

## Education and Cognitive Development: A Natural Experiment

Frederick J. Morrison  
Loyola University of Chicago

Lisa Smith and Maureen Dow-Ehrensberger  
University of Alberta

Using an arbitrary cutoff date, school districts regulate which children will begin school. This “natural experiment” was used to examine effects of age- and schooling-related influences on memory and 3 levels of phonological segmentation in children who just made vs. missed the cutoff. Group comparisons over time permitted assessment of schooling influences and Age  $\times$  Experience interactions. Short-term memory was enhanced by grade one schooling, with no evidence of an Age  $\times$  Schooling interaction. For phonological segmentation, both schooling- and age-related influences appeared, with unique patterns for each level of segmentation. The cutoff method proved sensitive to important changes in cognitive skills during this age period.

In many Western societies, the period from late preschool through early elementary school is characterized by widespread, perhaps qualitative, shifts in children’s cognitive, social, and moral functioning. Collectively, the changes have been referred to as the 5–7 *shift* (White, 1965). In the intellectual realm, children’s thinking has been described as becoming more logical (Piaget, 1960) and more abstract (Rogoff, 1981); memory performance improves as rehearsal and organizational strategies become more active (Bjorklund, 1987; Ornstein & Naus, 1978); language skills become more reflective and refined (Read & Schreiber, 1982); and increased metacognitive skills yield greater planning, control, and evaluation over the sequencing of cognitive acts (Case, 1985; White, 1965).

Although their uniqueness may be challenged, the existence of major changes between ages 5 and 7 is not in dispute. However, the relative contribution of maturation versus experience (e.g., schooling) has not been resolved. For most of the past 2 decades, the maturationalist view has dominated theory and research. The work of Piaget and others (Case, 1985; Kagan, 1984) has emphasized regular, uniform, and seemingly universal changes in thinking across the age range that appeared internally driven and controlled by a maturational timetable. Nevertheless, recent findings have revealed that specific learning experiences may play a crucial role in the growth of selected cognitive skills. First, cross-cultural research has documented major differences between schooled and unschooled children in growth of perceptual and memory skills, concept development,

logical thinking, and concrete operations such as conservation (Rogoff, 1981; Wagner, 1981). Second, research on the development of specialized knowledge or expertise (e.g., on 10-year-old chess masters or 5-year-old dinosaur experts; Chi, 1978; Chi & Koeske, 1983; Chi, Hutchinson, & Robin, 1989) has revealed the degree to which intensive learning experiences can improve memory and other thinking skills, at least in the domain of expertise (Ceci & Liker, 1986). Finally, the superior mathematics performance exhibited by Japanese elementary school children over American children (Stevenson, Lee, & Stigler, 1986) appears to stem in large part from differing parental expectations and specific instructional practices in and outside school (Stevenson, Lee, Chen, Stigler, Hsu, & Kitamura, 1990). Taken together, these findings have reawakened interest in the role played by specific learning experiences in shaping when and how cognitive skills develop (Fischer, 1980).

Unfortunately, interpretation of results from cross-cultural and specialized expertise research is sometimes hampered by a number of problems, the most serious being participant selection biases. For example, inferences about the effects of specific schooling experiences in comparisons between schooled and unschooled children are confounded by the fact that the children who go to school are often those who are thought by parents to be especially bright and likely to benefit from schooling (see Rogoff, 1981, for discussion). Likewise, superior cognitive skills of 10-year-old chess masters may reflect developmental processes in very bright children or in unique learning environments. As such, the generalizability of the effects to the larger population of children remains unknown.

In recent years, alternative methods have been developed for examining age-related versus experience-related (e.g., schooling) changes in cognitive skills (Bentin, Hammer, & Cahan, 1991; Bowey & Francis, 1991; Cahan & Cohen, 1989). In our own work, we have examined the influence of a culturally valued learning experience (i.e., schooling) through use of a “natural experiment” (termed *school cutoff*) that circumvents some, if not all, of the biases found in other research (Bowey & Francis, 1991). Each year, school boards proclaim that those children whose birthdate precedes some specified date will be allowed to go to kindergarten

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Frederick J. Morrison, Department of Psychology, Loyola University of Chicago; Lisa Smith and Maureen Dow-Ehrensberger, Department of Psychology, University of Alberta, Edmonton, Alberta, Canada.

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Correspondence concerning this article should be addressed to Frederick J. Morrison, Department of Psychology, Loyola University of Chicago, Chicago, Illinois 60626. Electronic mail may be sent to FMorris@orion.it.luc.edu.

or first grade whereas other children who just miss the cutoff will not be allowed entry. By choosing children whose birthdates cluster closely on either side of the cutoff date, we can effectively equate two groups of children developmentally on some target psychological skill or process. Furthermore, pretest assessments can ensure equal levels of performance at the beginning of the school year on the target and other control variables (e.g., IQ, socioeconomic status (S.E.S.), preschool experience). By comparing the degree of change in the target skill from pre- to posttest in children who just make versus those who just miss the cutoff, one can assess the impact of the schooling experience on growth of that skill (see also Baltes & Reinert, 1969; Cahan & Cohen, 1989). Though it is tempting to place the school learning experience in contrast to general maturation or development, the more neutral comparison is between a schooling experience and another kind of experience.

A separate feature of the cutoff methodology permits examination of possible Age  $\times$  Experience interactions on growth of cognitive skills. For example, when the older kindergarten children go to first grade they are almost 1 year older than the young Grade 1 children were when they were in first grade. If growth of cognitive skills is exclusively a product of the schooling experience, patterns of change shown by the older kindergartners over the course of first grade should be identical to those exhibited by the young Grade 1 group a year earlier. If, however, maturational or other age-related influences interact with the schooling experience, the cognitive growth of the older kindergarten children over first grade should exceed that of their younger grade one counterparts.

