The Spacing Effect

A Case Study in the Failure to Apply the Results of Psychological Research

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ABSTRACT: The spacing effect would appear to have considerable potential for improving classroom learning, yet there is no evidence of its widespread application. I consider nine possible impediments to the implementation of research findings in the classroom in an effort to determine which, if any, apply to the spacing effect. I conclude that the apparent absence of systematic application may be due, in part, to the ahistorical character of research on the spacing effect and certain gaps in our understanding of both the spacing effect and classroom practice. However, because none of these concerns seems especially discouraging, and in view of what we do know about the spacing effect, classroom application is recommended.

The spacing effect—which refers to the finding that for a given amount of study time, spaced presentations yield substantially better learning than do massed presentations—is one of the most remarkable phenomena to emerge from laboratory research on learning. It is remarkable in several respects. First, the spacing effect is one of the most dependable and replicable phenomena in experimental psychology. Second, it is remarkably robust. In many cases, two spaced presentations are about twice as effective as two massed presentations (e.g., Hintzman, 1974; Melton, 1970), and the difference between them increases as the frequency of repetition increases (Underwood, 1970). Moreover, demonstrations of achievement following massed presentations often are only slightly higher than that following a single presentation (e.g., Melton, 1970). Third, the spacing effect is truly ubiquitous in scope. It has been observed in virtually every standard experimental learning paradigm, with all sorts of traditional research material (Dempster, 1987a; Hintzman, 1974; Melton, 1970).

With all of these characteristics in its favor, the spacing effect would seem to have considerable potential for improving classroom learning. However, there is little evidence that this potential has been realized. Neither American classrooms nor American textbooks appear to implement spaced reviews in any systematic way, and by comparison, Soviet mathematics textbooks provide a much more distributed method of presentation than do their American counterparts (Stigler, Fuson, Ham, & Kim, 1986). Nor is there much evidence that the next generation of educators is being better informed. In a recent sampling of practitioner-oriented textbooks suitable for use in teacher education programs, I found either little or no mention of the practical benefits of the spacing effect, and in some cases the spacing effect was confused with other phenomena (e.g., Good & Brophy, 1986; Mayer, 1987; Slavin, 1986; Woolfolk, 1987). One well-known educator, in fact, advised against spaced practice at least in the early stages of learning (Hunter, 1983).

Why is it that research findings that appear to have significant implications, such as the spacing effect, often are not utilized by teachers and curriculum makers? In general, the problem is that there is no well-developed implementation model, nor is there a standard methodology for analyzing the conditions that foster the transfer of knowledge from the laboratory to the classroom (see Hosford, 1984, for a discussion). Obviously, issues regarding the utilization of findings from basic research are complicated, and there are many potential impediments to the implementation of research findings in the classroom. In this article, I explore nine potential impediments, all of which seem reasonable at first glance, in an effort to determine which, if any, apply to the spacing effect.

Impediments to Application

The Phenomenon Has Not Been Known Long Enough

Although the time lag between discovery and application varies greatly, some considerable period of time often intervenes between the publication of research findings and their application. In the case of the spacing effect, however, a considerable period of time already has passed since its initial documentation. The spacing effect was known as early as 1885 when Ebbinghaus published the results of his seminal experimental work on memory. With himself as the subject, Ebbinghaus found that for a single 12-syllable series, 68 immediately successive repetitions had the effect of making possible an errorless recital after seven additional repetitions on the following day. However, the same effect was achieved by only 38 distributed repetitions spread over three days. On the basis of this and other related findings, Ebbinghaus concluded that "with any considerable number of repetitions a suitable distribution of them over a space of time is decidedly more advantageous than the massing of them at a single time" (Ebbinghaus, 1885/1913, p. 89). Jost, also working with non-

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sense syllables, reported similar findings and in 1897 formulated what was to become known as Jost's Law: "If two associations are of equal strength but of different age, a new repetition has a greater value for the older one" (McGeoch, 1943, p. 140).

