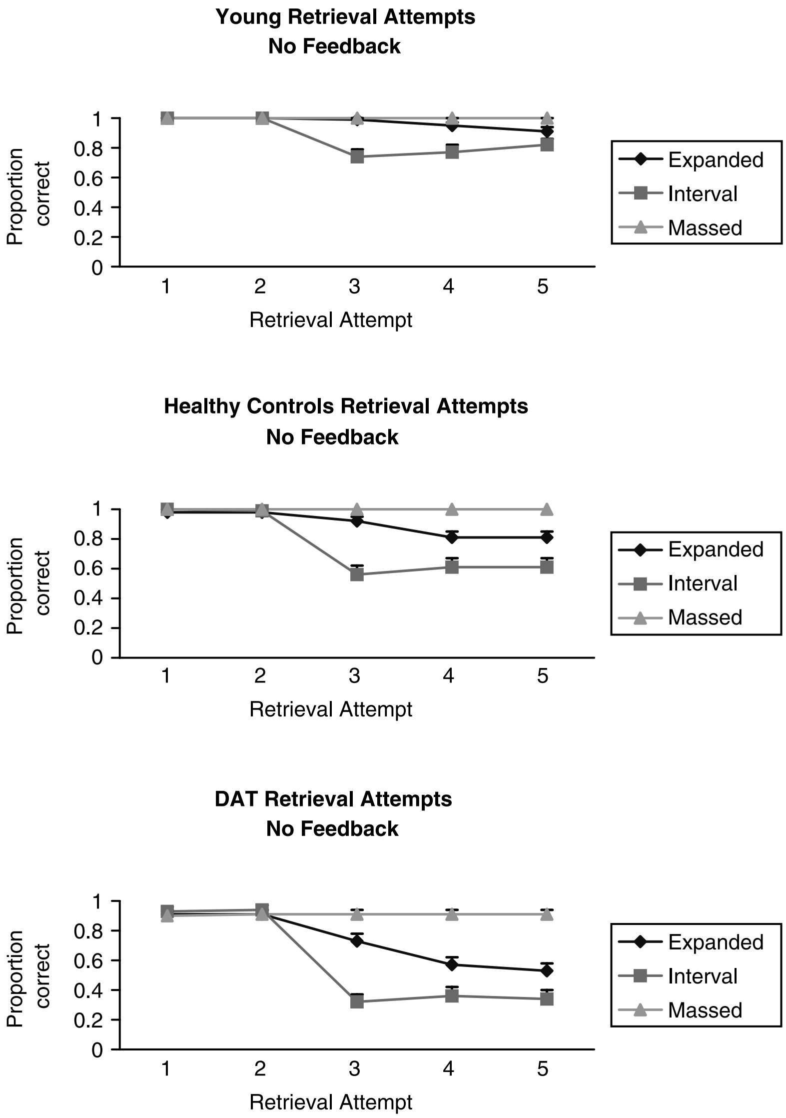


FIGURE 6.2 Mean proportion correct during the acquisition phase for the Young (top panel), Old (middle panel) and DAT (bottom panel) individuals, as a function of spacing, and retrieval attempt from Balota et al. (2005, Exp. 1).

Of course, one might be concerned that the Balota et al. (2005) and Carpenter and DeLosh (2005) study used the 3-3-3 and 1-3-5 comparison. Logan (2004) conducted a comprehensive study that compared three schedules of retrieval practice in healthy young and older adults, i.e., 0-0-0 versus 1-2-3 versus 2-2-2; 0-0-0 versus 1-3-5 versus 3-3-3; 0-0-0 versus 1-3-8 versus 4-4-4. An important additional contribution of the Logan study is that she also included both an

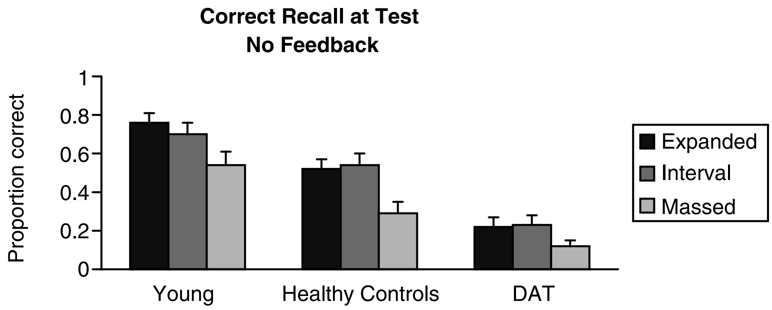


FIGURE 6.3 Mean final cued recall performance as a function of group and spacing schedule from Balota et al. (2005, Exp. 1).