There are two potential participant selection biases in this design. First, if they feel that their child is not optimally ready for school, parents of eligible children (i.e., those who just make the cutoff) may elect to hold their child out of formal schooling for a year or to retain him or her an extra year in kindergarten. Because children closest to the cutoff date are more likely than older children to be held out or retained, the potential for biased sampling must be addressed (Cahan & Cohen, 1989). However, the percentage of children held out or retained in the local school district is relatively small—approximately 5% overall and 10–12% for children born 1 or 2 months prior to the cutoff date. Furthermore, an independent comparison of background characteristics of relatively young children who had been either held out prior to kindergarten, retained an extra year in kindergarten, or promoted at the appropriate age revealed no group differences on measures of I.Q., parental occupation and education, and amount of daycare experience (Morrison & Griffith, in press). Hence, systematic sampling bias in the present study is very unlikely. Finally, comparison groups can be matched, if necessary, on potentially relevant background variables to eliminate potential sampling biases.

Second, parents of ineligible children (i.e., those who just miss the cutoff) may attempt to enroll them anyway (when legally permissible) if they feel that the children are ready to learn. Again, current figures from the local school system revealed that only three underage children (out of a total of 6,700 starting school) were permitted to enter school during the year of study. In addition, a pioneering study of phonological segmentation that used the school cutoff method (Bowey & Francis, 1991) failed to uncover any group differences on background variables such as receptive vocabulary. Furthermore,

their results revealed that the method was sensitive to important schooling influences and discriminated growth patterns between phonemic and subsyllabic segmentation.

Nevertheless, Cahan and colleagues (Bentin, Hammer, & Cahan, 1991; Cahan & Cohen, 1989; Cahan & Davis, 1987) considered these potential biases serious and, therefore, have opted to use a different approach, termed the *between-grades regression discontinuity design* (Cahan & Davis, 1987), in which children nearest the school cutoff are explicitly eliminated from consideration. In a recent study using this approach, Bentin, Hammer, and Cahan (1991) examined age and schooling influences on development of phonological awareness in kindergarten and first-grade children. Large samples of children spanning the range of birthdates within a given year were required to isolate the first and last phonemes in spoken words and in self-generated picture names. Regression techniques were then used to estimate the independent influences of age (within-grade) and schooling (between-grade) on phonological awareness. Within-grade estimates for kindergartners used the full range of birthdates, whereas, for first graders the estimate excluded the youngest children with birthdates 2 months prior to the cutoff. Findings revealed both age and schooling effects on growth of phonological awareness, with schooling effects four times larger than age effects.

These two developing methodologies offer distinct, though potentially complementary, approaches to disentangling age-related and schooling-related influences on cognitive growth. If successful, the fresh perspectives offered by these methodologies will advance our understanding of the nature and sources of psychological change.

### Focus of Inquiry

Ideally, the current methodology would be wedded to a coherent body of theory linking schooling with cognitive growth. Unfortunately, no overriding conceptual framework currently exists. Rather, localized changes in specific cognitive skills have been hypothesized to derive from several different characteristics of schooling. For example, changes in memory skills have been viewed as a by-product of learning to read as well as a consequence of greater environmental demands for deliberate memory (Rogoff, 1981). In our own research, we have examined potential influences of schooling on growth of syntactic knowledge (Ferreira & Morrison, 1994), development of memory and causal reasoning in narrative comprehension and production (Varnhagen, Morrison, & Overall, 1994), and changes in arithmetic computational skills and number conservation (Bisanz, Morrison, & Dunn, 1995). The present article focuses on the influence of schooling on growth of memory and language skills. These two areas were chosen for several reasons. First, a substantial body of literature in both memory and phonological segmentation provided a solid empirical base for examining schooling effects (Perfetti, 1985; Rogoff, 1981). Second, theoretically motivated predictions about the influence of schooling could be made in these areas. Third, both memory and segmentation skills (especially at the phonemic level) have been directly implicated as important cognitive processes in learning to read (Perfetti, Beck, Bell, & Hughes, 1987; Rayner & Pollatsek, 1989).

### Memory

From more than 20 years of memory research, we know that performance in free recall tasks improves substantially from 4 through about 12 years of age (Ornstein & Naus, 1978). Moreover, one major source of developmental improvement is increased use of active, cumulative rehearsal strategies, indirectly indexed by a heightened primacy effect in serial position analyses (Belmont & Butterfield, 1971; Hagen, Hargrave, & Ross, 1973) and by observed changes in overt rehearsal (Ornstein & Naus, 1978). The primacy effect in serial position curves (i.e., heightened recall of initial list items) is presumed to reflect greater or more elaborative rehearsal of earlier list items, facilitating transfer of items to long-term memory and subsequent retrieval (Ellis & Hunt, 1993). As noted, several authors have hypothesized that changes in memory performance may be a direct or indirect result of experiences in school. If so, we expected to find greater changes in memory performance for children entering first grade than for the almost age-matched children entering kindergarten.

### Phonological Segmentation

Several studies have demonstrated strong correlations between reading scores and phonemic segmentation skills (Fox & Routh, 1976; Share, Jorm, MacLean, & Mathews, 1984; Stanovich, Cunningham, & Freeman, 1984). However, controversy has arisen regarding the causal nature of the strong association between growth of phonemic segmentation skills (so-called *phonemic awareness*) and success in early reading acquisition. Several studies have revealed clear and specific improvements in reading ability following training in phonemic segmentation. For example, Treiman and Baron (1983) trained prereaders in segmentation skills and found that the children later showed success in reading words based on the symbol-sound correspondences used in the training procedure. Hence, accumulating evidence has demonstrated that early phonemic segmentation ability may be a prerequisite for, or at least facilitate, success in early reading.