In 1928, Ruch published a review of dozens of studies of the spacing effect. Although interpretation of the results of these studies (e.g., Dearborn, 1910; Perkins, 1914; Pyle, 1913; Starch, 1912) is complicated by other, potentially confounded variables, the results tend, in general, to confirm the earlier work by Ebbinghaus and by Jost. Thus, published reports of the spacing effect have been in existence since the latter part of the 19th century and the early part of the 20th century.

The Phenomenon Has Not Received Recent Documentation

In the absence of recent documentation, research findings may seem stale or anachronistic, but, as most, if not all, students of the learning literature know, the spacing effect has been well-documented in recent times. Many studies of this phenomenon were published during the 1960s and the 1970s, as reviews by Hintzman (1974), Melton (1970), and Glenberg (1979) attest.

Although much of the research included in these reviews was reminiscent of the work of Ebbinghaus in using easily analyzable simple verbal units, the fruits of this research are considerable from any perspective. For example, the ubiquitous, highly replicable character of the spacing effect fostered the notion that its existence must be telling us something important about memory (e.g., Hintzman, 1974). Also, it clearly demonstrated that the Total Time Law, which states that the amount learned is a direct function of study time regardless of how that time is distributed, was in deep trouble or at least in need of a major overhaul (Melton, 1970; Underwood, 1970).

More recently, the spacing of repetitions has been the subject of studies reported in a variety of journals, including some with an applied perspective (Bahrick & Phelps, 1987; Cuddy & Jacoby, 1982; Dellarosa & Bourne, 1985; Dempster, 1987b; Elmes, Dye, & Herdelin, 1983; Glenberg & Lehmann, 1980; Glover & Corkill, 1987; Toppino & DiGeorge, 1984; Toppino & Gracen, 1985). Thus, documented evidence of the spacing effect has appeared in the literature continually for the past 100 years.

The Phenomenon Cannot Be Linked to Issues of Current Concern to Educators

I agree with Glaser (1982) that research knowledge is most likely to inform educational practice if it can be related explicitly to large-scale educational issues or macro variables. Whereas the relationships between the rather fine-grained analyses of learning and memory conducted by researchers and the practice of education usually are not self-evident to the teacher and must be illuminated by the psychologist, this task should be relatively straightforward in the case of the spacing effect. After all, the spacing effect has immediate and obvious implications for how time in the classroom may be distributed optimally. In the wake of recent critiques and studies of schooling, such as *A Nation at Risk* (National Commission on Excellence in Education, 1983), *Time to Learn* (Denham & Lieberman, 1980), and *Perspectives on Instructional Time* (Fisher & Berliner, 1985), the use of time in the classroom has become a major educational concern.

The Phenomenon Has Not Been Demonstrated Satisfactorily in School-Like Activities

Such demonstrations are arguably the most important bridge between basic research and educational practice. In the case of the spacing effect, however, this bridge seems to have been crossed. Several demonstrations of the spacing effect reviewed by Ruch (1928) were, as he put it, "intended for schoolroom application" (p. 20). One of the most interesting of these effects, from an educational perspective, is that of Pyle (1913), who had a group of third-graders drilled in addition, either twice a day for 5 days (once in the morning and once in the afternoon) or once a day for 10 days. Their improvement in recall of addition facts, which was decidedly in favor of the latter instructional method, provided perhaps the earliest experimental confirmation of William James' (1901) advice to teachers and students that it is better to repeat an association on many different days than again and again on just a few days (p. 129).

Most of the early demonstrations of the spacing effect "intended for schoolroom application" focused on text processing tasks, and in three recent studies text processing again has been the focus. In a study by Kraft and Jenkins (1981), subjects attempted to free-recall the title and one idea unit from each of a series of twice-presented passages, with each repetition separated by lags of up to eight intervening passages. As in much standard verbal learning research, recall was a linear and much improved function of lag. One practical limitation of this study, of course, is that students rarely are asked to recall so little from a series of passages.