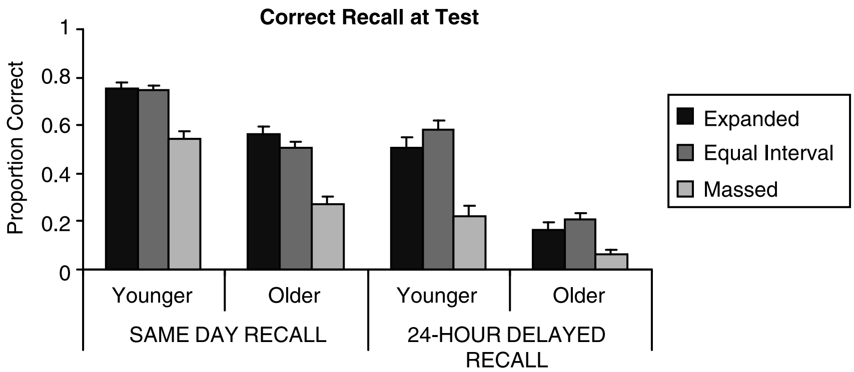


FIGURE 6.4 Mean final cued recall performance as a function of group, spacing schedule, and retention interval from Logan (2004).

immediate and a delayed retention interval. The retrieval schedule did not modulate the difference between expanded and equal spaced retrieval and so we will collapse across these schedules here. As shown in Figure 6.4, Logan obtained benefits of expanded retrieval over equal interval during the acquisition phase for both the young and the older adults. This acquisition advantage was retained on an immediate final cued recall test, at least in older adults. However, after a 24 hour delay between acquisition and final test, the advantage for items practiced on an expanding schedule compared to an equal interval schedule was lost in both age groups. In fact, memory was significantly worse for expanded items compared to equal interval items in younger adults. Thus, the findings from Logan imply that when an expanded retrieval advantage is found, it may be short-lived, compared to comparable equal interval spacing.

The Logan results are particularly intriguing in light of a recent study by Karpicke and Roediger (2005). These investigators compared massed (0-0-0), equal interval (5-5-5), and expanded (1-5-9) retrieval conditions for paired associates (vocabulary GRE practice items, such as *sobriquet–nickname*) in both an immediate 10 minute delayed, and 48 hour delayed cued recall test. The results indicated that again both spaced schedules produced better performance than the massed schedule at both retention intervals. More importantly, there was evidence of a benefit of the expanded condition over the equal interval condition in the immediate test, but the equal interval condition produced a clear benefit in the delayed recall test. This later pattern was replicated in a second study in which feedback was provided after each testing event, although the immediate test performance was limited by ceiling problems. Hence, the short-term gains of expanded over equal interval retrieval found in both the Logan (2004) and Karpicke and Roediger (2005) studies were either eliminated or turned into long-term losses in a delayed testing condition.

THEORETICAL IMPLICATIONS

The results of the current review lead us to conclude that, as expected, spaced practice produces considerable benefits in learning compared to massed practice; however, the additional benefits of expanded practice over equal interval practice have not been well substantiated in recent research. We find the lack of a benefit of expanded retrieval quite intriguing, because the acquisition phase data (when measured) clearly indicate that participants are at higher levels of retrieval success over a longer retention interval in the expanded condition than in the equal interval condition. For example, at the last retrieval event during the acquisition phase of the Balota et al. (2005) study, subjects correctly retrieved 16% more items in the expanded retrieval condition than in the equal interval condition, even though at this last retrieval event, the expanded retention interval was five items, and the equal interval was three items. Clearly, one would expect such a benefit to either persist or increase during a final recall test. However, there was no benefit in the final cued recall performance of expansion. Moreover, the results from Logan (2004) and Karpicke and Roediger (2005) indicate that one can either eliminate or actually reverse any acquisition benefit of expanded over equal interval retrieval when tested at a 1 or 2 day retention interval.