In contrast, others have argued that significant changes in phonemic awareness come about as a result of exposure to printed materials (Ehri, 1984; Perfetti, 1985; Read, Zhang, Nie, & Ding, 1986). For example, Morais, Carey, Alegria, and Bertelson (1979) found that adult illiterate Portuguese fisherman lacked phonemic awareness skills, whereas their recently educated fisherman counterparts did evidence phonemic segmentation ability. This and other evidence (Ehri & Wilce, 1979) strongly suggest that reading experience exerts a powerful influence on growth of phonemic awareness.

Recently, Perfetti (1985) and Perfetti et al., (1987) suggested that both views may be correct and that learning to read and growth of phonemic awareness have a reciprocal influence. Specifically, some appreciation for the phonemic structure of spoken words probably facilitates initial decoding. In addition, and perhaps more important, exposure to printed materials significantly enhances a child's ability to analyze words and to manipulate speech segments.

One problem in disentangling the cause-effect relation in this area has been lack of methodological tools capable of discrimi-

nating the effects of schooling from general age-related influences. The cutoff methodology afforded a reasonable way to test the nature of the association between phonemic segmentation and early reading acquisition. Specifically, although kindergarten children are exposed to letters and are read stories, formal reading instruction does not really begin until first grade in most North American school systems. If growth of phonemic awareness develops independently of formal instruction, we would expect to see significant changes in children's phonemic segmentation skills over the course of kindergarten. Conversely, if phonemic awareness is primarily or more strongly influenced by exposure to formal reading instruction, young grade-one children should show a more marked improvement over the year in phonemic segmentation skills. Evidence of change in both groups of children would confirm Perfetti's notion of reciprocal influence between reading experience and phonemic awareness. To address these issues, we compared growth of phonemic awareness in children who just made the cutoff for grade one (i.e., who received formal reading instruction) and in almost identically aged children who just missed the cutoff (i.e., who received no formal reading instruction).

Two additional issues regarding phonological segmentation were addressed in this study: First, which segments of speech do children have some skill in manipulating prior to reading experience, and second, which segments appear to develop through exposure to written materials? Existing evidence has documented that prereading children possess rudimentary skill in segmenting words into syllables but have greater difficulty initially segmenting syllables into phonemes (Bowey & Francis, 1991; Fox & Routh, 1976; Treiman & Baron, 1981). Evidence obtained by Treiman (1985) points to a level of segmentation ability in prereaders intermediate between syllables and phonemes, the so-called *intrasyllabic* or *subsyllabic* level. One proposed type of subsyllabic segmentation postulates a split between onsets and rhymes (e.g., in the one-syllable word "grasp," "gr" would constitute the onset and "asp" the rhyme). We examined segmentation ability in this study at all three levels: syllabic, subsyllabic, and phonemic. We hypothesized that, to the degree children are capable of syllabic and subsyllabic segmentation prior to formal reading instruction, minimal effects specific to first-grade schooling would be observed. In contrast, we anticipated a major increase in phonemic segmentation as a consequence of first-grade reading instruction because this level of analysis is initially quite foreign to prereaders. An independent investigation of levels of phonological development using an almost identical procedure (but without a longitudinal component) was reported by Bowey and Francis (1991). They compared performance of "old" kindergarten, "young" grade-one and "old" grade-one children on tasks assessing subsyllabic (e.g., onset-rhyme) and phonemic segmentation. Using a phonological oddity task (Bradley & Bryant, 1985), they found that only the two first-grade groups could successfully perform the phonemic tasks and that these two groups did not differ from each other. Most first-grade and kindergarten children showed sensitivity to subsyllabic units.

The second additional issue we addressed was whether changes across the three levels of segmentation skill would show a similar (so-called *domain-general*) pattern or whether changes would differ across levels of segmentation ability as a function

of age, schooling, or both in a more domain-specific pattern, perhaps sensitive to changes in curricular emphases from kindergarten through second grade. Discovery of distinctly different patterns of change across levels of segmentation within the language task or for the memory versus language tasks would reveal the cutoff methodology to be discriminatively sensitive to different sources of change in the two domains. If exactly the same pattern of change occurs across tasks or domains, it would raise a question about whether other sources of difference between the groups (e.g., differential motivation or familiarity with testing situations) might be responsible for performance changes. In this regard, it should be noted that Bowey and Francis (1991) found different patterns of schooling effects for subsyllabic versus phonemic levels of segmentation.

## Method

### *Participants*

Twenty children (10 per group, 6 females and 4 males) were originally selected. Young grade-one children (Y1) were those who turned 6 in January or February of the year following entry into grade one, thereby just making the March 1 cutoff. Kindergarten children (K) turned 6 in March or April of that year, hence they just missed the cutoff and went to kindergarten. On average, Y1 children were 41 days older than K children. The March 1 cutoff date for school entry in the local district is quite late by North American standards. Hence, Y1 children in this study were younger when they started school than are children in almost all other school districts on the continent. Fortunately, the late cutoff date permitted assessment of an important educational question, namely the role of school entrance age on academic achievement (Morrison & Griffith, in press).

Children were drawn from six elementary schools in predominantly middle- to lower-middle-class sections of the city (see Table 1 for summary of background characteristics). All children spoke English as their first language, and none of the children had any social or behavioral problems according to school records and teacher reports. At the time of study, the kindergarten curriculum in the local school system adopted an informal "learning as play" philosophy with almost no formal academic emphasis except for some exposure to the letters of the alphabet. For example, no specific instruction occurred during kindergarten in learning the sounds of letters or in initial consonant stripping.

