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The Effect of Spacing Repetitions on the Recognition Memory of Young Children and Adults

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In Experiment 1, preschoolers, first graders, and third graders were presented a list of pictures that included twice-presented items separated by varying numbers of intervening items. Performance on a subsequent recognition test improved as the spacing between repetitions increased, but the effect of spacing did not interact reliably with grade level. In Experiment 2a, we replicated the spaced-repetition effect in young children and found a similar effect in college students. In Experiment 2b, we varied the conditions under which lists were presented to college students and again found a spacing function that was comparable to that of very young children. The results are consistent with the hypothesis that spaced-repetition effects in recognition are produced by fundamental memory mechanisms that are operational at a very early age and which undergo little change with development.

One of the most fundamental variables affecting learning and memory is repetition. Performance generally improves as a result of exposure to repeated information. However, the extent of the improvement depends upon the spacing between repetitions. When repetitions are massed (i.e., presented in immediate succession), their beneficial effect is often minimal. The benefit of repetition is much more substantial when repetitions are spaced (i.e., separated by other events or items of information).

The effect of spacing repetitions has been a major concern of theorists and researchers interested in understanding the mechanisms through which repetition influences learning and memory. However, the vast majority of the research has involved adult subjects and has been nondevelopmental in orientation. Spaced-repetition effects in children have been investigated

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in only a few studies, and virtually all of these studies have involved free recall (e.g., Rea & Modigliani, 1987; Toppino & DeMesquita, 1984; Wilson, 1976). We essentially have no information about the effect of spacing repetitions on children's performance in other memory tasks such as recognition. The present research was intended to partially remedy this situation by investigating spaced-repetition effects in children's recognition performance. Assessing these effects as a function of development should both expand our understanding of memory processes in children and constrain the range of acceptable explanations for spaced-repetition effects in general.

In free recall, it was initially thought that the performance of preschool children was uninfluenced by the spacing between repetitions (Toppino & DiGeorge, 1984). However, more recent evidence has indicated that preschoolers *do* exhibit a spaced-repetition effect in free recall (Rea & Modigliani, 1987; Toppino, in press). Studies assessing the development of spaced-repetition effects from the preschool years into the mid-elementary-school years (Rea & Modigliani, 1987) and across the elementary school years (Toppino & DeMesquita, 1984) have found no evidence of developmental differences within the age ranges tested. However, it remains possible that some developmental differences might emerge if studies used older subjects and longer spacings than those used in the studies conducted so far (Toppino & DeMesquita, 1984; Wilson, 1976).

Preschool children often have been characterized as being nonstrategic learners and memorizers in tasks such as those used to study spaced-repetitions (e.g., Appel, Cooper, McCarrell, Sims-Knight, Yussen, & Flavell, 1972; Myers & Perlmutter, 1978; Ornstein, Baker-Ward, Naus, 1988; Paris, 1978), and, at the very least, they are unsophisticated in terms of strategy use (Wellman, 1988). Thus, the fact that preschool children manifest a spaced-repetition effect in free recall has been interpreted to support the hypothesis that fundamental, automatically activated, memory processes are sufficient to produce the effect. The findings that spaced-repetition effects in free recall are relatively invariant from the preschool years through the elementary-school years is also consistent with this hypothesis.

Unfortunately, there is no certain theoretical or empirical basis on which to generalize the above results and conclusions from free recall to recognition. With respect to theory, there are several explanations of spaced-repetition effects which depend on automatic, or potentially automatic, processes that might be expected to generalize to recognition (e.g., Hintzman, 1974; Jacoby, 1978). From other theoretical perspectives, however, one might not expect similar results in free recall and in recognition (e.g., Greene, 1989).

