On the Interaction Between Phonological Awareness and Reading Acquisition: It's a Two-Way Street

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We have investigated the reciprocal influence of reading acquisition and phonemic awareness. Using a between-grades quasi-experimental design, we have found that learning to read is the most important factor that accounts for the drastic improvement of phonemic segmentation skills during the first year of schooling. On the other hand, we found that improving phonemic skills in kindergarten facilitated reading acquisition in children at risk for developing reading disorders. We suggest that, for most children, exposure to the alphabet automatically triggers phonemic awareness, which is a necessary condition for efficient acquisition of reading. However, the emergence of phonemic awareness requires a previously developed sensitivity to phonology, which in some children may be absent. The present data suggest that, if phonological skills are absent, they may be developed in preschoolers by explicit training, thereby preventing failure in reading acquisition.

Almost two decades of research have provided ample evidence that phonological skills and reading acquisition are interrelated. Many studies have demonstrated that children's ability to isolate and con-

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sciously manipulate syllabic, subsyllabic and phonemic segments of spoken words (hereafter "phonological awareness") correlates highly with their reading skill in the early school grades in English (Bradley and Bryant 1985; Calfee, Lindamood and Lindamood 1973; Fox and Routh 1975; Liberman et al. 1977; Rosner and Simon 1971; Treiman and Baron 1981) as well as in other languages such as Italian (Cossu et al. 1988), Swedish (Lundberg, Olofsson, and Wall 1980), Spanish (de Manrique and Gramigna 1984), and French (Bertelson 1987).

Correlative studies, however, tell us very little about the nature of a relationship. A high positive correlation might exist between two independent skills if they are similarly affected by a tertiary factor. On the other hand, it is also possible that the correlation reflects a causal relationship as, for example, when one skill is a prerequisite, or triggers the second. Theoretical considerations suggest that phonological awareness and reading acquisition are directly interdependent and that the positive correlation might reflect mutual influence and even causality between these two skills (for detailed discussion of these considerations see, for example, Ehri 1979; Leong 1986; Liberman 1989; Liberman, Shankweiler, and Liberman 1989; Rozin and Gleitman 1977).

Attempts to elucidate how phonological awareness and reading acquisition influence each other led, initially, to two opposing views. The first was that, because the basic orthographic segments in alphabetic systems (the letters) usually represent single phonemes, awareness of the phonological structure of spoken words and the ability to isolate and manipulate phonemic segments is a prerequisite of understanding the alphabetic principle (Liberman 1989, 1992; Liberman and Mattingly 1989). This view was supported by studies showing that performance on phoneme segmentation tasks is predictive of success in reading (Blachman 1984; Bradley and Bryant 1985; Juel, Griffith, and Gough 1986; Lundberg, Olofsson, and Wall 1980; Mann 1984; Share et al. 1984), and by studies suggesting that training on phonological awareness skills in prereaders facilitates reading acquisition (Ball and Blachman 1991; Bradley and Bryant 1983, 1985; Lundberg, Frost, and Peterson 1988). The second view was that learning to read an alphabetic orthography triggers, or at least significantly enhances, phonological awareness (Bertelson et al. 1985). This view may account for the observation that performance on phonemic segmentation tests is very poor among preschoolers and improves dramatically during the first grade (Liberman et al. 1974).

Learning to read clearly affects phonological awareness skills. For example, Read et al. (1986) found better phonological awareness among Chinese subjects who learned to read the alphabetic (pinyin) orthographic system than among subjects who read only the logographic system (kanji). Equivalent results were found with children

learning to read an alphabetic orthography in first grade; those who learned to read according to the "analytic" (segmental) method performed better on tests of phonemic segmentation than those who learned to read by the "global" (holistic) method (Alegria, Pignot, and Morais 1982). However, the strongest support for the view that phonemic segmentation skills do not develop spontaneously in the absence of reading acquisition is provided by a series of studies by Morais and his colleagues showing that illiterate adults perform very poorly on tests of phoneme deletion, although they may manipulate phonology at syllabic and word levels (Morais et al. 1979, 1986, 1987).

The two views described above are not mutually exclusive. Indeed, new ideas emerged suggesting that although some forms of phonological awareness, particularly syllabic segmentation and the sensitivity to syllable onset and rime may develop in preschoolers and may be independent of reading acquisition (Bryant and Goswami 1987; Goswami and Bryant 1990; Kirtley et al. 1989), phonemic segmentation skills are usually triggered by reading an alphabetic orthography (Bertelson and de Gelder 1989; Bertelson et al. 1989). It is, therefore, possible that the first steps in reading acquisition require a potential ability to understand that words contain smaller phonological units, but the ability to isolate and manipulate single phonemes develops concomitantly with, and as a result of alphabetic reading instruction (Bowey and Francis 1991; Perfetti et al. 1987).

The purpose of the present study was twofold: On the one hand, to examine the effect of reading instruction on the development of phonemic segmentation skills and to disentangle this effect from other factors related to maturational factors; on the other hand, to shed additional light on the effect of training phonemic segmentation skills in kindergarten children on the speed and efficiency of reading acquisition in first grade. Together, the results of the present study should help clarify the nature of the reciprocal influence of phonological awareness and reading acquisition.

The Effect of Learning to Read on Phonological Awareness

A caveat about interpreting developmental studies of phonological awareness, and, particularly the striking improvement in phonemic segmentation ability during the first grade, is that all such studies share the serious problem of possible confounding of differences in the extent or method of reading acquisition with other age-related variables that may have influenced phonological awareness (e.g. the amounts of informal linguistic experience and general cognitive development). Therefore, before definite claims about a causal relationship

between phonological awareness and reading could be made, it was still necessary to isolate the effect of reading acquisition on the appearance and development of awareness of individual phonemic segments.