Two Y1 children were not seen at Posttest 2; the family of one child moved out of the district, and the other family declined to continue participation in the study. Despite this attrition, the background characteristics of the remaining sample of Y1 children were essentially unchanged.

### *Materials*

A picture memory test adapted from Baker-Ward (1985) was used for the memory test. Pictures of colored objects were cut from magazines, pasted onto black construction paper, covered with a transparent folder, and placed in a black three-ring binder. Four practice trials were prepared, two each with three and six pictures, respectively. Four separate sets of experimental trials were also constructed, each consisting of nine different pictures.

Three sets of 30 words each were selected for the syllabic, subsyllabic, and phonemic segmentation tasks (see Appendix). Words in the syllabic segmentation task were one, two, or three syllables in length (10 each), whereas the majority in the subsyllabic and phonemic tasks were monosyllabic (25 of 30) and ranged from two to five phonemes. Segmentation of subsyllabic units (ranging from one to four units) used

a simple rhyme-onset differentiation. Bisyllabic words were segmented using the same rhyme-onset differentiation either separately within each syllable for three words (e.g., s-o-d-a) or on the second syllable for two words (e.g., i-t-em). All words had a standard frequency index of at least 40 in the Carroll, Davies, and Richman (1971) norms.

Finally, reading achievement scores were obtained from the children with the Wide Range Achievement Test-Revised (WRAT-R; Jastak, 1978). I.Q. scores were also obtained with the Stanford-Binet Intelligence Scale-Revised (Thorndike, Hagen, & Sattler, 1986).

### *Procedure*

Children were tested individually in a quiet room in the school. Once seated at a table for the memory test, the experimenter said,

We are going to play a memory game. I am going to show you some pictures. When you look at each picture, I want you to study it hard because I want you to remember all the pictures that I show you. When you look at the pictures, if you do anything to help yourself remember them, say it out loud so I can write it down. Okay? Are you ready?

The child was then given two practice trials with three pictures, followed by two more practice trials with six pictures. Subsequently, children were presented four different sets of experimental trials, each with nine pictures. Pictures were presented one at a time for approximately 5–7 s. As each picture was shown, the experimenter named the object depicted. The end of each list was signaled by a red piece of construction paper. At this point, the child was asked to verbally recall as many of the names of the pictures as he or she could. No direct rehearsal instructions were given; between each list, however, the experimenter encouraged the children to overtly verbalize whatever they were doing to help them remember.

The phonological segmentation test consisted of a training phase and a testing phase. During the training phase, children were told that they would hear a word and had to decide how many sounds were in the word by placing the appropriate number of poker chips in front of them on the table. They were encouraged to say the sounds out loud as they placed the chips. If the child's response was incorrect, the experimenter modeled the correct response, including accompanying verbalizations. Three consecutive correct responses constituted the criterion for advancing to the testing phase. All children were successful in the training phase. During the testing phase, a child's response was counted as correct only if the right number of sounds was spoken and the correct number of chips placed on the table. Because all children participated in all three segmentation tasks, they were run on separate days to minimize fatigue and other order effects. Order of presentation of language and memory tasks was counterbalanced across participants.

Testing was conducted on three occasions separated by exactly 1 year: at the beginning of grade one or kindergarten for both groups (Pretest); at the beginning of Grade 2 or Grade 1 for the two groups, respectively (Posttest 1); and at the beginning of Grade 3 or Grade 2 for the two groups respectively (Posttest 2). These three tests allowed examination of the effects of schooling on memory and language development (Posttest 1) as well as any potential Age  $\times$  Experience interactions (Posttest 1 and Posttest 2).

Each fall, testing was initiated shortly after school opened in early September and completed by mid-October. The average age of the groups at first testing was approximately 5 years, 6 months (K) and 5 years, 8 months (Y1). On the two subsequent testings, the groups were, on average, exactly 1 year older.

## Results

### *Background Information*

As part of a larger study of the role of entrance age in school readiness, information on a number of potentially relevant

background factors was gathered. Included were I.Q., parental education and occupation, and daycare experience. As depicted in Table 1, no statistically significant differences were found between groups on any of the background variables nor did any consistent pattern of differences favoring either group emerge. Two factors (I.Q. and daycare experience) tended to favor the Y1 children, whereas the remaining four factors favored the K group.

For the most part, the background variables revealed the groups to be representative of the larger population of school children and families in the area. Most parents had a high-school or slightly higher education. The mean occupational rankings ranged from secretarial to managerial or supervisory positions. The I.Q. scores (111 and 118) seemed somewhat higher than expected, even for a select sample of school children.

### Memory Task: Recall Performance

A 2 (group)  $\times$  3 (testphase) split plot analysis of variance (ANOVA) was conducted on mean number of pictures recalled (averaged across four recall trials for each child) with group (Y1 and K) as a between-participants variable and repeated measures on test phase. Significant main effects of Group,  $F(1, 18) = 10.1, p < .0005$ , and Testphase,  $F(2, 36) = 15.4, p < .0005$ , were qualified by a significant Group  $\times$  Testphase interaction,  $F(2, 36) = 4.4, p < .02$ . Subsequent analyses focused on comparisons between Pretest and Posttest 1 and separately between Posttest 1 and Posttest 2.

Figure 1 depicts recall performance for Y1 and K children across the three testing phases of the study. As illustrated, no group differences in memory performance emerged at Pretest,  $t(18) = 1.39, ns$ , whereas at Posttest 1 Y1 children recalled significantly more than K children,  $t(18) = 8.2, p < .001$ . Separate comparisons on the change scores (from Pretest to Posttest 1) confirmed that the degree of improvement in picture recall by Y1 children was reliably higher than that of K children,  $t(18) = 8.70, p < .001$ . Somewhat surprisingly, recall performance of the K children did not improve over the year-long period in kindergarten,  $t(9) = 0.2, ns$ . Major improvements in memory performance in children similar in age appeared to be almost entirely influenced by exposure to formal schooling in grade one.