In the second of these recent spacing effect studies, Dempster (1986) contrasted lags—defined as the interval between two opportunities to read a passage of text material—of 30 seconds, 5 minutes, 20 minutes, and 48 hours in one experiment, and 5 minutes and 30 minutes in a second experiment. In the first experiment, subjects in the 48-hour condition recalled significantly more idea units than did subjects in either of the two shortest lag conditions. In the second experiment, recall was significantly higher in the 30-minute condition than in the 5-minute condition. In both experiments, the recall advantage associated with the best performing group was about

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the same (between 25% and 30%), even though different text passages were used in the two experiments. Thus, the effect was both robust and replicable. Finally, Glover and Corkill (1987) observed the spacing effect (0 lag versus a 30-minute lag) in subjects' memory for paragraphs they read as well as for brief lectures (125 words) they heard.

In addition to text recall, spacing effects have been demonstrated in programmed instruction, where the objective has been the learning of science and mathematical concepts. In one study, the meanings of a series of programmed scientific terms were learned much more effectively when repetitions were spaced than when they were massed (Reynolds & Glaser, 1964). In another study, arithmetical rules presented by a computer-assisted instruction system and expressed as verbal statements were learned better when reviews occurred one and seven days after original learning than when they occurred one and two days after original learning (Gay, 1973, Experiment 2).

Finally, spacing effects have been found in vocabulary learning. In a study by Dempster (1987b), 38 uncommon English words and their definitions were presented three times, either with each repetition of any given word separated by every other word (i.e., each repetition of a word was separated by 37 other words or 4 minutes, 19 seconds) or with each repetition of a word massed in succession. In addition, the words were presented either with or without sentence contexts. The results were quite clear. In three experiments in which spaced versus massed presentations were evaluated in this manner, spaced presentations yielded substantially higher levels of vocabulary learning than did massed presentations. In some cases, in fact, the number of word meanings recalled was over 50% greater under spaced conditions than under massed conditions.

In Dempster's (1987b) study the retention interval averaged less than an hour—short, from a practical perspective. Thus, the question might be asked, "Would spacing effects emerge in the retention of vocabulary words tested at much longer intervals?" Fortunately, there are data relevant to this question. Bahrick and Phelps (1987) tested 35 individuals who had learned and relearned 50 English–Spanish word pairs for recall and recognition after an interval of eight years. One variable of interest was the interval between successive relearning sessions—either 30 days, 1 day, or 0. The data show that the intersession interval had a very large effect on recall, with the recall probability associated with the 30-day interval about 2.5 times the probability associated with the zero interval. In turn, the 1-day interval was associated with much better retention than the zero interval. For both comparisons, the effect on recognition, exclusive of recall, was much less pronounced. Moreover, their data clearly indicate that even five or more presentations are unlikely to facilitate long-term retention if the interval between successive presentations is one day or less. With respect to the educational implications of their study, the authors concluded that long-term retention would almost certainly be enhanced if foreign language courses

> make certain that students independently retrieve target information at intervals that are as long as 1 month, over a period of several years, instead of the more typical intervals of 1 to 2 days over periods of from 10 to 15 weeks. (p. 349)

There Are Serious Discontinuities in the Literature on the Spacing Effect

Another possible reason for the failure to apply the results of research on the spacing effect is that there are serious discontinuities in the literature on the spacing effect, such that most recent studies seem uninformed by the research of earlier ones. Although the spacing effect has a lengthy published history, there are discontinuities of this sort. For example, much of the important work from an applied perspective done in the early 1900s is not cited by studies published later. More generally, most recent studies tend to give the impression that, with the exception of the work of Ebbinghaus and Jost, all we know about the spacing effect dates only as far back as the 1960s. I cannot help but wonder how widespread a problem this is in the learning literature, and what sorts of consequences it has for the evolution of the science of learning and its application. Why is it that we occasionally—and perhaps frequently—give up on, or simply lose interest in, a phenomenon before we have definitive answers to basic questions and, then much later, return to the phenomenon as though we had just recently discovered it?