Owing to the impossibility of experimenting with elementary school attendance, previous attempts to control for general age-related effects on phonological awareness were based on comparisons between the youngest and the oldest children within one grade level (Bowey and Francis 1991), or between the oldest children in the kindergarten and the youngest children in the first grade (Bowey and Francis 1991; Morrison 1988). Although suggestive, these studies are not conclusive because the cut-off date for school admission is never strictly imposed. Moreover, the exceptions are not random. Intellectually advanced children who are slightly younger than the official school age are often admitted, while children who are somewhat older than the cut-off point but insufficiently developed may be held back an additional year (Cahan and Davis 1987; Cahan and Cohen, 1989). This creates a situation of "missing" children in each grade, particularly among children at the extreme ages. Such selective misplacement usually leads to overestimation of the schooling effect (Cahan and Cohen 1989).

In a recent study Bentin, Hammer, and Cahan (1991) proposed a solution to this problem. Rather then comparing empirically obtained data from children at the extreme ages in each grade, the authors predicted these data on the basis of the best fitting regression of test scores on chronological age across the entire legal age range in each grade, with the exclusion of the selection-tainted birth dates near the cut-off point. The separate effects of schooling and aging were estimated by means of a regression discontinuity design (Cook and Campbell 1979) involving the regressions of phonemic segmentation scores on chronological age. The effect of age was reflected by the slope of the within-grade regressions, whereas the effect of schooling was reflected in the discontinuity between the two regression lines.

The sample consisted of all first graders born in 1981 (with the exceptions described above) attending the seven elementary schools serving four neighborhoods of Jerusalem (319 children) and all children born in 1982 from the 19 kindergartens serving the same neighborhoods (352 children of both genders). Phonological awareness was measured by a battery of four sub-tests of constrained phonemic segmentation; the phonological awareness score of each child was the percentage of correct responses across all four sub-tests. The entire sample was tested within the last two weeks of February. Hence, the school children had had five months of reading instruction.

As expected, the percentage of correct responses on the phonemic

segmentation battery was higher in school children (76 percent, SD = 14 percent) than in the kindergarten group (35 percent, SD = 23 percent) ($t(674) = 29.12$, $p < .0001$). However, this difference reflected the combined effects of age and schooling. The separate effects of these two factors were revealed in the analysis of the within-grade linear regressions of phonological awareness scores on age (Figure 1).

Because the difference in the slopes obtained within each grade level was not significant, it was assumed that the two regression lines were parallel. Accordingly, the net effects of chronological age and schooling were obtained from the regression coefficients of age (in months) and grade level in the multiple regression equation of test scores on age and grade. The net effect of the difference of one year in chronological age was 9 percent (SE = 3.0 percent), and the net effect of one year of schooling was 32 percent (SE = 3.4 percent) (see Figure 1). Both effects and the difference between them were significant ($p < .05$).

The results of the study by Bentin, Hammer, and Cahan (1991) corroborated the initial findings reported by Morrison (1988), pointing to schooling as a major factor affecting the development of phonological awareness. While they proved that an age difference of one year significantly improved performance on some segmentation tests, the results revealed that the experience accumulated during the first five months

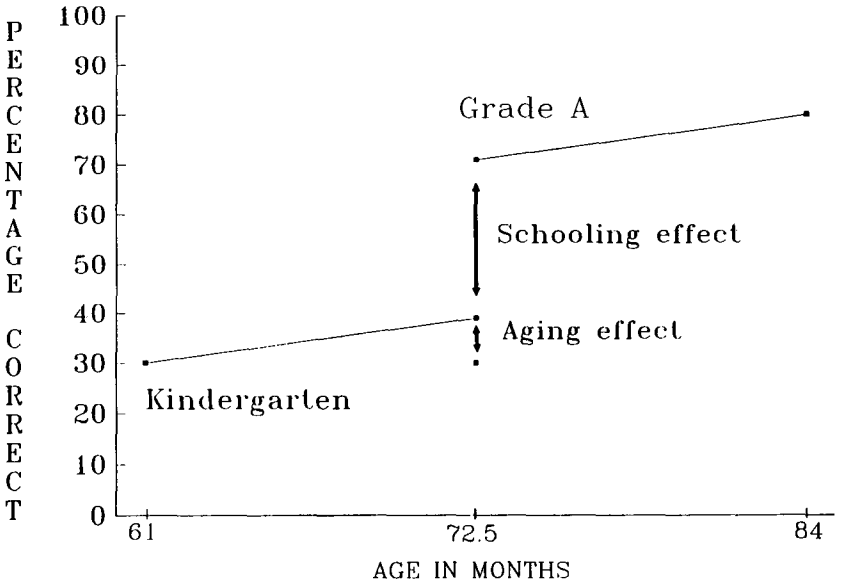

Figure 1. The regression of phonological awareness scores on age in kindergarten and school (Grade I) children.

of schooling enhanced phonological awareness four times as much. Interpreting the schooling effect we should consider that the children were tested during the last two weeks of February. Hence, this effect was based on only the first five months in school.[1] Although during the first grade Israeli school children are involved in a variety of scholastic topics, the main curricular activity during the first half of the year is primarily dedicated to reading instruction. At the same time, the kindergarten activity includes no formal exposure to the alphabet. Consequently, Bentin, Hammer, and Cahan (1991) suggested that the schooling effect observed in that study reflected primarily reading instruction and, therefore, supports the contention that learning to read significantly enhances phonological awareness.