In one relatively recent theory, Jacoby (1978; Cuddy & Jacoby, 1982) proposed, and provided support for, an hypothesis that would lead to similar expectations for free recall and recognition. Jacoby likened the encoding process to solving a problem and assumed that the effect of repetition is inversely related to how readily processing the second presentation of a repeated item triggers retrieval of the first presentation. If the first presentation is retrieved too readily, learners need not fully process the second presentation. That is, they can simply retrieve the previous "solution" without reengaging in the problem-solving (encoding) activity. This situation, which is assumed to produce relatively poor memory on a later test, is likely to occur when repetitions are massed. As the spacing between repetitions increases, retrieval of the first presentation will become more difficult, and learners will be more likely to re-solve the problem (i.e., engage in full encoding processes), thereby producing better memory for the repeated information. Although the problem-solving metaphor seems to carry an implication of voluntary processes, apparently no such implication was intended. Jacoby's theory is very similar to explanations of spaced-repetition effects based on levels-of-processing theory (e.g., Rose & Rowe, 1976; Rose, 1980, 1984), and, like them, Jacoby's theory can easily be conceptualized in terms of automatically activated processes. In any event, if this theory is assumed to account for a spaced-repetition effect in children's free recall, we would expect that they would also produce a spaced-repetition effect in recognition.

Greene (1989) recently proposed a theory in which he hypothesizes that different processes underlie spaced-repetition effects in free recall and in "cued memory tasks" such as recognition. (Also see Glenberg, 1979.) Greene proposed that contextual information is stored automatically and that, as the spacing between repetitions increases, different contextual information becomes more likely to be stored as a result of each presentation. Thus, more varied contextual information is assumed to be encoded automatically for spaced repetitions than for massed repetitions. This provides a retrieval advantage for spaced repetitions in free recall which is assumed to depend heavily on contextual cues. However, the encoding of varied contextual information does not facilitate recognition which does not depend heavily on contextual cues. Instead, a spaced-repetition effect in recognition is assumed to be a product of voluntary, strategic processing. Greene assumes that learners voluntarily control the degree to which they study or rehearse each to-be-remembered item. When the second presentation of a massed repetition is presented, it is assumed that learners mistakenly judge the item to be already well learned. They, therefore, are assumed to devote less study (rehearsal) time and effort to the item which results in relatively poor memory on a later test. As the spacing between repetitions increases, it is assumed that the second occurrence of a repeated item receives more processing which results in better performance on a later test.

Greene's theory clearly allows for the possibility that spaced-repetition effects in free recall might not generalize to recognition, and there is at least some evidence with adult subjects that spaced-repetition effects in the two tasks can be different (e.g., Glenberg & Smith, 1981; Greene, 1989). With respect to developmental effects, Greene's theory is consistent with spaced-repetition findings in children's free recall but would seem to predict that very young children might not exhibit a spaced-repetition effect in recognition. In the kinds of list-learning tasks employed in spaced-repetition research, there is little evidence that preschool children use effective rehearsal strategies. Even when the precursors of strategies have been found in preschoolers, they have proved to be mnemonically ineffective (Baker-Ward, Ornstein, & Holden, 1984; Ornstein, Baker-Ward, & Naus, 1988). Furthermore, it seems unlikely that very young children will systematically study items judged to be unlearned more than items judged to be learned. For example, in the context of multi-trial tasks, there is evidence that even 6- and 7-year-olds fail to differentially allocate study time as a function of whether or not an item was recalled on an immediately preceding test (Bisanz, Vesonder, & Voss, 1978; Masur, McIntyre, & Flavell, 1973). Thus, although some theoretical perspectives would lead us to expect that spaced-repetition effects obtained with children in free recall would generalize to recognition (e.g., Jacoby, 1978), there is at least some theoretical reason to question this expectation.

Empirical considerations are equally ambiguous. Although Cornell (1980) reported a spacing effect in 5- and 6-month-old infants using a differential viewing paradigm, it is not clear that these findings would generalize to other kinds of tasks. The differential viewing procedure used to study recognition in infants is an "indirect" memory measure (e.g., Johnson & Hasher, 1987; Richardson-Klavehn & Bjork, 1988), whereas "direct" memory measures involving conscious episodic memory have been used to study spaced-repetition effects in the recognition of older children and adults. There is no guarantee that the infant procedures tap into memory processes that are comparable to those operating in studies of recognition memory in older subjects (Werner & Perlmutter, 1979).