Upon reflection, this ahistorical character of research on the spacing effect would seem to have at least two unfortunate consequences, either of which could impede application. From a scientific perspective, such research is less likely to be as cumulative—where cumulative refers to empirical laws and theoretical structures building on one another so that later developments extend and unify earlier work (Hedges, 1987)—as would be more historical research. From a practical perspective, it will seem as if the spacing effect has not weathered continuous scrutiny over a lengthy period of time.

There are, of course, many possible reasons for discontinuities in the literature of a phenomenon. In the case of the spacing effect, however, three appear to stand out. First, for the most part, studies conducted from an applied perspective and those conducted from a basic research perspective constitute two distinct streams of research. For example, although widely cited reviews by Crowder (1976), Glenberg (1979), Hintzman (1974), and Melton (1970) report dozens of studies of the spacing effect using simple list learning materials, none of the many studies using more complex material with clearer classroom analogues are reported. This is the case despite the fact that some still viable accounts of the spacing effect (see for example, Cuddy & Jacoby, 1982, and Hintzman, 1974) were anticipated and supported in earlier studies done from a more applied perspective (see, for example, Ausubel, 1966).

Second, different terminology has been used to refer to similar, though distinguishable, phenomena—a situation that seems to have created some confusion. For example, a number of writers have distinguished between

the "spacing effect" and both the "Melton" or "lag effect" and the "massed-versus-distributed practice" effect. Lag effects have been said to occur when performance improves as a function of the number of intervening items between successive presentations, whereas massed versus distributed practice effects often have been restricted to comparisons between spacings of zero (massed practice) and all spacings greater than zero (distributed practice). The use of this terminology, however, is somewhat uneven. Some researchers have used these terms interchangeably or have included other variables (e.g., length of period of study, retention interval) in their characterizations of the spacing effect (e.g., Ruch, 1928). Also, much of the massed versus distributed practice research, which has focused on perceptual motor skills tasks and lists of nonsense syllables, has yielded weak effects of spacing. According to Underwood (1961), who reviewed 10 years of distributed practice research, "Even under the most favorable conditions for facilitation by distributed practice, one could not recommend its use in an applied setting" (p. 230). Apparently following his lead, some older educational psychology texts advised that there were no clear practical implications to be drawn from distributed practice research (e.g., DeCecco, 1968; Mathis, Cotton, & Sechrest, 1970).

Third, the spacing effect is just one of a family of similar, though less thoroughly investigated, phenomena that are occasionally confused in the literature. One such phenomenon is the so-called "test-spacing" effect, which refers to the fact that spaced tests, particularly tests with intertest intervals of an expanding nature, result in greater retention than do massed testings (Landauer & Bjork, 1978; Rea & Modigliani, 1985; Spitzer, 1939). Another related phenomenon has been observed when once-presented written exercises or materials in a short course in statistics either are spread over the course of several sessions or are presented in a single session—a situation that is analogous to "cramming" for a test. In this case, students learn more when the material is distributed over several sessions (Bloom & Shuell, 1981; Smith & Rothkopf, 1984). Finally, Reder and Anderson (1982) found that, with total study time equated, repeated, well-spaced presentations of a text were more effective than was a single, longer presentation. Similarly, Edwards (1917) compared groups who studied various school materials, including history and geography, six and one-half minutes continuously or with the same amount of time divided into a study period of four minutes followed some days later by a review of two and one-half minutes. Lag and test intervals, difficulty of the material, and age of the subjects were so variable that it is difficult to interpret the results; however, without exception they favor the repeated, spaced-study groups.