The Influence of Phonological Awareness on Reading Acquisition

The significant influence of reading acquisition on the development of phonological awareness should not be interpreted as evidence against the importance of phonological awareness in reading acquisition. A survey of the development of writing systems clearly demonstrates that the emergence of the alphabetic orthography was not accidental. Rather, it was a direct consequence of failing to communicate meanings or ideas directly, using graphic symbols (DeFrancis 1989). In fact, embracing the alphabetic principle, writers adopted the basic principle of speech: an infinite number of phonological units (i.e., words) can be formed using different combination of a limited and relatively small set of building blocks—the phonemes. Most (although not necessarily all) phonological units that form the lexicon are associated with meanings; however, the spoken message conveys phonological rather than semantic units. The understanding of a spoken word requires deciphering the phonological unit from the acoustic stream before it can be used to access the semantic network. Because words may differ by a single phoneme, the recovery of a word necessarily requires phonemic analysis.

Using a similar principle, an alphabetic script is based on a small set of basic orthographic units, the letters, which represent the phonemes, and, as in speech, written words are formed by combining let-

[1]We assumed that the "grade effect" primarily reflects the drastic change in scholastic activities from kindergarten to elementary school rather than the much smaller changes between the type of experience accumulated during the second and the first half of the year in kindergarten. This assumption is supported by a comparison of phonological awareness of the same children at the beginning and the end of the last year in kindergarten (see the next section). This comparison showed that in the absence of specific training, phonological awareness during that year improved at about the same rate as suggested by the "age" effect in the present study.

ters in sequences that are fairly similar to the sequence of phonemes in the respective spoken word. Hence, in order to understand a written word, the reader should be able to decipher the phonological unit from its printed form. Even assuming that a fluent reader may form direct associations between some printed patterns and their meanings and use these associations to access the semantic information directly, the ability to decipher phonology from print is a prerequisite for reading and understanding printed words at the first encounter and needs to be mastered before efficient reading can exist (for a recent and elaborated discussion of the orthographic code see Liberman and Liberman 1990).

The above account of the reading process implies that, while learning to read, the child learns the basic mapping rules from the domain of the letters set to the range of the phonemes. Obviously, the acquisition of mapping rules requires explicit knowledge of the members of the domain and those of the range. The items in the domain (the letters) are explicitly taught by the teacher. On the other hand, the members of the range (the phonemes) are not taught in the classroom. When a child starts learning to read, he is expected to be aware of the phonological structure of spoken words or at least to become aware of it very quickly. Unfortunately, this condition is not always met for reasons which are beyond the scope of the present paper (for a recent discussion of this issue see Liberman 1989). Children who are not aware of the single phonemes that are combined to form a word may only learn to recognize words as wholes, and, consequently, their ability to read is limited by their ability to remember visual patterns. Such children will frequently fail to read words that they did not explicitly learn. Hence, it appears that efficient reading acquisition requires prior awareness of the phonemic structure of spoken words or at least the ability to become aware of the phonemic structure early in the process of reading acquisition.

The results of our previously reported study (Bentin, Hammer, and Cahan 1991) suggest that, once they are exposed to the alphabetic principle, most children quickly become phonologically aware. It is possible, however, that stimulating phonological awareness before the child starts learning to read may facilitate the reading acquisition process. Moreover, such training might be particularly important to children for whom, for various reasons, exposure to letters might not be sufficient to trigger phonological awareness. Indeed, several studies revealed that improving phonological skills in kindergarten has a positive influence on reading acquisition (Ball and Blachman 1991; Bradley 1989; Bradley and Bryant 1983, 1985; Lundberg, Frost, and Peterson 1988; Perfetti et al. 1987; Vellutino and Scanlon 1987; for a recent review see Bentin 1992; Goswami and Bryant 1990). Despite this rather con-

vincing evidence, however, the importance of phonological skills in reading acquisition is still under debate. In particular, teachers who dismiss the phonological awareness theory, taking the so called "holistic" approach, claim that vocabulary size and the ability to comprehend and manipulate text are more important factors for reading acquisition than phonological awareness. Therefore, there is still room for studies aimed at comparing the effect of training phonological skills with training other language related skills on reading acquisition. Such a comparison may help to disentangle the specific effect of training phonological awareness from the positive effects that training general linguistic skills may have on reading acquisition (see also Ball and Blachman 1991). The aim of the present study was to observe the consequences of training phonological awareness in children at risk and to assess the effects of this training on reading acquisition in comparison with children who showed relatively good phonological awareness in kindergarten. In addition, the present study was run in Hebrew, a language whose specific consonantal orthography requires that, most of the time, the smallest unit used by the teacher for reading instruction includes two phonemes: a consonant letter and a vowel diacritical mark. Given this orthogrpahic structure, it was possible that starting to read Hebrew requires awareness of different phonetic segments than is necessary in other languages.

Method

The study lasted two consecutive years. During the first year, awareness of phonemic segments was tested in a population of kindergarten children. On the basis of this assessment, children with the lowest phonological awareness were selected to form the different training and control groups. By the end of the school year, following training, these groups were retested to assess the consequences of training phonemic segmentation skills on phonological awareness. During the second year, the reading ability of all experimental children was tested and compared with the reading ability of children who had initially average or above average phonological awareness scores.

Subjects. Our original population of subjects included 508 children (294 boys), 59–77 months old (mean = 66.71, SD = 3.49), who attended 15 different public kindergartens. The kindergartens were randomly sampled from middle-class neighborhoods. By official standards, all the children were considered "normal" (as contrasted with children who require special education). With the exception of children who were not expected (due to young age) to join elementary school at the end of the year and children whose parents did not consent to participation (less than 0.1 percent), all the children in those

kindergartens were tested. The regular kindergarten activity did not include reading acquisition or formal exposure to printed words.