Why might the benefits of expanded retrieval over equal interval retrieval observed during the acquisition phase be lost in a later cued recall test? One simple possibility is that long-term retention is simply a function of the average amount of spacing. Since this is equated in the equal interval and expanded condition, there is, on average, no effect. A more intriguing possibility is that there are counteracting influences, as a function of retention interval. Specifically, it is indeed beneficial to maintain high levels of retrieval success during acquisition, but there is a potential cost of maintaining these high levels, i.e., a loss of one of the spaced intervals. Consider for example, the 1-3-5 schedule compared to the 3-3-3 schedule. The initial retrieval event during acquisition in the expanded condition occurs after only one intervening item. In some sense, one could argue that the 3-3-3 condition involves *three* functional spaced events during acquisition, whereas, the 1-3-5 condition only involves *two* spaced events during acquisition.

As noted earlier, one theoretical account of the spacing effect is encoding variability theory, which nicely handles the intriguing spacing by retention interval interaction. This framework may also be relevant to the expanded vs equal interval spacing results. Specifically, although expanded retrieval does indeed produce higher performance during the acquisition phase, this benefit may be lost in longer delays, precisely as any benefit of massed spacing is relatively short lived. The notion is that the equal interval condition will on average involve three distinct encoding events, whereas, as noted above, the expanded condition on average will involve two distinct encoding events. Because long-term retention is a reflection of the context at retrieval matching one of the encoding events, the equal interval condition may produce a benefit in long-term retention, since this condition affords an additional unique encoding of context. Interestingly, as noted above, there is already evidence by Logan (2004) and Karpicke and Roediger (2005) that initial benefits of expansion during a short retention interval turn into losses a day or two later. Thus, although there is the benefit of expansion in maintaining high levels of performance at increasing delays during acquisition, the long-term consequence of expansion may produce a decreased amount of contextual variability, because of the relatively immediate presentation of the first test. Of course, we know that maintaining high levels of retrieval success during acquisition is not the only variable that is critical to memory performance, since massed study produces the highest level of performance during acquisition but the lowest level of performance during a long-term retention test. Clearly, further work is needed to better understand the balance between spacing and retention interval in more complex expanded and equal interval schedules.

PRACTICAL IMPLICATIONS

Although the review of recent empirical work has questioned the benefits of expanded retrieval over equal spaced retrieval, there are two reasons that may support the use of expanded retrieval in more applied settings. First, as Camp and colleagues have nicely demonstrated, this procedure is relatively easy to implement in a clinical setting. That is, gradually increasing retrieval intervals, while maintaining success, benefits from feedback driven performance, i.e., providing positive feedback at increasing retention intervals because of retrieval success. Alternatively, a priori picking the best spaced retrieval practice schedule may be relatively difficult to accomplish, especially for someone who is having global cognitive impairments. Second, and more importantly, maintaining high levels of retrieval success during acquisition in the face of increasing retention intervals is likely to be reinforcing for the user. Of course, such reinforcement should ultimately increase the likelihood that individuals will use such a schedule in the future, and so this is a natural way of nurturing the use of spaced practice. Thus, although there may be reasons to question the long-term benefits of expanded over equal interval schedules, there may also be practical reasons to use the expanded retrieval schedule to implement simple spaced acquisition.

FUTURE RESEARCH

Clearly, there is much work to do to better understand the influence of study schedules on long-term retention. Comparing different acquisition schedules is a natural avenue to pursue. Most studies have only used three retrieval attempts, and the extension to a greater number of retrieval attempts would be likely to reflect the sequence of events in more applied settings, such as in the Camp et al. studies. Consider, for example, the possibility of comparing an expanded schedule of 1-2-3-4-5-6-7 with a retrieval schedule of 4-4-4-4-4-4-4. Without feedback provided, we would expect that in this case the expanded schedule may produce a benefit over the equal interval schedule, but this is an open empirical question. Likewise, in addition to exploring different schedules, the influence of feedback and the possibility of restudying nonretrieved information are both aspects of acquisition that typically occur outside the laboratory. With feedback, one might expect the equal interval condition to possibly produce better performance in the above example. Finally, as Logan (2004) and Karpicke and Roediger (2005) have nicely demonstrated, retention interval is critical. In general, what appears to be a benefit of expanded retrieval during acquisition can be quickly lost and even reversed at longer retention intervals. In this light, we are reminded of Bjork's (1999) arguments regarding the importance of desirable difficulties during acquisition, and the counterintuitive observation that variables that produce benefits immediately on tests sometimes produce losses in long-term retention. Although there will clearly be constraints on when expansion will and will not produce benefits over equal interval schedules, the present review makes clear that the power of spacing is paramount in learning and memory.

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