To complicate matters further, research on allied phenomena also has an ahistorical character. For example, Rea and Modigliani (1985) failed to cite Spitzer (1939), even though Spitzer's work showed that if the interval between original learning and the first test in a series is too lengthy, test spacing effects are likely to be vitiated. Also, Reder and Anderson (1982) failed to cite Edwards (1917), and neither Bloom and Shuell (1981) nor Smith and Rothkopf (1984) seemed aware of the work of Ash (1950), who found only minor differences in retention between groups treated like theirs.

Too Many Studies Using School-Like Activities Have Failed to Show the Spacing Effect

Although the spacing effect is one of the most dependable phenomena in the learning of standard verbal learning lists, there have been more than a half-dozen documented failures to observe the spacing effect in tasks with classroom analogues. The results of these studies make it quite clear that the spacing effect is subject to certain not fully understood boundary conditions. Specifically, five sorts of boundary conditions are suggested. First, it has been found that under certain circumstances spaced presentations are no better than (Austin, 1921) and sometimes even worse than (Gordon, 1925) massed presentations in tests of immediate recall. For example, Austin found that massed readings (e.g., five times in one day) of text material proved as effective as spaced readings (e.g., daily for five days) in tests of immediate recall, whereas the spaced readings were much more effective in delayed tests, particularly if they came two to four weeks after learning. Second, it has been found that massed practice often is more efficient for certain simple, isolated skills, such as writing the products of number pairs as rapidly as possible (Thorndike, 1916). Third, evidence from traditional learning research suggests that the spacing effect may not apply to preschool age children, although it does emerge in a robust manner by age seven (Toppino & DiGeorge, 1984). Fourth, two studies have shown that the spacing effect can be eliminated if paraphrased rather than verbatim versions of the repeated materials are used (Dellarosa & Bourne, 1985; Glover & Corkill, 1987).

Finally, the results of a number of studies seem to suggest that beyond a certain lag interval, further increases in lag are not always associated with further increases in learning. For example, English, Wellborn, and Killian (1934) found that four readings of a text at three-hour intervals were associated with better learning than four consecutive unspaced readings; however, readings at three-hour intervals were no better than readings at either one- or three-day intervals. Similarly, Lyon (1914), Peterson, Ellis, Toohill, and Kloess (1935), and Sones and Stroud (1940) reported essentially no differences in retention between groups with rereading reviews spaced 1 and 7, 1 and 9, and 1 and 17 days after original learning. These findings were later corroborated by Ausubel (1966) and by Gay (1973).

Of these boundary conditions, the last two seem the most serious and most puzzling in view of the fact that the spacing effect has been found in paraphrased material (Rothkopf & Coke, 1966) and in view of long-lag effects obtained with traditional verbal learning material (Glenberg & Lehmann, 1980) and in vocabulary learning (Bahrick & Phelps, 1987). With respect to the latter, it may be that under certain lengthy lag conditions, the usual

benefits of spaced repetitions do not obtain because the results of initial processing efforts have been forgotten (see Lyon, 1914, and Sones & Stroud, 1940, for earlier discussions of this hypothesis).

In any case, the spacing effect, especially in text processing, cannot be taken for granted. Although there have been relatively few documented failures to obtain the spacing effect, they certainly could have raised enough doubt about the dependability of the effect to discourage application.

The Phenomenon Has Not Been Demonstrated Satisfactorily in the Classroom

With very few exceptions (Dempster, 1986; Glover & Corkill, 1987; Pyle, 1913), even research using educationally relevant materials has been conducted in the laboratory. Moreover, the rather simple learning situations created in classroom studies of the spacing effect fail to approach the complexities facing curriculum developers and teachers. Curriculum developers and teachers have to concern themselves with the design of instruction conveyed in classes that often meet every day for a school term, under conditions in which much if not most of the content is organized in ways that imply systematic movement through learning hierarchies, curricular sequences, and so forth. Thus, it may be argued that it is not at all clear what specific implications demonstrations of the spacing effect in simple, isolated classroom situations have for curriculum designers and teachers faced with decisions about how much material to include in a course, how to sequence it, and how to optimally phase in new material and phase out old material.

