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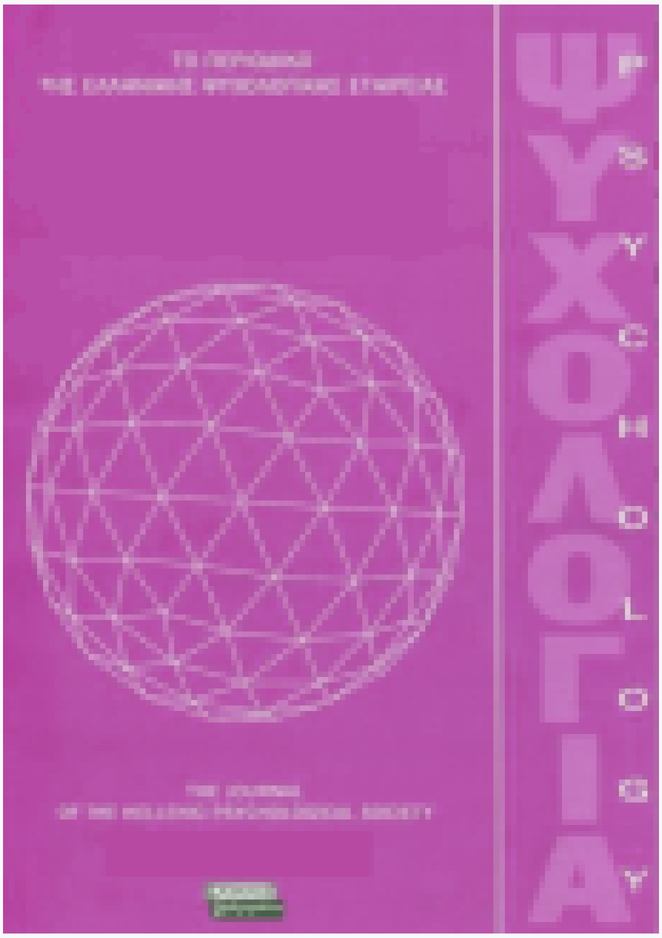

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The effectiveness of kindergarten programs which aim at preventing reading and spelling problems in school: A comparison of three different approaches

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ABSTRACT A training study was conducted in German kindergartens to explore the efficiency of programs that aim at preventing subsequent reading and spelling problems. There were two major research goals. First, the general assumption was tested that training programs focusing on children's phonological awareness and letter knowledge should help in preventing subsequent reading and spelling problems in elementary school. Second, the validity of the so-called 'phonological linkage hypothesis' (Hatcher, Hulme, & Ellis, 1994) was addressed. That is, it was assumed that a combination of phonological awareness and letter-sound training should be more successful than phonological awareness and letter-sound training alone. Three groups of children at risk for dyslexia were randomly assigned to these three training approaches and compared with a control group of 'normal' kindergarten children. As a main result, it was found that both assumptions could be confirmed. All of the three training approaches were successful in that they raised children's levels of phonological awareness and/or letter knowledge and thus decreased children's risk of becoming dyslexic at school. Overall, the combined training program was most successful, confirming the 'phonological linkage hypothesis' and indicating that linking phonological awareness training with the instruction of letter-sound correspondence rules yields rather powerful effects in children at risk for dyslexia.

Keywords: Children at risk for dyslexia, Kindergarten prevention programs.

Research on the acquisition of literacy conducted within the last two decades indicates that *phonological awareness* undoubtedly plays an important role in the acquisition of reading and spelling (e.g., Bradley & Bryant, 1985; Goswami & Bryant, 1990; Lundberg, Frost, & Petersen, 1988; Schneider, 1989; Tornéus, 1984; Wagner & Torgesen, 1987). Phonological awareness refers to the ability to reflect on the sound structure of spoken language and to segment speech into linguistic units such as syllables or phonemes. Meanwhile, numerous studies have shown that it is important for the beginning reader to get insight into the sound structure of language in order to acquire the alphabetic principle.

The findings of several recent longitudinal training studies indicate that phonological competencies can be taught successfully and that children's subsequent reading and spelling performance could be enhanced (e.g., Bradley & Bryant, 1985; Kozminsky & Kozminsky, 1995; Lundberg, Frost, & Peterson, 1988; Schneider, Kuespert, Roth, Visé, & Marx, 1997). However, a closer look at the results of this kind of literacy research indicates that the most impressive findings stem from intervention studies where children received a combined training program

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emphasizing the integration of phonological skills with letter knowledge (Ball & Blachman, 1991; Bradley & Bryant, 1985; Byrne & Fielding-Barnsley, 1989; Cunningham, 1990).