Phonological Awareness Tests. In the present study we focused on the ability to segment words into phonemic constituents. Phonemic awareness was measured by a battery of seven tests of constrained phonemic segmentation, each testing in a different way the child's ability to isolate and manipulate individual phonemes in perceived or self-produced spoken words or to categorize picture names on the basis of their initial phonemes. These tests were chosen because the ability to isolate phonemes was found to have the highest predictive validity for reading acquisition (e.g., Yopp 1988). In addition, these tests did not require subjects to perform cognitive operations other than phonemic segmentation and (in test 5) phonemic categorization (for a survey of various types of segmentation tests see Content et al. 1986; Stanovich, Cunningham, and Cramer 1984; Yopp 1988).

The tests were modifications of similar tests described by Wallach and Wallach (1976), (tests 1 through 5) and Rosner (1975) (tests 6–7):[2]

1. Isolation of the first phoneme in spoken words. The children were instructed to utter the first phoneme in words pronounced by the examiner. This test contained 20 uni-syllabic and 20 bi-syllabic words. Some began with a CV sequence (e.g., "DOG"—correct answer /d/), some with a CC sequence (e.g., "STAR"—correct answer /s/), and some with a VC sequence (e.g., "ARM"—correct answer /a/).
2. Isolation of the first phoneme in self generated pictures' names. The children were shown pictures of common objects and asked to pronounce the first phoneme of each object's name. (For example, the children were shown a picture of a dog, and they had to respond /d/). This test contained 20 items.
3. Isolation of the last phoneme in spoken words. Similar to test 1 except that the last phoneme had to be isolated. The words were different than in test 1. Some of the words ended with a CV (e.g., "HERO"—correct answer /o/) sequence and some with a VC sequence (e.g., "MAN"—correct answer /n/). This test contained 20 items.
4. Isolation of the last phoneme in self generated pictures' names. Similar to test 2 except that the last phoneme in the name of each object had to be isolated (For example a picture of a hammer was shown and the children were expected to respond /r/).

[2]Examples will be provided in English because we feel that the Hebrew version would be difficult to follow.

This test contained 20 objects that were different from those in test 2.

5. Picture names matching. In each trial the children saw a series of four pictures each representing a drawing of a common object. The task was to select the two objects (out of the four) whose name started with the same phoneme (For example seeing pictures of a flag, a table, a car, and a finger, the children had to take apart the flag and the finger). There were 16 series of pictures in this test.
6. "Find the missing sound." In each trial the children were presented with a meaningless phonological structure uttered by the experimenter. Adding one phoneme at the beginning of the meaningless structure would form the name of a common object which was simultaneously shown in a picture. The children were instructed to utter only the missing sound. For example, the experimenter would say /ook/ showing a book. The expected response in this trial was /b/. This test contained 30 items.
7. "What is left." In each trial the experimenter pronounced a word, followed by the phonological pattern that results when the last phoneme is taken out. In no case did their pattern have a meaning. The children were asked to say what was left out. For example the experimenter says "cat" followed by /ca/, and the expected response was /t/. There were 20 items in this test.

The words and object names were selected in collaboration with teachers in the respective grades to be part of the children's vocabulary. They were uni- to three-syllabic words. Tests 1 through 4 were used both before and after training (presenting different items each time). Test 5 was presented only in the initial battery, and tests 6 and 7 were given only after training. Like the first four, tests 6 and 7 examined awareness to single phonemes, but the testing procedure was considerably different. Because the training procedures included direct segmentation of initial and last phonemes in spoken words (see below), training might have had specific effects on test performance. On the other hand, the addition of the new tests allowed us to examine whether the children indeed improved basic phonemic segmentation skills and whether they were able to use these skills in new situations.

Each response was scored on a scale of 1 to 4. Correct phonemic segmentation was scored "1." Isolation of a CV segment (sub-syllabic segmentation) was scored "2." Syllabic segmentation was scored "3." Random segmentation, or complete failure was scored "4." The phonemic awareness score of each child was the percentage of correct responses across all tests presented at that time. In addition, the percent-

ages of all other response types were calculated and used at different levels of data analysis.

Reading Tests. Two reading tests were composed specifically for the purposes of this study. Both included single printed items that the child was instructed to decipher and read aloud. Each item was printed on a separate card, using a familiar font that presented the consonantal letters in conjunction with the diacritical marks that represent the vowels in Hebrew orthography (points). Note that in Hebrew all words are orthographically regular, and when the points are present, the pronunciation is unequivocally dictated by the print.

There were four sub-tests distinguished by the type of items. Two sub-tests included words and two nonwords (i.e., legal and pronounceable but meaningless phonological patterns). The distinction between words and nonwords was made in order to shed more light on the role of phonemic awareness on early reading ability. If phonemic segmentation skills are required only to facilitate grapheme-to-phoneme translation, no interaction should exist between the effect of training-group and the lexical value of the stimulus. In addition, a better performance in reading words than nonwords would suggest that addressed-phonology-based reading strategies are used from the early beginning. Within each stimulus type, one sub-test included one-syllable items and the second, two-syllable items. This manipulation was included to have a better gradient of difficulty avoiding floor or ceiling effects. The reading tests were compiled in collaboration with the classroom teachers, to include all the CV combinations that the children were supposed to know at the testing time. Reading was tested only in school. The first reading test (Reading test 1) was administered in December after four months of reading instruction, and the second (Reading test 2) at the end of the year.

Design. To be included in the experimental groups a child had to meet two criteria: To be on the lowest quartile on percentage of "1" scores and on the highest quartile of "4" scores. Thus, we ensured that the experimental children were at the lower end of the phonemic ability distribution.

Four intervention groups were formed by randomly assigning children to the different training treatments (see below). The groups were matched for age, initial phonological awareness ability, and general intelligence, as assessed by Raven Colored Matrixes (Table 1). A fifth group ($n = 17$) was selected among the children who were in the upper end of the phonological awareness distribution. These children were not approached during the training period, but were tested for reading during the first grade in school. The training-group was the major independent factor tested by ANOVA.