The present research was designed to examine spaced-repetition effects in recognition memory from a developmental perspective. Our first goal was to determine whether preschool children exhibit an effect of spacing repetitions in their recognition performance. If relatively sophisticated strategic processing is necessary to produce a spaced-repetition effect in recognition as proposed by some theorists (e.g., Greene, 1989), spacing repetitions may have little effect on preschoolers' recognition. However, if preschoolers do manifest a spaced-repetition effect in recognition, the finding would suggest that relatively fundamental memory processes may be sufficient to produce the effect. Our second goal was to provide preliminary information about how spaced-repetition effects in recognition may change, or not change, in the course of development.

In Experiment 1, we examined the effect of spacing repetitions on the recognition performance of preschool, first-grade, and third-grade children. In Experiment 2, we compared spaced-repetition effects for preschoolers and college students.

EXPERIMENT 1

Method

Subjects and design. The subjects were predominantly middle and upper-middle class children who attended nursery or elementary schools in suburban Philadelphia. The subjects included 20 (10 male and 10 female) preschool children (mean age = 57 months, age range 50–63 months), 20 (8 male and 12 female) first grade children (mean age = 82 months, age range 78–86 months), and 20 (10 male and 10 female) third grade children (mean age = 108 months, age range 101–118 months). These three grade levels comprised the between-subjects variable in a 3 (Grade Level) × 5 (Repetition/Spacing Condition) mixed factorial experiment. The repetition/spacing condition which was varied within-subjects was composed of the following levels: once-presented items, and twice-presented items that were repeated after lags of 0, 2, 4, or 8 intervening items.

Materials. Stimuli were colored pictures of common objects taken from a picture book for children. The pictures were selected so that they would be familiar to our youngest subjects but would bear no strong or obvious semantic relationships to one another. The pictures were individually photographed. Then, the photos were covered with transparent contact paper and arranged in stacks (i.e., lists) awaiting presentation.

Ten 68-presentation study lists were developed. Five lists used each of two different list structures which were constructed independently with the same set of general constraints as follows. The first four and the last four serial positions were reserved for once-presented items that served as primacy and recency buffers, respectively. The middle portion of the list structures contained six once-presented filler items and 30 experimental items which consisted of six items representing each of the five experimental conditions: once-presented items and twice-presented items repeated at lags of 0, 2, 4, and 8. Half of the items from each experimental condition occurred in each half of the list. As a further control on serial position, the mean serial positions of the second occurrences of items in each twice-presented condition were approximately equated with one another and with the mean serial position of the experimental once-presented items. The first list employing each list structure was constructed by randomly assigning pictures to experimental conditions and then to their respective serial positions within the list structures. A Latin-square principle was used to generate the remaining four lists involving each list structure so that, across each set of five lists, the same set of items served equally often in each experimental condition. Finally, within each age group, two randomly selected children received each of the ten lists.

Recognition test lists were constructed that contained the 30 experimental pictures that had been presented in the study lists and 30 new pictures (foils) that had not been presented previously. A total of five different test lists were generated in which old and new items were assigned randomly to serial positions according to a Gellermann (1933) series. Within each age group, each test list was used by four children who were selected randomly with the restrictions that they each had received a different list in the study or acquisition phase and that the study list had involved one list structure for two of the children and the other list structure for the remaining two children.

Procedure. The procedures were adapted from those that Brown and Scott (1971) previously had used successfully in recognition studies with young children. Each child participated individually in two separate sessions at his or her own school. During the first session, both the study and test procedures were explained and children were given a 10 item practice list to study followed by a yes/no recognition test. Then, children were told that they would be shown a much longer list and that they should try to remember the pictures for a recognition test that would not be given until the second session. The study list was presented manually at a rate of one picture every 5 s, and children attempted to name each picture as it was presented. Following list presentation, children were returned to their classroom.

The second session occurred after a retention interval of 2 weeks. This retention interval was chosen in an attempt to avoid serious problems with ceiling effects (Glenberg & Smith, 1981). Following instructions designed to remind children of the previous session and the relevant procedures, the recognition test list was presented. Items on the test list were presented successively at each subject's own pace. Subjects responded either "Yes," to indicate an old item or "No," to indicate a new item. For the first two or three pictures, the experimenter asked, "Did I show you this picture before or not?" as the picture was presented. This was intended to facilitate children's understanding of the task. Once it was clear that a child understood, the experimenter stopped asking the question. No feedback was provided during administration of the recognition test.