The by now classic intervention study supporting this view was carried out by Bradley and Bryant (1985) who examined effects of a training in sound categorization on reading and spelling performance. Sound categorization requires the ability to detect alliteration and rhyme. A total of 65 preschool children who were poor at sound categorization participated in the study. There were two experimental conditions: A first training group (N = 13) was instructed in sound categorization only. The second group (N = 13) categorized sounds by using plastic letters additionally in order to make clear the grapheme-phoneme correspondences. Moreover, there were two control conditions: The third group (N = 26) received a training in conceptual categorization, and the fourth group (N = 13) served control purposes in that no training program was conducted.

Although both the sound categorization group and the group with the combined training program performed significantly better on reading and spelling measures than both control groups in posttests, only those children who received training in sound categorization *and* instruction in grapheme-phoneme correspondences outperformed all other children of the remaining groups on reading and spelling measures in the long-term analyses (Bradley, 1988).

Similar results were found in the training study by Ball and Blachman (1991). These authors evaluated the effects of an intervention program that connected training in phoneme segmentation with instruction in letter-sound correspondences on kindergarten children's early reading and spelling skills. Eighty-nine preschool children participated in the study and were divided into three groups. The first group received training in segmenting words into phonemes *and* additionally instruction in letter-sound-correspondences (N = 29). The second group was only instructed in correspondences between letter names and letter sounds (N = 30). The third group was the control group and received no intervention (N = 30). Training outcomes indicated that phonological awareness training connected with instruction in letter-sound correspondences significantly improved early reading and spelling skills of the preschool children. However, instruction in letter names and letter sounds alone did not significantly improve phonological skills, reading or spelling skills.

These research findings support the conclusion that phonological awareness seems necessary but not sufficient for reading and spelling acquisition (see also Bus & van Ijzendoorn, 1999). Similarly, knowledge of letter-sound correspondences alone may also not be sufficient. The findings outlined above indicate that the most effective way to facilitate and improve children's literacy acquisition is to integrate phonological training with letter-sound training. As a consequence, Hatcher, Hulme, and Ellis (1994) developed what they called the "phonological linkage hypothesis" which suggests that an intervention involving a combination of phonological awareness training and letter-sound instruction (or more broadly reading instruction) should be more effective than an intervention involving either phonological awareness training or letter-sound instruction (respectively reading instruction) alone.

Hatcher et al. (1994) evaluated the phonological linkage hypothesis in a longitudinal intervention study. Participants were 124 poor readers who were at the early stage of reading instruction. There were four groups. Children of the first group received a reading instruction combined with phonological awareness training (N = 32), the second group was only instructed in reading (N = 31), the third group was only instructed in phonological awareness (N = 30), and finally a control group received no specific intervention (N = 31). In accord with the phonological linkage hypothesis, only children who received the combined training program that emphasized the connection between phonological awareness *and* reading skills significantly outperformed the control children in reading and spelling immediately after the intervention and in the follow-up analysis.

Hatcher et al. (1994) also explored the question whether the combined training program was more effective because this program was more effective in improving phonological skills than was the phonological awareness training alone. However, this hypothesis had to be rejected because the largest improvement in phonological awareness tasks was found in the phonological awareness group, and not in the phonological linkage group.

Overall, these training outcomes support the phonological linkage hypothesis. In order to obtain optimal training effects on subsequent reading and spelling, a training in phonological awareness should be explicitly connected with the teaching in literacy skills.

Based on these impressive research findings, we decided to carry out a training study that proves the validity of the phonological linkage hypothesis for German-speaking children. We were interested in the issue whether training outcomes for the English language could be also transferred to the German language. Like Hatcher et al. (1994) we chose three teaching conditions and one control condition: (1) training in phonological awareness alone, (2) both training in phonological awareness and instruction in letter-sound correspondences, (3) training in letter-sound correspondences alone, and (4) no specific intervention.

A specific concern of our study was the early intervention for "at risk" children who would probably develop reading and/or spelling disorders in school. One reason was that the prevalence rate of students with difficulties in the acquisition of literacy is about 15 percent per classroom, and reading and spelling disorders are often resistant to remedation with increasing years of schooling (Marx, 1992). Because of these problems, we considered it important to detect and prevent literacy acquisition problems as early as possible.