Testing Procedures. The phonological awareness of all the children

Table I
The Number of Subjects (boys), Their Age and IQ Transformation of Raven Colored Matrixes Test in the Four Experimental Groups

	Training Group			
	Group I	Group II	Group III	Group IV
N (boys)	25 (13)	25 (15)	25 (15)	16 (9)
Age (in months)	66.5	66.96	66.87	66.5
range	61–74	61–72	61–77	59–74
Raven scores	18.9	20.3	19.6	20.6

was initially assessed during the last three weeks of November, three months after the beginning of the school year. In addition to the first five among the seven tests described above, a blending test was also used, but was discarded because of ceiling effects. All tests were run in random order individually to each subject. The testers were students of a teachers' seminary who were specially trained and randomly assigned to kindergartens. They were naive about the purpose of the study and the specific predication until after the second testing session.

The first step in a testing session was to show the child all the pictures and ask him to name them one by one. The purpose of this step was to verify that the child recognized the pictures and knew the respective names. Each test began with a task demonstration followed by five practice trials to which the child responded and received feedback. If the response was wrong, it was corrected and explained. Practice continued if the experimenter was not convinced that the child understood the task. Following practice, the test trials were given without any time constraints. During testing, no feedback was provided except to encourage the subject to continue and maintain attention. The administration of the whole battery lasted about 30 minutes.

The second test of phonological awareness was administered towards the end of the year following training. It included tests 1 to 4 and tests 6 and 7. The testing procedure and scoring were identical to the initial testing phase.

Reading was tested individually at school in a quiet room. Each testing period lasted two weeks. Two trained seminary students participated in testing. One communicated with the subjects and administered the test, whereas the second, sitting aside, registered verbatim the children's responses. Scoring was done off line by one author (HL) who was not aware of the child group assignment.

Training Procedures. The intervention included two half-hours meetings per week, in groups of up to four children, during a period of

ten weeks towards the end of the school year. Two seminary students were assigned to each kindergarten. They were responsible for conducting all training procedures and for testing the children at the end of the training period. Each group was trained differently, as follows[3]:

A. *Group I—Phonemic segmentation.* This group was trained to recognize a single phoneme in words. Training procedures included, for example, categorizing objects by their first or last phoneme, finding words that contain a pre-uttered target phone, etc. Training was gradual, starting with distinctions between long and short words, paying attention to repetitive phonemes, and ending with direct training of phonemic segmentation using colored tokens to represent phonemes.

B. *Group II—Phonemic segmentation + Letter shapes.* This group was trained identically to Group I except that they were also exposed to the shape of the letters that represented the phonemic segments that they successfully isolated. This manipulation was included because previous training programs suggested that it could amplify the effect of training phonological awareness on reading acquisition (e.g., Bradley and Bryant 1983).

C. *Group III—General language skills.* The children in this group were trained for comprehension of spoken sentences, their vocabulary was enlarged, and they were taught correct sentence structure and syntactic rules. For example, children were trained to complete sentences with an appropriate cloze in some cases or with missing function words in other cases. Additional training included learning new words and forming sentences with these words, or generating sentences to convey meanings expressed by the teacher. This was a control group aimed at disentangling the effect of specific training of phonological awareness from that of general improvement of linguistic skills.

D. *Group IV—No specific training.* This was a second control group. The children in this group had about an equal amount of time in small groups with the training teachers, but their training included an additional normal kindergarten curricular activity.

Results

Phonological Awareness Before and After Training. Table II presents the percentage of each response type in each test, and the average percentage across the tests for the entire population at initial assessment of phonological awareness. The percentage of responses of Type 1 (cor-

[3]The details of the training procedures are available from the second author by request.

Table II
The Percentage (SD) of Each Response Type in Each Test at the Initial Assessment of Phonological Awareness of the Entire Population (n = 508)

	Response Type			
	Phonemic Segmentation	Subsyllabic Segmentation	Syllabic Segmentation	Random Response
Test 1	27.9 (18.6)	28.8 (11.4)	23.2 (14.3)	20.2 (17.2)
Test 2	25.7 (16.2)	50.1 (17.6)	9.4 (9.6)	13.5 (15.6)
Test 3	4.9 (16.5)	55.5 (30.2)	0.3 (3.1)	39.3 (30.3)
Test 4	20.3 (25.3)	19.1 (17.8)	20.2 (17.8)	39.8 (36.3)
Test 5	18.4 (23.6)	25.3 (20.4)	14.3 (12.8)	40.6 (35.8)
Mean Score	19.46	35.76	13.48	30.68

rect phonemic segmentation) and of Type 4 (complete failure) in each of the experimental groups is presented in Table III. Using the percentage of Type 1 responses as the measure of phonemic awareness, ANOVA showed that the pretraining phonemic awareness in the three groups was similar [$F(3,91) = 1.72$, $MSe = 28.4$, $p > .16$].