Results and Discussion

For each subject, we computed the proportion of old stimuli correctly identified as old (hit rate) and the proportion of new stimuli incorrectly identified as old (false alarm rate). The mean hit rates and false alarm rates are presented in Table 1.

TABLE 1
MEAN HIT RATE AS A FUNCTION OF GRADE LEVEL AND REPETITION/SPACING CONDITION AND MEAN FALSE ALARM RATE (FAR) IN EXPERIMENT 1

	Repetition/spacing condition					
Grade level	Once-presented	Lag 0	Lag 2	Lag 4	Lag 8	FAR
Preschool	.48	.72	.79	.84	.87	.12
First	.60	.80	.81	.88	.86	.11
Third	.64	.87	.88	.90	.89	.09
Total	.58	.80	.83	.87	.87	.11

A 3 (Grade Level) × 5 (Repetition/Spacing) mixed analysis of variance with repeated measures on the second factor was conducted on the hit-rate data, and an identical analysis was conducted on d' scores. Because both sets of analyses produced the same results, only the analysis of the hit-rate data will be presented here. A significance level of .05 was used for all analyses.

The analysis of variance indicated that significant main effects were produced by both the grade-level variable, $F(2, 57) = 3.68$, and the repetition/spacing variable, $F(4, 228) = 36.37$. However, the interaction of these factors did not approach significance, $F(8, 228) < 1.00$. Tukey post hoc paired comparisons indicated that third graders significantly outperformed preschoolers and that first graders did not reliably differ from either of the other grade conditions. Aside from the obvious fact that twice-presented items were recognized better than once-presented items, paired comparisons of the repetition/spacing variable indicated that recognition of repeated items improved from lag 0 to lag 4 but showed no further improvement with greater spacing.

Our findings indicate that children from the ages of 4 to approximately 9 years old manifest a spaced-repetition effect in recognition. Most importantly, preschoolers' recognition showed a relatively large monotonic increase as a function of spacing, leaving little doubt that these children exhibit an effect of spacing repetitions. To the extent that sophisticated strategic processing can augment more basic processes in producing a spaced-repetition effect, the effect might be expected to become greater with increasing age. However, our data were unclear with respect to this issue. There was a nonsignificant trend for the size of the spaced-repetition effect to become *smaller* with increasing age. Unfortunately, this trend appeared to be attributable to a ceiling effect that could have overridden and obscured an effect in the opposite direction. The ceiling effect may also account for the fact that the spacing function did not increase beyond lag 4.

EXPERIMENT 2A

Experiment 2a employed preschool children and college students whose recognition performance was assessed as a function of lags ranging from 0 to 12 intervening items. In order to avoid ceiling effects with the college students, it was necessary to present study stimuli to them at a faster rate than to the younger children. Experiment 2b was a partial replication and extension involving only college students. It was designed to clarify the results of Experiment 2a.

Method

Subjects and design. The subjects were 32 (20 male and 12 female) preschool children (mean age = 51 months, age range = 41–60 months) and 80 (28 male and 52 female) college students from predominantly middle to upper-middle class families. The preschoolers were recruited from the same population as were the preschool children in Experiment 1, and college students participated in partial fulfillment of a course requirement. We ran a large number of college students because we feared (needlessly, as it turned out) that the fast presentation rate we used with those subjects would produce highly variable data.

Our subjects participated in a 2 (Grade Level) × 4 (Spacing) mixed factorial experiment. The spacing variable which was manipulated within-subjects consisted of twice-presented items repeated after lags of 0, 4, 8, or 12 intervening items.

Because we expected recognition performance in this experiment to be somewhat poorer than in the previous experiment, an a priori decision was made to eliminate and replace any subject who seemed unable to discriminate old from new items in the recognition test. The criterion decided upon was that the subject's hit rate should exceed his or her false alarm rate by at least .20. As a result of this decision, three college students were eliminated and replaced by subsequent subjects.