Arguably, the relative lack of applied research in educational settings is, from an educational perspective, the most serious shortcoming of research on the spacing effect. There is no substitute for applied research, and the absence of at least several convincing demonstrations of the spacing effect in ongoing classroom situations under naturalistic conditions may well have been an impediment to application.

Too Little Is Known About Actual Classroom Practice to Justify Widespread Application of the Spacing Effect

To the best of my knowledge, nothing has been published concerning the proportion of time in the classroom teachers usually devote to review (i.e., any re-presentation or practice activity pertaining to a particular educational objective), and to what extent reviews are massed as opposed to spaced. Moreover, the general nature of classroom review activities apparently has not been characterized. For example, to what extent are reviews verbatim or paraphrased? Because several studies have failed to show spacing effects in text processing when paraphrased rather than verbatim versions of the repeated materials were used (Dellarosa & Bourne, 1985; Glover & Corkill, 1987), the answer to this question is of practical importance.

In short, due to significant gaps in our understanding of classroom practice, the application potential of the spacing effect cannot be estimated with any precision. Accordingly, it may be assumed wrongly that efforts to implement the spacing effect would result in little benefit.

The Phenomenon Is Not Sufficiently Understood

Phenomena that are not well understood are likely to invite skepticism among practitioners—particularly those who are familiar with any one of several instances in which the application of a poorly understood finding has had extremely unfavorable consequences (e.g., thalidomide). For example, educators, who often give the impression of having a low regard for fact memorization, might feel that the spacing effect would interfere with the operation of "more laudable, higher mental processes," because it is exactly such memorization to which spacing applies most clearly.

In fact, the theoretical picture surrounding the spacing effect is confused and uncertain, despite numerous attempts at clarification (e.g., Dellarosa & Bourne, 1985; Hintzman, 1974). A recent case in point is a published failure to replicate findings implicating a component-levels interpretation of the spacing effect in standard verbal learning tasks (Toppino & Gracen, 1985). The component-levels hypothesis is one of a group of hypotheses that attribute the spacing effect to increasing independence of encoding events with increasing intervals between repetitions.

With more naturalistic material, theoretical work has been slow to develop, and little has been done in the way of theoretically derived hypothesis testing. However, it is worth noting that Ausubel (1966), in a rarely cited study, offered the following explanation for the advantages of spaced review in meaningful learning:

> In the first place, after a longer retention interval, when more material is forgotten, the learner is more highly motivated to profit from the opportunity for review. He is less likely to regard this opportunity as unnecessary and superfluous and is hence more disposed to take good advantage of it in terms of effort, attention, and concentration. (p. 197)

Apparently, Ausubel (1966) was on the right track when he stressed the role of attention and effort in the spacing effect. Recent evidence indicates that some sort of attentional account of the spacing effect is at least as viable as any other account and well worth pursuing (Dellarosa & Bourne, 1985; Dempster, 1986; Elmes, Dye, & Herdelin, 1983; Magliero, 1983). For example, Dempster (1986) had subjects respond to a questionnaire administered following a recall test of a twice-read passage, with the two readings spaced either 30 minutes apart or 5 minutes apart. The questionnaire consisted of 10 items, each followed by a 10-point rating scale, which was designed to elicit self-reports of various cognitive and affective states and processes during reading and testing. Included were questions concerning levels of attention, interest, anxiety, rehearsal, and changes of interpretation from one reading to the next. The results were quite clear. Significant group differences emerged on only two of the

items, specifically one asking the subjects to indicate how "interested" they were during the second reading—an affective state—and one asking them to indicate how much "attention" they paid during the second reading—a cognitive process. In both cases, the average ratings of students in the spaced 30-minute condition (those who also did best on the recall test) were higher than those in the massed 5-minute condition. Moreover, a correlational analysis, applied to the scores of both groups combined, revealed a significant correlation between recall and only one of the questionnaire items—that is, the attention paid during the second reading. Those who reported having paid more attention tended to have learned more from the text.