The consequences of the training regimen in the four groups are graphically presented in Figure 2. Clearly, phonological awareness improved in groups I and II where phonemic segmentation ability was explicitly trained, but not in groups III and IV where segmentation skills were not trained. The statistical reliability of these effects was tested by a mixed-model ANOVA followed by post hoc HSD (Tukey-A) comparisons. The between factor was the training group, and the repeated factor was the testing session (pre- or post-training). This analysis showed that both main effects were significant [$F(3,91) = 11.81$, $MSe = 327.3$, $p < .0001$ and $F(1,91) = 64.67$, $MSe = 279.2$, $p < .0001$ for the training group and testing session, respectively]. However, a significant interaction showed that the groups were differently affected by training [$F(3,91) = 10.70$, $MSe = 279.2$, $p < .0001$]. Post-hoc compari-

Table III
The Distribution of Type 1 (phonemic segmentation) and Type 4 (random) Responses Among the Four Training Groups

	Training Group			
Response	Group I	Group II	Group III	Group IV
Type 1	11.9%	9.4%	10.6%	9.5%
Type 4	39.4%	42.8%	34.6%	38.7%

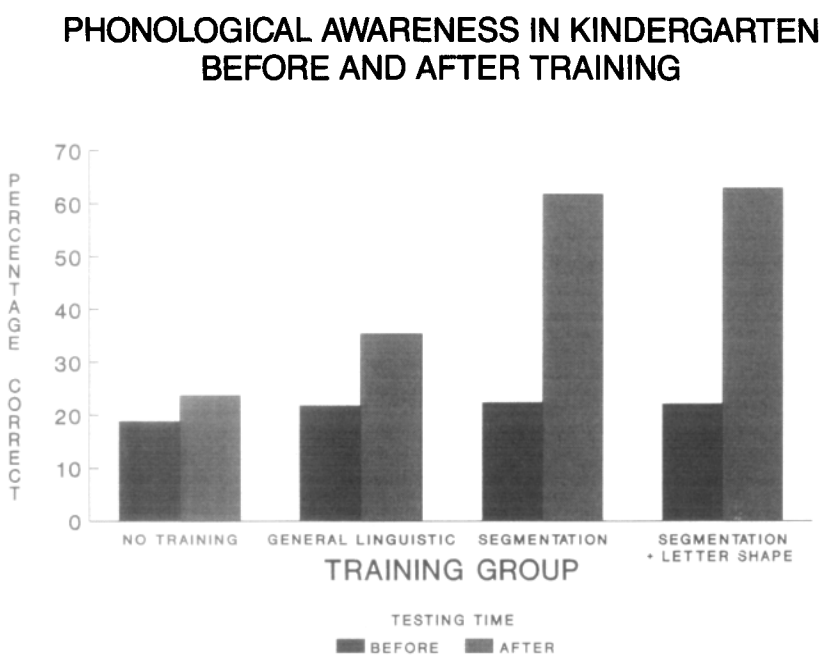

Figure 2. The results of training phonemic segmentation skills on phonological awareness scores.

sons revealed that the training effect was reliable in group I (32.5 percent) and group II (35.4 percent), but not in group III (8.2 percent) and group IV (3.7 percent) [HSD ($p < .05$) = 11.6]. In addition one-way ANOVA of the post-training scores showed that, at that time, the phonological awareness in groups I (61.7 percent) and II (62.8 percent) was significantly higher than in groups III (35.4 percent) and IV (23.7 percent). Finally a comparison between the post-training phonological awareness results of the children who were trained on phonemic segmentation and children who were initially high in segmentation skills revealed that the two groups were not significantly different [$F(1,42) < 1.00$].

Reading Acquisition and Reading Ability.[4] The reading scores of each group after four months and nine months of reading instruction are presented in Figures 3 and 4. The effect of lexical status (word/non-

[4]As frequently happens in longitudinal studies some children who were included in the experimental groups were not available for testing during the school year, while others were available only at some testing sessions but not for all. The data is presented and analyzed using the maximal number of children that were tested in each condition, as revealed by the degrees of freedom. Across tests analyses included only children who participated in all the testing sessions.

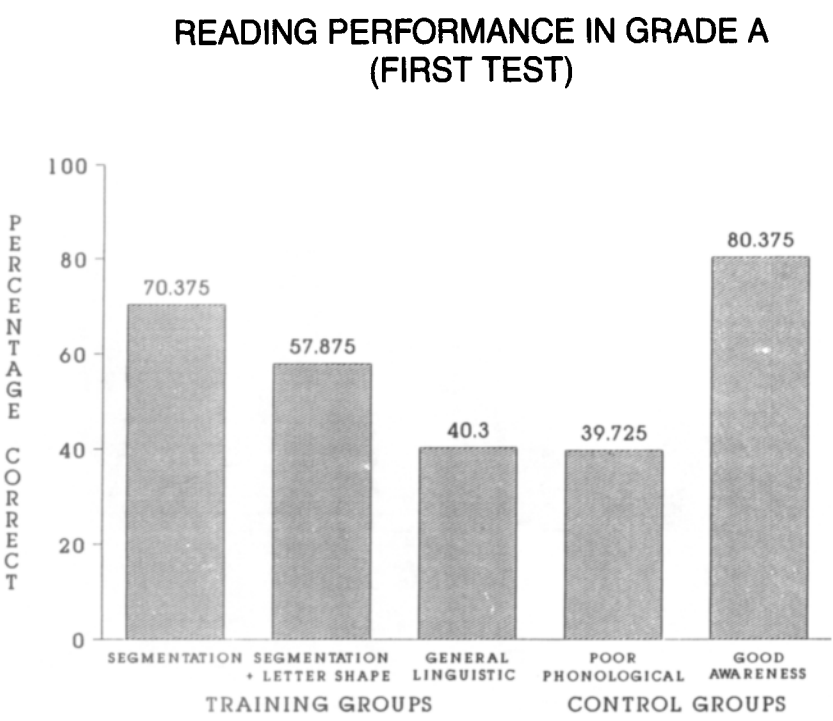

Figure 3. The results of training phonemic segmentation skills in the kindergarten on reading performance after four months of reading instruction.

word) and phonological structure (one/two syllables) on reading ability is evident in Table IV.