Materials. List structures and study lists were constructed according to the same specifications as those employed in Experiment 1. However, study lists were composed of 50 pictures rather than only 44. List structures contained 74 slots or positions. These slots were reserved for 10 primacy and 4 recency buffer items, 12 once-presented filler items, and 24 experimental items (6 at each of the 4 lags employed). Four study lists were constructed from each list structure for a total of eight lists. Within each set of four study lists, the same set of items represented each spacing condition equally often. Recognition lists consisted of the 24 experimental items randomly intermixed with 24 new pictures that were not previously presented. Eight recognition lists were constructed in the same manner as the recognition lists of Experiment 1. In both grade levels, an equal number of randomly selected subjects received each study list and recognition list.

Procedures. The procedures were exactly the same as they had been in Experiment 1 with the following exceptions. For preschoolers, the study list was presented manually at the rate of one picture every 3 s. For college students, we presented the study list at a rate of one picture every 1.5 s. At this speed, we were unable to present stimuli manually. Instead, the photographs used with preschoolers were converted to slides, and we prepared the lists for presentation by videotaping electronically controlled slide sequences. The lists were subsequently presented to college students on a color TV via a VCR. Finally, for both age groups, a 3-week retention interval intervened between the study session and the test session.

Results and Discussion

Once-presented items were not included in the design of Experiment 2. Therefore, mean hit rates and false alarm rates are presented in Table 2 as a function of grade level and the spacing between repetitions. Because analyses on the hit rates and on d' scores again produced identical results, only the former analyses are reported. Again, a .05 level of significance was employed for all analyses.

A 2 (Grade Level) × 4 (Spacing) mixed analysis of variance with repeated measures on the second factor revealed that only the spacing between repetitions produced a reliable effect, $F(3, 330) = 4.69$. Tukey post hoc paired comparisons indicated that performance improved from lag 0 to lag 8 but did not change significantly from lag 8 to lag 12. Although college students performed better than preschoolers, the difference failed to achieve conventional levels of significance, $F(1, 110) = 2.49$, $p < .12$. Finally, the Grade Level × Spacing interaction did not approach significance, $F(3, 330) < 1.00$.

These findings replicated and extended those of Experiment 1 by showing that preschoolers and college students exhibit a spaced-repetition effect in recognition. The fact that the results failed to reveal any significant change in the spaced-repetition effect between the age of four years and young adulthood seems inconsistent with the hypothesis that sophisticated strategic processing contributes to the effect in recognition. However, a possible alternative interpretation is suggested by the failure of college students to perform significantly better than preschoolers (i.e., the main effect of grade level). Perhaps the very fast presentation rate used with college students forced them to rely on fundamental memory processes and prevented them from using strategies that they would have used ordinarily.

This hypothesis was assessed in Experiment 2b by varying the presentation rate between two groups of college students. We had used a 1.5 s presentation rate with college students in Experiment 2a because we had thought it would be needed to avoid a ceiling effect. As it turned out, we could have used a slower presentation rate and, in Experiment

TABLE 2
MEAN HIT RATE AS A FUNCTION OF GRADE LEVEL AND LAG AND MEAN FALSE ALARM RATE (FAR) IN EXPERIMENT 2A

Grade level	Lag 0	Lag 4	Lag 8	Lag 12	FAR
Preschool	.67	.74	.78	.69	.17
College	.72	.77	.80	.77	.17
Total	.70	.76	.79	.74	

2b, we did. One group of subjects received study lists at the fast 1.5 s rate used previously. A second group received study lists at the rate of one picture every 3 s which is slow enough to allow strategic processing. If spaced-repetition effects can be augmented by strategies which college students are unable to employ when a fast 1.5 s presentation rate is used, we should obtain an interaction such that the effect of spacing is greater with the slower 3 s presentation rate.

EXPERIMENT 2B

Method

Subjects and design. Eighty college students (34 males and 46 females) were assigned randomly to two presentation-rate groups (40 subjects per group) which comprised the between-subjects variable in a 2 (Presentation Rate) × 4 (Spacing) mixed factorial design with the second factor manipulated within-subjects. The college students were sampled from the same population as those who participated in Experiment 2a.

Materials and procedures. Materials and procedures were identical to those used with college students in Experiment 2a with the following exceptions. Presentation rate was varied such that subjects in one experimental condition received study lists at a rapid rate of one picture every 1.5 s, and subjects in the other condition received study lists at a slower rate of one picture every 3 s. A 1-week retention interval was employed. Subjects participated either individually or in small groups of two or three. They were not required to label pictures during presentation of the study list, and, during the test, they indicated whether each stimulus was old or new by circling either a "yes" or a "no," respectively, on prepared answer sheets.