One year later (see Figure 1, Posttest 2), recall performance of the K children (following grade one) had improved signifi-

cantly,  $t(9) = 6.16, p < .001$  for change score from Posttest 1 to Posttest 2, whereas that of the Y1 children (now in grade two) did not increase,  $t(7) = .42, ns$ . The degree of improvement in picture recall from Posttest 1 to Posttest 2 by K children was significantly greater than for the Y1 children,  $t(16) = 6.23, p < .001$ . Nevertheless, the degree of improvement of the K group during their grade one year (from Posttest 1 to Posttest 2) was not reliably greater than the improvement made by the Y1 group during their first-grade experience (Pretest to Posttest 1,  $t[16] = 1.9, ns$ ). Finally, no group differences emerged on mean number of pictures recalled at Posttest 2,  $t(1.16) = .85, ns$ . Hence, for both groups of children memory improvement over the period studied was directly influenced by exposure to formal schooling in grade one, with no evidence of an independent or interactive contribution of age-related factors.

### Memory Task: Serial Position Curves

Memory strategies used by the two groups were examined by scrutinizing serial position effects. A 2 (group)  $\times$  3 (testphase)  $\times$  3 (serial position) ANOVA was performed on mean percentage recalled across serial position with Groups (Y1 and K) as between-participants variable, Testphase (Pretest, Posttest 1 and Posttest 2) as one within-participant variable, and Serial Position (primacy, Positions 1–3; middle, Positions 4–6; and recency, Positions 7–9) as the other within-participant variable.

In addition to the aforementioned main effects of group and testphase, percentage recall differed across the three serial positions,  $F(2, 36) = 182.04, p < .0001$ , and the main effects were qualified by a significant two-way interaction between serial position and group, Serial Position  $\times$  Group  $F(2, 36) = 4.61, p < .01$ . No other interactions reached significance. As depicted in Figure 2, levels of performance at pretest did not differ between groups at any serial position ( $t$  values  $< 1.0$  for group comparison at three serial positions). As predicted, planned comparisons revealed that the Y1 group showed significant improvement in primacy recall following their year in first grade,  $t(9) = 4.11, p < .01$ , for comparison of Pretest with Posttest 1, whereas the K group's primacy recall did not improve over the same period,  $t(9) = .02, ns$  for comparison of Pretest with Posttest 1. Somewhat surprisingly, a similar pattern of findings emerged for recall at the middle positions, with Y1 children exhibiting enhanced recall following exposure to first grade,  $t(9) = 3.86, p < .01$ , whereas recall of K children did not change for the middle positions,  $t(9) = .06, ns$ .

Table 1  
Background Information on Kindergarten and Young Grade 1 Children

Variable	Kindergarten	Young Grade 1	$t(18)$
I.Q.	111.00	118.00	1.20
Mother's education (no. of years)	12.80	11.40	0.52
Mother's occupational status <sup>a</sup>	9.75	9.00	0.38
Father's education (no. of years)	14.30	12.20	1.10
Father's occupational status	11.20	10.00	0.77
No. of months in daycare	5.11	8.00	0.49

Note. All  $t$  values are nonsignificant.

<sup>a</sup> Occupational status derived from Pineo-Porter-McRoberts (1977) 16-point scale (1981 revision).

Consistent with predictions, the K group showed a sharp, reliable increase in primacy recall following their first-grade experience,  $t(9) = 4.01, p < .01$  for comparison of Posttest 1 with Posttest 2, whereas the original Y1 group showed no additional increase in primacy recall following second grade,  $t(7) = -.16, ns$  for comparison of Posttest 1 with Posttest 2. More important, the degree of improvement in primacy recall shown by the K group during first grade was not reliably greater than the degree of improvement demonstrated a year earlier by the Y1 group,  $t(16) = .44, ns$  for comparison of change scores from Posttest 1 to Posttest 2 for K group with those from Pretest to Posttest 1 for Y1 group.

Overall, the findings for recall across serial positions reinforced the findings for general memory performance and provided evidence that first grade schooling enhanced use of active memory strategies (perhaps verbal rehearsal) indexed indirectly by heightened primacy recall following first grade.<sup>1</sup>

### Phonological Tasks: Phonemic Segmentation

A 2 (group)  $\times$  3 (testphase) split plot ANOVA with repeated measurement on testphase was conducted on percentage correct trials. Significant Group,  $F(1, 18) = 8.6, p < .01$ , and Test Phase,  $F(2, 36) = 4.0, p < .05$ , effects were qualified by a significant interaction,  $F(2, 36) = 3.18, p < .05$ . As depicted in Table 2, there were no group differences in phonemic segmentation scores at Pretest,  $F(1, 18) = .47, ns$ . Nevertheless, both groups made reliable progress in phonemic segmentation skill during the school year. The K children showed a modest but significant increase in performance from Pretest to Posttest 1,  $t(9) = 8.4, p < .01$ . In fact, their performance at Posttest 1 (i.e., the end of kindergarten) was significantly higher than that of the Y1 children at Pretest (the end of their kindergarten) thereby revealing on Age  $\times$  Experience interaction during the kindergarten year,  $t(18) = 4.2, p < .01$ . More striking, the degree of improvement from Pretest to Posttest 1 for the Y1 children,  $t(9) = 11.5, p < .01$ , was significantly greater than that of the K children,  $t(18) = 8.9, p < .001$ , and Posttest 1 scores of the Y1 children were higher than those of the K children,  $t(18) = 7.2, p$