In order to compare our results with previously published data regarding the relation between phonological awareness and reading ability, we computed the linear correlation between the phonological awareness score obtained at the beginning of the kindergarten year and reading scores. Obviously, children who were trained during kindergarten were excluded from this analysis. Hence, it included only groups IV and V (the low and high phonological awareness groups that have not been trained), and an additional group of 52 children from the original population whom we could find and test during first grade. A positive and statistically significant ($p < .01$) correlation was found between initial percentage of Type 1 (phonemic segmentation responses) responses and reading scores after five months of reading instruction ($r = .55$, $df = 58$, $p < .0005$), and after eight months of reading instruction ($r = .35$, $df = 72$, $p < .005$). Lower, but still highly significant correlations, were found between the percentage of Type 2

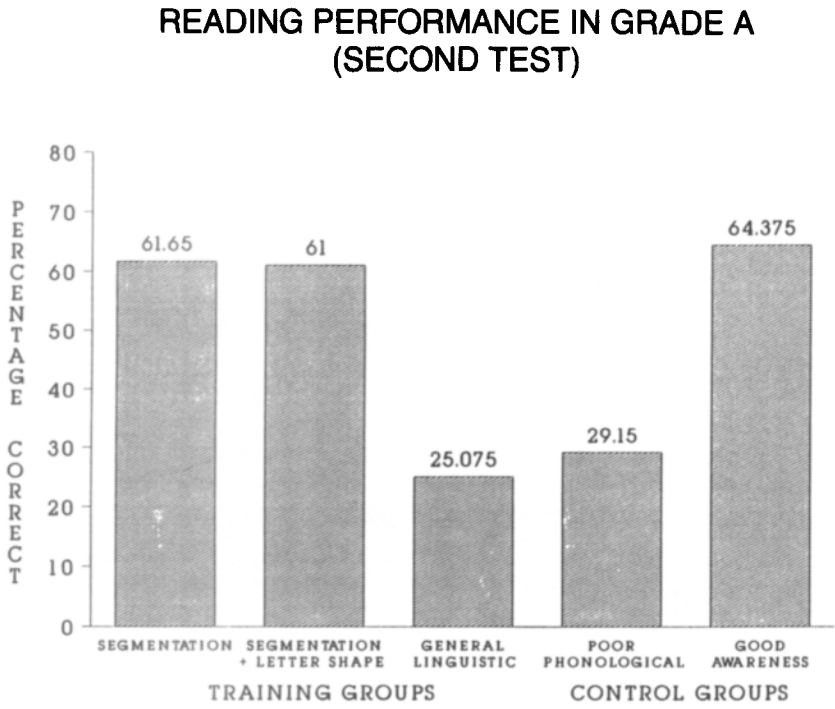

Figure 4. The results of training phonemic segmentation skills in the kindergarten on reading performance after nine months of reading instruction.

(CV sub-syllabic segmentation) and the first reading test ($r = .36$, $df = 58$, $p < .005$) but not with the second reading test ($r = .19$, $df = 72$, NS). In contrast, there was no correlation between Type 3 responses (syllabic segmentation) and reading score either at the first ($r = -.02$) or at the second reading test ($r = .00$).

The influence of training phonemic segmentation skills on reading performance was tested by comparing the reading scores in the four training groups and in the fifth group that included children who scored high on the initial phonological awareness test. Clearly, children who started the reading instruction process with relatively higher phonological awareness performed better in reading tests than children who started with a relatively lower phonological awareness. This trend held regardless of whether pre-school phonemic awareness was enhanced by explicit training (groups I and II) or whether it developed without any formal instruction (group V). This effect was observed throughout the first grade (Figures 3 and 4).

Because the reading tests after four and after nine months of read-

Table IV
Percentage of Correctly Read Items (SEm) of Each Stimulus Type after Four Months and Nine Months of Reading Instruction

Stimulus Type	Group I	Group II	Group III	Group IV	Group V
			First Reading Test		
Words					
One Syllable	85.5 (4.7)	76.7 (8.5)	63.4 (8.5)	59.9 (6.3)	94.5 (2.0)
Two Syllables	72.9 (4.9)	66.1 (7.9)	46.2 (7.8)	46.3 (7.4)	87.1 (3.7)
Nonwords					
One Syllable	64.7 (7.9)	43.4 (9.7)	26.1 (7.0)	28.3 (8.2)	75.0 (5.2)
Two Syllables	58.4 (7.8)	45.3 (9.7)	25.5 (7.2)	24.4 (8.5)	64.9 (7.7)
			Second Reading Test		
Words					
One Syllable	66.6 (6.0)	70.7 (5.7)	35.2 (6.1)	38.6 (11.)	68.2 (4.8)
Two Syllables	63.9 (5.6)	66.2 (7.8)	21.8 (4.2)	29.6 (10.)	64.4 (4.5)
Nonwords					
One Syllable	63.4 (6.3)	59.6 (7.7)	27.0 (5.3)	28.8 (11.)	67.4 (6.8)
Two Syllables	52.7 (5.8)	47.5 (9.7)	16.3 (3.5)	19.6 (8.6)	57.5 (7.5)

Note: Different tests were given each time, to correspond with the respective reading level. (Group V included children that scored high in the initial assessment of phonological awareness in kindergarten).