Results and Discussion

Mean hit rates and false alarm rates are presented in Table 3 as a function of presentation rate and spacing. Analyses of both hit-rate data

TABLE 3
MEAN HIT RATE AS A FUNCTION OF PRESENTATION RATE AND LAG AND MEAN FALSE ALARM RATE (FAR) IN EXPERIMENT 2B

Presentation Rate	Lag 0	4	8	12	FAR
1.5 s	.73	.80	.80	.79	.22
3.0 s	.76	.85	.89	.86	.21
Total	.75	.83	.85	.82	

and *d'* scores yielded the same results so only results of the former analyses are presented. A .05 level of significance was employed for all analyses.

A 2 (Presentation Rate) × 4 (Spacing) analysis of variance with repeated measures on the second factor indicated that college students showed superior recognition when study lists were presented at a rate of 3 s per picture rather than at a rate of 1.5 s per picture. $F(1, 78) = 4.78$. Additionally, there was a significant effect of spacing which corresponded to the effect obtained in Experiment 2a, $F(3, 234) = 7.04$. But, the Presentation Rate × Spacing interaction did not approach significance, $F(3, 234) < 1.00$.

When a relatively slow 3 s presentation rate was employed rather than a rapid 1.5 s rate, college students were able to use the extra time in a way that substantially improved their subsequent recognition performance. However, there was no corresponding change in the size of the spaced-repetition effect. These results do not support the hypothesis that the spaced-repetition effect in adults' recognition is importantly influenced by strategic processes which are inhibited when a fast presentation rate of 1.5 s per picture is employed. Rather, these results strengthen the tentative conclusion drawn from Experiment 2a that spaced-repetition effects in recognition are developmentally invariant between 4 years of age and young adulthood.

GENERAL DISCUSSION

Prior to the current research, there were no developmental investigations of spaced-repetition effects in conscious, episodic recognition memory. Furthermore, on the basis of existing theories of spaced-repetition effects, it was unclear what to expect. Two questions were of particular interest: (1) Would very young children exhibit a spaced-repetition effect in recognition and, (2) would there be evidence of developmental differences in the spaced-repetition effect in recognition?

Our results clearly indicate that preschool children as young as 4 years old exhibit a spaced-repetition effect in recognition. These findings are consistent with those of Cornell (1980) who reported a spacing effect in infants using a differential viewing task. Although we cannot be certain that the same processes mediated performance in both cases, the correspondence between the two sets of findings suggests that spacing repetitions produces parallel effects on young children's performance in direct and indirect memory tasks.

In addition, our results failed to reveal any evidence of developmental differences in spaced-repetition effects in recognition. In Experiment 1, there were no significant differences in the effect of spacing from the ages of 4 to 9 years although a possible ceiling effect rendered this finding inconclusive. In Experiments 2a and b, we obtained a similar effect of spacing for 4 year olds and for adults who were tested under several variations of the same procedure. One curious aspect of the latter findings was the tendency for the recognition of both preschoolers and college students to improve from lag 0 to lag 8 and then to decline somewhat from lag 8 to lag 12. However, it should be noted that performance at lags 8 and 12 did not differ reliably and that a decline in performance at longer lags is not unprecedented in either the recall or recognition literature (e.g., Foos & Smith, 1974; Glenberg, 1976). The main point is that we obtained a clear effect of spacing repetitions which was very similar for both young children and adults.

Of course, similar results at two age levels cannot rule out the possibility of nonmonotonic developmental changes, and appropriate caution should be exercised in interpreting these findings. However, there are no compelling theoretical or empirical reasons to expect such a nonmonotonic developmental function with respect to spaced-repetition effects. The best interpretation at the present time is that spaced-repetition effects in the recognition of pictures are invariant from early childhood to young adulthood.