In summary, our longitudinal training study had two main goals: First, training programs were implemented that aimed at improving phonological awareness and letter knowledge in children-at-risk. We assumed that such programs should facilitate literacy acquisition and help in preventing the development of reading and spelling disorders in at-risk children. Second, the validity of the phonological linkage hypothesis was examined for a sample of German children. It was assumed that a combination of phonological awareness and letter-sound training represents the most effective way to improving young children-at-risk's literacy acquisition.

Method

Participants and Design

Participants of the experimental groups were 208 preliterate kindergarteners with an average age of five years and eleven months who were identified as "at risk" children by a revised version of the Bielefeld Screening Battery (Jansen, Mannhaupt, Marx, & Skowronek, 1998). These children were selected from a total of 726 kindergarten and represented the subgroup with the lowest phonological processing scores (i.e., bottom quartile of the distribution). They attended 25 kindergartens in the south-east of Wuerzburg. The children-at-risk were assigned to one of three training conditions: 82 children participated in the phonological awareness training, 77 children received both training in phonological awareness and in letter-sound correspondences, and finally 49 children were only taught letter-sound-correspondences. The training programs were conducted by the kindergarten teachers who had received careful instruction by our research team. The phonological awareness training and the combined training programs were spread over 20 weeks. The letter-sound training took about 10 weeks.

In addition to the three training groups, 146 unselected preschool children who attended six kindergartens in the north of Wuerzburg were recruited for the control group. Because of ethical reasons we decided to choose no "at risk" children for the control group but to compare the development of trained at-risk children with that of 'normal' controls. Overall, 354 kindergarten children were included in the study.

Immediately before the beginning of the training period, a pretest was given to all children which was similar to that used by Lundberg et al. (1988) and was adopted from Schneider et al. (1997). The pretest measures focused on indicators of phonological awareness but also included measures of phonological memory and information processing speed. In addition, children's vocabulary and their letter knowledge as well as their early reading skills were assessed. The same tests were also used as posttests immediately after completion of the training period, that is, about six months after the pretests. Another four months later, a transfer test was given at the beginning of first grade which assessed children's phonological awareness using different and more difficult test materials. At the end of grades 1 and 2, standardized tests of reading and spelling were provided to assess long-term training effects on the acquisition of literacy. During the kindergarten period of the study, care was taken to ensure that there was no opportunity for the kindergarten teachers of the training groups and the control group to exchange information on the different training programs and their purposes.

The dropout rate corresponded to usual in this kind of research figures. From pre- to posttests we lost a total of 22 children. Thus, only 193 of 208 children-at-risk and 139 of 146 control children participated in both pre- and posttests. Whereas nine children moved away from the Wuerzburg area, five children quit the training programs for various reasons (e.g., because of emotional and behavioural disorders). Eight children could not be post-tested anymore because they went on holidays while this part of the study was completed. The largest proportion of children was lost during the period between the end of kindergarten and the beginning of school (N = 49). A total of 21 trained children were lost because their families left the area. From the 146 children originally recruited for the control group, a total of 31 had dropped out by the end of grade 2. Thus complete data sets from 138 children at risk and from 115 control children were available for the analysis of reading and spelling data obtained during the end of grade 2.

Instruments

The Bielefeld Screening Battery. The main purpose of the Bielefeld Screening Battery concerns the early identification of children-at-risk who will probably develop reading and spelling problems in school. Thus, the screening procedure contains subtests assessing phonological information-processing skills and visual attention that are significant for literacy acquisition. The subtests were constructed to produce ceiling effects in the sample in order to discriminate well in the lower third of the distribution (Jansen, Mannhaupt, Marx, & Skowronek, 1998).

Four subtests assessed *phonological awareness:* First, in the *rhyme production* task the child had to produce rhyming pairs finding a word or non-word that sounded similar to a given word (e.g., "What sounds similar to *ball*?"). Second, the *rhyme matching* task required the comparison of an orally given standard word with four pictorially represented words that were phonological or semantically related to the standard word. The child had to detect which pictorially represented word sounded similar to the orally given word. Third, a *syllable segmentation* task was given where the child had to break two-, three-, and four-syllabic words into separate syllables by using plastic coins to mark each syllable. Fourth, a *phoneme-word matching* task was presented where the child had to decide whether an isolated vowel that was spoken out aloud occurred in one of two pictorially and orally given words (e.g., "Can you hear an */a/* in *cake* or in *dog*?). Each subtest consisted of three practice and 12 test items. The amount of right answers was registered in each case.