However, why should spaced presentations be more interesting (see also Elmes et al., 1983) and receive more attention than massed presentations? Here again, Ausubel (1966) seemed to have anticipated more recent developments when he suggested that it has to do with the relative accessibility of previous encodings (in his words, the activity of "trying and failing to remember material," p. 197). If a student receives massed presentations, the information learned during earlier presentations should be relatively easy to retrieve from memory during subsequent presentations. Thus, subsequent presentations should be relatively redundant or familiar and thus relatively boring. By contrast, if a student receives two well-spaced presentations, the information learned during initial presentations should be relatively inaccessible during subsequent presentations, which should heighten interest level and the amount or quality of attention subsequent presentations receive. According to this account, then, massed presentations are relatively ineffective because they may not actually result in much repetitive processing (see also Cuddy & Jacoby, 1982; Dellarosa & Bourne, 1985; Greeno, 1970; Jacoby, 1978; Underwood, 1970).

One implication of this account is that anything that increases the likelihood that a repetition will receive full processing, such as events that make it difficult to retrieve the results of prior encodings, should improve learning. Thus, this account helps to explain failures to obtain the spacing effect with paraphrased repetitions, that is, repetitions having a changed surface structure (Dellarosa & Bourne, 1985; Glover & Corkill, 1987), and under lengthy lag conditions (Ausubel, 1966; English et al., 1934; Gay, 1973; Lyon, 1914; Peterson et al., 1935; Sones & Stroud, 1940).

In sum, although recent studies have yielded some promising clues to the mechanisms underlying the spacing effect, our theoretical ignorance may have been and may continue to be an impediment to application or might contribute to inappropriate applications.

Summary and Conclusions

The spacing effect would seem to have considerable potential for improving classroom learning, yet there is no evidence of widespread application. In this article, I have considered nine possible impediments to the implementation of research findings in the classroom. Of the nine, five appear to apply to the spacing effect. These include the ahistorical character of research on the spacing effect, some failures to obtain the effect with school-like activities, a paucity of impressive classroom demonstrations of the phenomenon, limited knowledge of classroom practice, and an incomplete understanding of the psychological bases of the spacing effect. By contrast, the fact that the phenomenon (a) has been known for a long period of time, (b) has received recent documentation, (c) can be linked to current educational issues, and (d) has been shown to extrapolate to school-like activities suggests that the first four dimensions of analysis considered do not apply.

The following question now arises: To what extent *should* the list of plausible impediments to the application of the spacing effect in the classroom discourage application? After addressing each of these concerns, I conclude that we do know enough about the effect of spacing to make a very strong argument for application without any additional knowledge about the spacing effect or classroom practice.

Consider first the ahistorical and somewhat confusing character of research on the spacing effect. Given the long history of research on the spacing effect and the considerable recent documentation, the discontinuities in the literature on the spacing effect do not seem terribly important. In fact, the spacing effect has weathered continuous scrutiny over a lengthy period of time. Of course, the fact that the spacing effect is just one of a family of similar phenomena would seem only to strengthen and broaden the appeal of "spacing" in the classroom.

A second plausible reason for the absence of widespread application of the spacing effect is that there have been some failures to obtain the effect in school-like tasks. The spacing effect, in fact, does appear to be subject to certain, not fully understood boundary conditions. However, it would be unrealistic to expect the spacing effect to apply in every situation, and the relatively few failures to obtain the spacing effect seem trivial in light of its many demonstrations. For this reason and in the absence of any serious contraindications to the application of the spacing effect, the fact that the spacing effect does not always work hardly seems to justify resistance to its application.