Our findings are difficult to reconcile with theories that attribute spaced-repetition effects to sophisticated forms of strategic processing. For example, in one such theory, Greene (1989) proposed that, as each to-be-remembered item is presented, subjects make a metamemory judgment regarding how well the item is learned and allocate study time and effort to the item in inverse relation to its judged degree of learning. The spaced-repetition effect occurs because the second occurrence of a spaced repetition typically is judged to be less well-learned, and, thus, receives more processing, than the second occurrence of a massed repetition. However, we found that 4-year-old children exhibit a spaced-repetition effect in recognition even though the kind of flexible, self-regulated processing which is assumed to underlie the effect is not characteristic of these children. Furthermore, we detected no developmental differences in the spaced-repetition effect in recognition between early childhood and young adulthood. If sophisticated strategic processing played an important role in producing spaced-repetition effects in recognition, developmental differences would be expected because strategic processing should become increasingly flexible, self-regulated, and effective with increasing age.

Our results are more consistent with the hypothesis that very fundamental, perhaps even primitive, memory mechanisms which operate automatically are sufficient to produce spaced-repetition effects in recognition. Although our research was not intended to determine the exact form that such mechanisms may take, several possibilities can be considered.

As we noted in the introduction, one type of theory which is consistent with our findings incorporates the assumption that the effectiveness of repetition is inversely related to the ease with which the second presentation triggers retrieval of the first presentation (e.g., Jacoby, 1978). If repetitions are massed, this study-phase retrieval occurs after only superficial processing of the second occurrence which reduces the beneficial effect of repetition on subsequent memory. As spacing increases, memory for repeated information improves because the second presentation must undergo more extensive processing before it triggers study-phase retrieval. According to a related kind of theory (e.g., Thios & D'Agostino, 1976), successfully retrieving an item's first presentation at the time of its second presentation strengthens the retrieval operations that are used. As the spacing between repetitions increases, the operations involved in study-phase retrieval become increasingly similar to the retrieval operations required on a later test and, thus, have a greater beneficial effect on test performance.

At least two theories have been proposed in which spaced-repetition effects are explained in terms of the temporal properties of assumed physiological processes. One hypothesis is that, when repetitions are massed, consolidation of one presentation interferes with consolidation of the other before the latter is complete (e.g., Landauer, 1969). Another hypothesis is that some aspect of the encoding mechanism habituates and must recover before it is capable of fully responding to the same stimulus again (Hintzman, 1974). Thus, if the second presentation of a repeated item occurs before recovery is complete, as is likely with massed repetitions, the system may be unable to fully respond, and relatively poor memory would result. Although these theories explain spaced-repetition effects in terms of fundamental, nonstrategic processes that may well be developmentally invariant, it is unclear whether they are consistent with our findings because the time course of consolidation and habituation has not been adequately specified. Perhaps for this reason, there is little evidence in the spaced-repetition literature actually supporting these theories (e.g., Hintzman, Summers, & Block, 1975).

Finally, an encoding variability explanation of our findings might be offered. According to this class of theory (e.g., Bower, 1972; Glenberg, 1979), repeating an item improves memory to the extent that repetitions are encoded differently. The likelihood of differential encoding is assumed to increase as the spacing between repetitions increases. To the extent that variable encoding and its relation to spacing can be attributed to fundamental, developmentally invariant memory processes, such a theory would be consistent with our findings. There is some evidence that encoding variability influences repetition and spaced-repetition effects in children's recall (e.g., Toppino & DeMesquita, 1984; Waters & Waters, 1976, 1979). However, when the essential elements of encoding variability theory have been directly assessed in the recall and/or recognition performance of adults, results frequently have failed to support the theory (e.g., Postman & Knecht, 1983; Ross & Landauer, 1978).

The present research should be viewed as a necessary first step toward understanding spaced-repetition effects in recognition and their relationship to development. Further developmental research clearly is needed on spaced-repetition effects both in recognition and in recall. Such research can play an important role in delineating the nature of the processes underlying spaced-repetition effects and may yield insights that are simply unavailable from research conducted from a nondevelopmental perspective. In addition, attempts to understand the mechanisms responsible for spaced-repetition effects in children should make important contributions to our growing understanding of memory development. It is possible that future research on spaced-repetition effects will discover developmental differences that reveal important changes occurring in the developing memory system. Alternatively, future research may converge on the conclusion that spaced-repetition effects are produced by developmentally invariant processes. In either case, understanding of the memory system as it develops requires that we understand both those components of the system that change and those that remain constant.

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