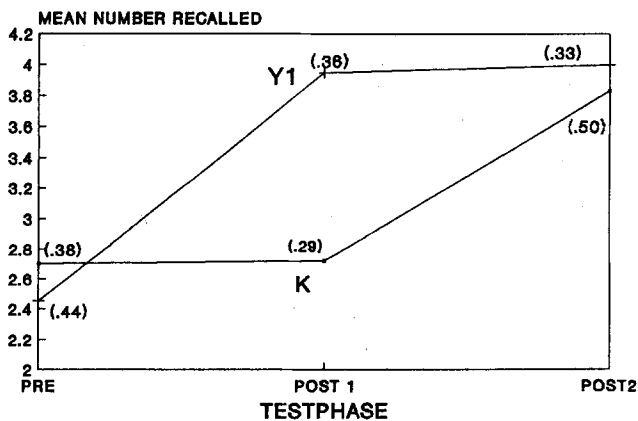


Figure 1. Mean number of pictures recalled by the kindergarten (K) and young grade one (Y1) groups across the three testing intervals (standard deviations in parentheses).

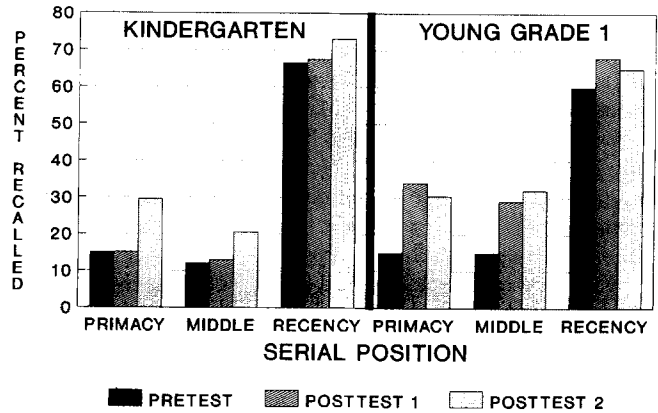


Figure 2. Mean percentage recall at the three serial positions (primacy, middle, recency) for kindergarten (K) and young grade one (Y1) groups across the three testing intervals.

$< .01$ . Overall, K children not exposed to formal reading instruction did make some progress in learning to analyze phonemes. Nevertheless, far greater advances were made by the almost-same-aged children who received formal reading instruction in grade one. On the surface, therefore, the pattern of results is consistent with Perfetti's notion that phonemic awareness develops both independently and as a direct consequence of reading experience. Comparatively, however, formal reading instruction emerged as the more powerful determinant of growth of phonemic segmentation in same-age children over the period studied.

One year later, both groups of children were tested again (following grade one for the original K children and grade two for the original Y1 children). We reasoned that if significant improvement in phonemic awareness was predominantly a product of reading experience, K children should make about the same degree of progress as had the Y1 children. If, however, the K children surpassed the gains of the Y1 children, this finding would reveal that the older children benefitted more from the formal reading instruction, perhaps due in part to the higher level of phonemic awareness with which they began first grade.

Table 2 depicts performance on phonemic segmentation at Posttest 2. As can be seen, the K children made significant progress segmenting phonemes during grade one (i.e., from Posttest 1 to Posttest 2;  $t[18] = 10.5, p < .001$ ). Nevertheless, the original kindergartners' degree of progress from Posttest 1 to Posttest 2 was not significantly different from the progress of the Y1 children during their corresponding grade one period,  $t(16) = 2.0, ns$ . In addition, the Posttest 2 level of performance for K children was not significantly different from that of Y1 children,  $t(16) = .79, ns$ .

<sup>1</sup> In addition to findings from serial position curves, evidence of strategy use by children was scrutinized by examining type of rehearsal activity during picture presentation. Though findings from this analysis were suggestive of a schooling effect on use of active, cumulative rehearsal strategies, relatively small sample sizes precluded drawing firm conclusions.

Table 2  
Levels of Performance on Reading and Phonological Segmentation Tasks by the Two Groups of Children Across the Three Testing Intervals (Standard Deviations in Parentheses)

Task/group	Testphase		
	Pre	Post 1	Post 2
Phonemic segmentation (% correct)			
K	6.5 (3.5)	20.8 (6.8)	52.2 (12.8)
Y1	10.2 (4.1)	50.5 (11.3)	56.8 (11.8)
Syllabic segmentation (% correct)			
K	62.5 (18.6)	59.8 (16.4)	60.0 (20.1)
Y1	60.0 (20.2)	63.8 (18.4)	91.6 (11.9)
Subsyllabic segmentation (% correct)			
K	21.3 (15.7)	36.2 (18.4)	57.5 (21.6)
Y1	35.0 (21.1)	39.5 (20.7)	59.5 (17.4)
Reading achievement (raw scores)			
K	30 (13.2)	32 (14.6)	54 (20.6)
Y1	32 (15.1)	58 (21.1)	66 (24.4)

Note. K = kindergarten children; Y1 = young grade one children.

### Phonological Tasks: Syllabic Segmentation

A similar 2 (group)  $\times$  3 (testphase) ANOVA on syllabic segmentation scores revealed that neither Group,  $F(2, 36) = 1.4$ , *ns*, nor Testphase,  $F(1, 18) = 1.1$ , *ns*, yielded significant main effects, but a significant interaction was revealed,  $F(2, 36) = 3.3$ ,  $p < .05$ . As shown in Table 2, neither group demonstrated much change in syllabic segmentation from Pretest to Posttest 1. Finally, a separate contrast revealed that the overall level of syllable segmenting skill at Pretest was considerably higher than that of phonemic segmentation,  $t(18) = 10.2$ ,  $p < .001$ .