Phonetic recoding in working memory was assessed with the subtest *repeating pseudowords*. The child had to repeat a pseudoword that consisted of three to five syllables (e.g., "ki-blo-sa" or "wut-za-tri-no-was"). This task tested the precision in articulating unknown words. There were three practice and 12 experimental trials. The total number of correctly segmented words served as dependent variable.

Speed of access to phonological information (in accessing the semantic lexicon) was administered by two subtests called *rapid naming* of colours. In the first subtest, children had to name the colours of 24 uncoloured objects (plum, lemon, tomato, and salad) as quickly as possible. In the second subtest, the objects were drawn in wrong colours (e.g., a blue lemon) and the child had to name the correct colours of the objects. Both accuracy (number of errors) and speed of naming were recorded.

Finally, *visual attention* was assessed by a *word matching* task. Each child received a set of cards (four practice and 12 experimental trials). A four-letter meaningful word (target) was written on top of each card, and four alternative words that corresponded in all, three, two or one letters with the target word were written below on the next line. For instance, the target word 'lion' was given on top, and the line below included the words 'leon', 'lian', 'liom', and 'lion'. The children's task was to detect the word in this line that was identical to the target word. The number of correct answers was recorded. The screening procedure lasted for about 30 minutes and was administered individually in a separate room of the kindergarten.

Pre- and posttests. Pre- and posttest measures were conducted individually. The administration of the complete test took about 40 minutes (including a short break). Besides phonological abilities, early literacy was assessed. Most subtests tapping phonological awareness were adopted from the training study by Lundberg and colleagues (1988). In the first task, *phoneme blending*, the experimenter pronounced the phonemes of a word in isolation, one phoneme after another. The child's task was to blend the single phonemes and then to select the right word out of four pictures (e.g., "Combine these sounds to a word: /b/-/e/-/d/!"). The task consisted of eight items. In the second task, *phoneme segmentation*, it was the other way around. That is, the child had to divide a simple word into the constituent phonemes and to mark each phoneme with a plastic coin (e.g., "What sounds do you hear in the word *car*?"). Pictures representing the words were shown simultaneously in order to reduce memory load. A total of eight items were presented. The third subtest required the *identification and deletion of initial phoneme* in a word. The child was first asked to identify the initial phoneme of the word that was represented in a picture. Then the child had to delete the initial phoneme and had to name the remaining part of the word (e.g., "What is the first sound in the word *man*?" - "What word would be left if the first sound /m/ were taken away from the word *man*?"). These tasks also consisted of eight items. Finally, the *sound categorization task* of Bradley and Bryant (1985) that taps the ability to detect rhyme and alliteration was added to the pre-/posttest. Only the endsound and firstsound categorization task was used where the child had to find out which word differs from the others in the end sound or in the first sound (e.g., first sound: Tag, Tat, Tal, *Rad*; end sound: Saum, Baum, *Laut*, Raum). Each task consisted of 10 items.

Two tasks were given to assess *early literacy*. *Letter knowledge* was assessed by presenting a set of randomly arranged capital letters. The number of letters correctly identified was the dependent variable. A *word reading task* consisting of seven real words and non-words was given to those children who knew at least three letters. The total number of words read correctly was chosen as the dependent variable.

Metalinguistic transfer test. A battery of *metalinguistic tasks* adopted from Lundberg et al. (1988) and Wimmer, Landerl, Linortner, and Hummer (1991) was administered at the beginning of elementary school. None of the tasks had been practiced in the kindergarten training program. In the first subtest, *initial sound analysis*, children had to draw lines between objects with the same initial sounds. The maximum possible score was 10. A similar task, *identification of end sounds*, required children to draw lines between objects that shared the same end sound. Again, the maximum score was 10. In the new *phoneme analysis task*, children had to segment words into their sounds by using a plastic marker. The words were represented by line drawings to reduce memory load. Ten words were used, yielding a maximum score of 10 for this subtest. In the fourth subtest, *word length analysis*, the children were asked to mark the object whose word had the largest number of sounds from a set of four pictures. Again, the maximum score was 10. In the subtest *supply of initial consonant* (Stanovich, Cunningham, & Cramer, 1984), children were first provided with a word pair (e.g., man – an) and were asked to identify the initial sound that produced the difference between the two words. The number of correct answers (max = 10) was the dependent variable. Finally, the subtest *vowel substitution* (Wimmer et al., 1991) required children to replace the vowel 'a' by the vowel 'i' in ten words (e.g., the word 'hand' had to be reproduced as 'hind'). Again, the maximum score was 10.