ing instruction differed in complexity, a direct comparison between them was not informative. Therefore, the statistical reliability of the observed differences was examined separately for each session by two-way mixed-model ANOVA. The between-subjects factor was training group, and the within-subjects factor was stimulus type. These ANOVAs showed that the training effect on reading was reliable both after four months of reading instruction [$F(4.64) = 6.47$, $MSe = 2552$, $p < .0002$] and at the end of the first year in school [$F(4,69) = 11.02$, $MSe = 2115$, $p < .0001$]. For both tests, there was a significant effect of stimulus type [$F(3,192) = 68.33$, $MSe = 218.8$, $p < .0001$, and $F(3,207 = 18.17$, $MSe = 190.2$, $p < .0001$ for the first and second test, respectively]. No interactions were found between the training effect and stimulus type. Post-hoc comparisons revealed that the reading performance of children who were trained for phonemic segmentation and children who were trained for phonemic segmentation and were also taught the letter shapes in the kindergarten was similar (65.17 percent and 61.34 percent, respectively). The reading performance of these children was similar to the children who were initially high in phonological awareness (73.76 percent). The reading ability of children who were trained only for general linguistic skills or were not trained at all was significantly inferior to that of the other three groups without a reliable difference among themselves [HSD ($p < .05$) = 20.9 percent]. Post-hoc analyses of the stimulus type effects revealed that at the first test all children read words better than nonwords and one-syllable words better than two-syllables words. Number of syllables did not influence performance with nonwords [HSD ($p < .01$) = 7.83]. At the end of the year, however, the number of syllables was more influential: For both words and nonwords one-syllable items were read more accurately than two syllable items. On the other hand, one-syllable nonwords were read as well as two syllable words [HSD ($p < .01$) = 7.05].

Although, as mentioned above, a direct comparison of reading performance in the two tests was meaningless, we have combined the results of the two tests in a two-factors mixed-model ANOVA in order to examine the possibility that the training had a different effect on reading later in the year than earlier. The between-subjects factor was the training-group and the within-subjects factor was the testing session. This analysis revealed a tendency for the training group effect to be bigger at the end of the year than after four months, but this interaction only approached significance [$F(4,54) = 2.42$, $MSe = 557.7$, $p < .06$].

Discussion

The present study supports the view that phonemic segmentation skills and reading acquisition are highly interrelated. It appears that

learning to read is the main factor accounting for the sharp increase in phonological awareness that was frequently observed between six and seven years of age. Moreover, the present results provide strong empirical support for previous claims that reading acquisition is facilitated by prior training of phonological awareness. In particular, our results point to the ability to isolate and manipulate single phonemes in words as a major factor influencing reading acquisition.

On the other hand, it is noteworthy that in both tests children read words much better than nonwords. Because the nonwords that we used were all regular and were formed to include the same consonants + vowel dots as the words, the word superiority effects suggest that even for beginner readers reading is not simply a pre-lexical grapheme-to-phoneme translation process. Rather, it is probably a complex process in which multi-phonemic orthographic patterns are very quickly incorporated in the lexicon and support the deciphering of print in a top-bottom manner. Apparently this process is effective from the earliest stages of reading.

Our findings converge with other recently published studies of phonological training and reading acquisition (e.g., Ball and Blachman 1991; Lundberg, Frost, and Peterson 1988). First, we found that children who performed poorly in the initial test of phonological awareness and were not trained to improve their phonological skills (Groups III and IV) did not pass (in absolute scores) the reading tests in school. Obviously, because our tests were not standardized, we should consider any absolute scores with extreme caution. Recall, however, that our reading tests were constructed in collaboration with the classroom teachers in several schools, and reflected the expected reading level at each testing time. Second, supporting previous reports, our data show that improving the phonological skills of children who were initially at the lower end of the phonological awareness distribution, significantly facilitated reading acquisition. In contrast to groups III and IV, all the children who were trained and improved their phonemic segmentation skills passed the tests at a level that was close to that of children with higher initial level of phonological awareness.

An interesting addition of our study to previous findings is that it was done in Hebrew. As mentioned in the introduction, because Hebrew vowels are not represented by letters, even when using an "analytic" approach to reading instruction, teachers in Israel very commonly use CV sub-syllabic segments as the basic units. This procedure may account for the fact that although in the kindergarten the percentage of sub-syllabic segmentation was already three times as frequent as syllabic segmentation (Table II), an analysis of errors made by children in a different study suggested that, in Israeli students, reading acquisition in first grade increased the percentage of CV sub-syllabic errors

even more (Bentin, Hammer, and Cahan 1991). This trend contrasts with trends found in other languages in which the percentage of subsyllabic segmentation decreased during the first grade (Cossu et al. 1988). Nevertheless, we found that phonemic, rather than subsyllabic segmentation ability, best predicts reading performance during first grade. Hence, the present data contribute evidence that despite the orthography, reading acquisition requires awareness of the basic units of speech, the phonemes.

We are apparently left, then, with a puzzle: On the one hand, Bertelson, Morais, and their colleagues have shown that phoneme segmentation skills do not normally develop without some reading instruction (e.g., Bertelson et al. 1985; Morais et al. 1979). Consistent with this hypothesis, Bentin, Hammer, and Cahan (1991) found that schooling is indeed the major factor that enhances phonological awareness. On the other hand, however, our present data also show that children who lack phonemic awareness risk developing reading disabilities and that this risk can be attenuated or even completely prevented by training phonemic segmentation skills in the kindergarten. The latter data suggest that awareness of phonemic segments is a necessary condition for reading acquisition.

How can phonemic skills be a cause and an effect at the same time? A way out of this apparent paradox is provided by a recent study by Bertelson et al. (1989) who suggested that phonologic awareness is a heterogeneous (as opposed to a unitary) ability. Some forms of phonological awareness such as the ability to manipulate words' onset and rime (see Kirtley et al. 1989; MacLean, Bryant, and Bradley 1987) may develop in young children, independently of reading. These abilities may be the foundation on which phonemic awareness can be developed. We suggest that phonemic awareness is a necessary condition for normal reading acquisition, and in most children it is a consequence of reading instruction. If the basic phonological skills are normally developed, phonemic awareness is triggered automatically by exposure to the alphabetic principle. Reading disorders may occur if the basic phonological skills are absent and phonemic awareness is not automatically triggered. In such a case, it is necessary to help the child develop phonemic awareness by explicit and direct training. Our present study, as well as previous studies of training phonological skills, demonstrate that phonemic segmentation skills can be developed prior to reading instruction and that such training may help prevent reading disorders of this nature.

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