The following year, an unexpected result emerged: An apparent grade two effect. The Y1 group showed a reliable, rather sharp increase in syllabic segmentation scores, rising close to ceiling,  $t(7) = 14.57$ ,  $p < .001$ .

### Phonological Tasks: Subsyllabic Segmentation

Finally, Table 2 depicts performance on the subsyllabic segmentation task. Notice first that Pretest performance levels on the task were intermediate between the levels attained on the syllabic and phonemic tasks. In fact, performance on the syllabic task was significantly higher than on the subsyllabic task,  $t(18) = 3.89$ ,  $p < .01$ , which was reliably above performance on the phonemic task,  $t(18) = 3.96$ ,  $p < .01$ . A 2 (group)  $\times$  3 (testphase) ANOVA revealed only a main effect of Testphase,  $F(2, 36) = 4.5$ ,  $p < .05$ , with no effect of group and no interaction. The apparent difference between K and Y1 groups at Pretest did not reach significance,  $t(18) = 1.65$ , *ns*. The pattern of results from the subsyllabic segmentation task supported the notion that prereaders possessed greater segmentation skill for subsyllables than for phonemes but were not as skilled at segmenting subsyllables as syllables. Overall, however, little evidence for any unique schooling effects on subsyllabic segmentation were observed during first or second grade.

### Reading Achievement

Finally, a 2 (group)  $\times$  3 (testphase) split plot ANOVA was conducted on reading achievement scores. Significant main

effects of Group,  $F(1, 18) = 9.6$ ,  $p < .01$ , and Testphase,  $F(2, 36) = 8.8$ ,  $p < .01$ , were qualified by a reliable interaction,  $F(2, 36) = 5.3$ ,  $p < .01$ . As shown in Table 2, although no group differences emerged at Pretest,  $F(1, 18) = .88$ , *ns*, Y1 children outperformed K children in reading at Posttest 1,  $F(1, 18) = 3.56$ ,  $p < .01$ . Y1 children made significantly greater progress in reading in grade one than the K children made in kindergarten,  $t(18) = 3.3$ ,  $p < .01$ . Clearly, measurable progress in elementary reading skill was restricted to the group of children receiving formal reading instruction in grade one.

The K children made significant progress in reading during grade one (i.e., Posttest 1 to Posttest 2;  $t[9] = 3.92$ ,  $p < .01$ ), but as is evident, they made no more progress than had the Y1 children a year earlier,  $t(16) = .50$ , *ns*. Hence, the higher phonemic awareness scores of the K children on entering grade one did not translate into higher levels of reading achievement at the end of the first grade.

## Discussion

### Memory Development

Results from the recall and serial position analyses suggested that growth of immediate memory skills and strategies is primarily a function of exposure to formal schooling in first grade. Without such experience, same-age children attending kindergarten showed almost no improvement in memory performance and skills. Furthermore, age of child (older vs. younger) when receiving first grade schooling did not affect memory development. Overall, we conclude that the 5–7 shift is almost exclusively a product of schooling and related experiences, at least in the limited area of memory development studied here.

The present findings clearly documented the power of the schooling experience in shaping the memory skills of children in this age range. Less clear was the exact source of the experiential influences on memory development. At least two environmental factors might be implicated. First, memory development could be a by-product of reading experience. Most models of reading (Just & Carpenter, 1980; Kintsch & Van Dijk, 1978)

postulate the existence and operation of a short-term memory buffer for rehearsing, recycling, and integrating information from successive fixations. Because successful comprehension critically depends on effective use of short-term memory processes, greater reading experience in school could provide more opportunities to exercise and perfect rehearsal and other short-term memory strategies. In turn, these strategies may generalize to and be activated by other situations (including psychology experiments) requiring good memory performance.

Alternatively, memory skills may be directly enhanced by teacher behavior, classroom activities (Rogoff, 1981), or even direct instruction. School activities require increased reliance on memorization and on answering questions from knowledge in memory as well as on abstract, verbal modes of communication more dependent on memory processes divorced from supporting stimulus contexts. In general, schooling might increase the tendency to activate processes aimed at enhancing storage and retrieval of information needed for effective school performance.

Finally, the sources of influence on grade one children may not be restricted to experiences in school. Parents and other family members of grade one children may treat them differently than do families of kindergarten children. Parents may encourage more reading in grade one, purchase more "word" books in contrast to picture books, and query children about what they are reading. All these school-related activities in the home could directly or indirectly enhance growth of memory skills. Hence, it is probably more accurate to attribute the differences found in the present experiment to schooling and related experiences.

### *Phonological Segmentation*

Results for the segmentation tasks revealed a number of interesting findings about the nature and development of word segmentation skills. First, several findings confirmed the powerful influence of formal reading instruction on growth of phonemic awareness skills. Young grade one children made significant progress in segmenting phonemes concurrently with increased reading instruction. Moreover, advances shown by the kindergarten children following their exposure to grade one schooling were no greater than those of their younger counterparts a year earlier. Hence, the gains in phonemic awareness in grade one seemed exclusively a product of reading experience. In addition, the parallel trends shown by phonemic awareness and reading achievement curves further reinforced the relative superiority of formal instruction in enhancing phonemic segmentation. Thus, phonemic awareness and reading scores improved when reading instruction occurred. Without reading instruction, phonemic awareness did not improve as much, and reading scores did not increase at all.