Arguably, the most serious of the plausible impediments to the application of the spacing effect is the paucity of impressive classroom demonstrations of the phenomenon. Clearly, programmatic research on the effects of spacing in education settings is long overdue, as the results of such efforts would likely aid in its application. The most useful studies of this sort would be those involving curriculum design and classroom teaching that help shed light on the implications of the spacing effect for specific applied issues, such as homework, frequency of testing and feedback, learning hierarchies, mastery learning, and questioning strategies.

Although additional classroom research is desirable and even necessary in order to make the most effective

use of spacing, I do not think we have to withhold all judgment on the applicability of the spacing effect at this point. For example, we know that children study vocabulary in a variety of subjects and that the spacing effect facilitates vocabulary learning. Likewise, children are exposed to numerous scientific terms and arithmetical rules while in school—each of which is a domain in which spacing has been found to be effective. When coupled with what we already know about the effects of spacing in text processing, there is ample reason to believe that the spacing effect will improve classroom learning in a wide variety of subject areas.

Although we do not know much about current classroom applications of the spacing effect, there are many reasons to believe that the spacing effect is underutilized in the classroom in terms of its potential for improving learning. In addition to the reasons indicated earlier, there is the fact that the spacing effect is somewhat counterintuitive. The spacing effect typically refers to a phenomenon that occurs under conditions in which the retention interval between the last presentation and the test is held constant. Thus, one might reason that because the retention interval between the first presentation and the test is shorter under massed conditions, this condition should result in superior performance. Even experienced educators, when judging the instructional effectiveness of text passages, tend to rate prose in which the repetition of a given unit of information is massed as better than those in which it is spaced (Rothkopf, 1963).

In short, the spacing effect is neither intuitively obvious, nor well known among educators. Accordingly, it is reasonable to assume that those who become teachers, administrators, curriculum developers, or writers of reading series are ignorant of the spacing effect, just as many psychologists are not clear about the totality of educational situations that call for its application. Thus, our ignorance of actual classroom practice should not be interpreted to mean that widespread implementation of the spacing effect has little or no potential for improving classroom learning.

The final plausible impediment to the application of the spacing effect is that it is not well understood theoretically. However, in view of the absence of evidence linking the spacing effect to some undesirable psychological process or outcome, this impediment is extremely hard to justify. For example, there is no evidence that the spacing effect impairs the ability to conceptualize or to think critically. Even if it is found that the psychological basis of the spacing effect applies only or largely to memorization tasks, memory is of central importance to any complex intellectual activity.

Nevertheless, a fuller understanding of the spacing effect could eventually aid in its application and might help to avoid some inappropriate applications. Hence, I believe the search for the underlying cause(s) of the spacing effect should proceed. As part of this effort, some attempt should be made to determine if spaced presentations tend simply to increase the amount of information learned (the quantitative hypothesis), or if they tend to increase the learning of only certain kinds of information (the qualitative hypothesis). So far, these hypotheses have been examined only in relation to the more general issue of how repetitions improve learning, with mixed results (Annis & Annis, 1987; Bromage & Mayer, 1986; Mayer, 1983). They have not been examined in the context of comparisons of massed and spaced repetitions, although such comparisons might be fruitful from both a theoretical and a practical perspective.

Recently, I was told that the spacing effect has been "studied to death," and on another occasion that "we know all that we need to know about the spacing effect." Clearly, the spacing effect is one of the most studied phenomena in the 100-year history of learning research, and we *do* know a lot about it—enough to recommend application. However, it would be a mistake to do what these comments imply—which is simply to stop investigating the phenomenon. Although it may take some clever research to avoid diminishing returns, continued experimental study of the spacing effect can yield valuable information regarding its parameters and cause(s). Then too, applied research and widespread application should produce the data base needed to evaluate the particular conditions under which the spacing effect works best.

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