One finding demonstrated that progress in phonemic segmentation occurred outside the context of formal grade one reading instruction. Kindergartners showed measurable improvements in segmenting phonemes and greater improvements than their younger counterparts apparently had during their kindergarten year. The most straightforward interpretation of this finding is that aspects of the kindergarten environment (e.g., rhyming activities, word games, general language

stimulation) facilitated growth of phonemic awareness and that the older children benefitted more from this environmental stimulation. Nevertheless, one additional piece of evidence from this study raised the possibility that a specific facet of early reading experience, namely learning letter names, may have contributed to the kindergartner's progress in phonemic segmentation. One part of the WRAT-R requires a child to name printed letters of the alphabet and point to two letters in his or her name. At Pretest, all of the kindergarten children could name all the tested letters. Thus, the children in this study could recognize many letters of the alphabet before they showed any skill in phonemic segmentation. Therefore, the possibility that knowing the letter names and their visual symbols facilitated development of phonemic awareness during kindergarten cannot be dismissed. In this regard, it is noteworthy that initial reading levels attained by the K and Y1 groups on the WRAT-R meant that, on average, they could read a few words. This finding reinforced the view that some preliminary progress in word reading is needed before phonemic segmentation can improve substantially.

The present study also examined the levels of word segmentation children could handle prior to and following exposure to formal schooling. Overall, the findings confirmed recent evidence that prereaders segment syllables reasonably well, segment subsyllabic units less well, and segment phonemes not well at all (Bowey & Francis, 1991). Reading instruction in grade one greatly enhanced phonemic segmentation ability. Syllabic segmentation showed no change in grade one and a sharp increase in grade two. The reason for the specific increase at grade two is not entirely clear, though a combination of increased orthographic sensitivity, spelling ability, and motivation may push the child toward perfect mastery at this level of word analysis. In contrast, though prereaders appeared to possess some rudimentary knowledge of subsyllables, little evidence for any instructional effects was observed through the end of second grade. Improvements in subsyllabic segmentation may emerge later in elementary school when orthographic units smaller than the syllable (such as word stems) become more salient in word decoding.

Finally, the three levels of word segmentation skill showed distinctly different patterns of change over time. Hence, growth of phonological segmentation ability did not appear to involve acquisition of a central, domain-general skill used widely across different levels of word segmentation. Each level of phonological segmentation appeared to undergo its own unique developmental or experiential trajectory.

Results from the present study complement earlier findings by Bowey and Francis (1991) using the cutoff method and by Bentin et al. (1991) using the regression discontinuity design in emphasizing the relative importance of early reading instruction in shaping growth of phonemic segmentation skills. Although not discounting the importance of maturational change or informal language enrichment in enhancing some degree of phonemic awareness, findings from this and related studies suggest that early exposure to formal reading instruction represents the stronger force molding growth of phonemic awareness.

In this regard, the present results do not necessarily discount the possibility that other skills, such as rhyming, and alliteration, develop prior to formal reading instruction and enhance



reading acquisition directly. In a series of studies, Bryant and his colleagues (Bradley & Bryant, 1985; Goswami & Bryant, 1990) have established that prereading experience in rhyming and alliteration skills can enhance early reading efforts. Subsyllabic segmentation findings (requiring analysis into onsets and rhymes) from the present study were consistent with these results. At least initially, children's skill at segmenting subsyllables was reliably higher than their skill at phonemic segmentation. Furthermore, no evidence of unique enhancement by schooling was found in subsyllabic segmentation skills. Hence, individual differences in activities and experiences prior to school that promote awareness of subsyllabic or rhyming units may play a causal role in shaping early-reading success.

Taken together, findings from the present study convincingly documented that early schooling produced marked and unique improvements in selected aspects of children's memory and language development. Furthermore, the pattern of observed changes differed across the two cognitive tasks and across different conditions within the segmentation task. This varied pattern rules out any general factor (such as familiarity or motivation) differentiating the Y1 from the K group. Clearly, major differences in task familiarity, motivation, or both would have produced a similar pattern of differences favoring Y1 children across all tasks and conditions.

The present findings are relevant to current controversies in education about the relation between a child's entrance age and his or her school readiness (Meisels, 1992). Motivated by concerns about declining levels of literacy, some educators have claimed that a major source of educational problems in the United States and Canada lies in children entering school too young, when they are not cognitively or socially mature enough to benefit from formal schooling. Consequently, proposals to remedy the problem have included raising the age of school entry, holding out young entrants from kindergarten, retaining children in kindergarten an extra year, or adding so-called "transition" years. Although well-intentioned, such practices have been criticized by several researchers as misguided and potentially counterproductive (see Meisels, 1992). The present findings revealed quite clearly that young first graders made substantial progress in elementary memory and phonemic awareness skills over the course of first grade. They benefitted measurably from the early schooling experience, surpassing an almost identically aged group of children who did not receive the first grade schooling experience. Recall that the relatively late cutoff date in the local district yielded groups of first graders who are chronologically the youngest in North America receiving formal first grade instruction. Because children this young are learning and thriving, it is reasonable to expect that young entrants in other school districts across North America will succeed as well. A more direct examination of this issue is contained in Morrison and Griffith (in press).

Although clearly revealing the power of early schooling to shape growth of cognitive skills, the present experiments leave open the question of what aspects of schooling and related experiences are responsible for cognitive growth and exactly how environmental influences produce change. Despite these limitations, results of the present experiments demonstrated convincingly that the cutoff methodology could prove valuable in

addressing the nature and sources of cognitive growth in children during the important 5–7 shift.

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## Appendix

## List of Words Used in the Phonological Segmentation Tasks

All tasks	Subsyllabic and phonemic tasks only		Syllabic tasks only
ear	art	Two syllables:	flutter
in	ox		private
ape	ask		stupid
ink	tar		pressure
gas	pin		climate
plan	rate	Three syllables:	benefit
glare	pray		coconut
break	spit		gravity
toast	fence		delicate
drift	soft		visitor
penny	storm		relative
apron	drink		definite
item	spend		regular
vary	grasp		typical
soda	flask		popular

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