Nonverbal IQ. Children's nonverbal IQ was assessed by using the Culture Fair Intelligence Test (CFT 1, Cattell, Weiss, & Osterland, 1997).

Tests of reading and spelling skills. The reading test *Würzburger Leise Leseprobe* [Würzburg Silent Reading Test] developed by Küspert and Schneider (1998) was given at the end of grade 2. This test assesses *decoding speed* and consists of 140 lines, with each line composed of a word at the left and four pictures at the right. Whereas one picture contains the target word, the other pictures represent a phonologically similar, a semantically similar, and an unrelated distractor. The children's task is to go through the test as quickly and accurately as possible within 5 minutes, crossing out as many target pictures as possible.

The *Diagnostische Rechtschreibtest DRT 2* [Diagnostic Spelling Test for Second Graders] was given to assess spelling skills at the end of grade 2. This cloze test requires children to fill in missing words. The list of dictated words included both regular and irregular words and also differed widely regarding the degree of familiarity. In total, 32 words had to be filled in by the children, yielding a maximum score of 32.

Training programs

Training in phonological awareness. We adopted the phonological awareness training program by Lundberg, Frost, and Petersen (1988), which was translated and evaluated in preceding intervention studies in Würzburg (Schneider, Küspert, Roth, Visé, & Marx, 1997; Schneider, Visé, Reimers, & Blaesser, 1994). The main goal of the phonological awareness training was to give children insight into the phonological structure of language. The program consisted of six metalinguistic exercise units. In the initial stages, larger units of speech were presented in order to prepare children for smaller phonological units such as phonemes to be introduced later. The first training unit started with easy *listening games* where the children had to identify different verbal and nonverbal sounds. The second unit included *rhyming games*, using nursery rhymes, short stories for rhyme identification and production. Children had to complete sentences by finding rhyming word pairs, or pictures were presented to which rhyming words should be produced. In the next training periods the children were taught to recognize phonological units like *sentences and words*. Children recognized that a sentence consists of different words, and that words can be combined or divided to produce new words ("Snowman" consists of "snow" and "man"). This was followed by games that were focused on *syllable segmentation and blending*. Children segmented short and long words into syllables by clapping hands, dancing and marching around. Vice versa they had to blend single syllables to a word, when a robot produced words in a fragmented, syllable-by-syllable mode (e.g., "kin-der-gar-ten").

In the next period, beginning with the 10th week of training, the smallest phonological unit, the phoneme, was introduced. At first the children were taught to identify and manipulate the *initial phoneme*. Children had to pay attention at the beginning of a given word to discriminate the first sound. They also learned that the initial phoneme could be omitted from a word or added to a word, in order to produce a new word with a different meaning. In the last training unit (at the beginning of the 12th week) games and exercises including *phoneme blending and segmentation* were conducted. Children listened to a hobgoblin who spoke like a robot saying words phoneme by phoneme. The child's task was to blend the single phonemes to a whole word. Vice versa, children themselves had to identify the single phonemes in a word by using coloured bricks to mark the different phonemes. Exercises started with simple vowel-consonant and consonant-vowel words and proceeded to more complex words with three and more phonemes.

Training in phonological awareness and in letter-sound correspondences. In this training condition, the training in phonological awareness described above was combined with the training in letter-sound correspondences. The instruction program in letter-sound correspondences was developed by the authors and was based on the training version by Ball and Blachman (1991). The children were taught 12 letter-sound correspondences that occur most frequently in the German language (A, E, M, I, O, R, U, S, L, B, T, N).

The letter-sound training program contained two steps. First, children were told *letter-sound stories* where they had to produce a certain sound that occurs in the world around us. Next, they had to connect this acoustic sound with the corresponding visual symbol (grapheme-phoneme correspondences). For example, the children imagined a visit at the dentist where they had to articulate the sound "aaa", or children buzzed like a bee ("sss") and were shown the corresponding letter afterwards.

In the second step children learned to discriminate the first sound of a word. This was important in order to connect the initial sound with the corresponding letter. Thus, picture cards were used to produce *initial sound associations*. Children played games where they had to relate the initial phoneme of a pictorially represented word to the corresponding grapheme and vice versa (e.g., an apple for the letter *a*, or a moon for the letter *m*).

Children in the phonological linkage group (combined training) first followed the training in phonological awareness as mentioned above. After ten weeks of training, at about the time when the training unit of identifying the initial phoneme was just introduced, instruction in letter-sound correspondences started and was integrated into the phonological awareness program. From this point on, children were taught both phonological awareness and grapheme-phoneme correspondences.

Training in letter-sound correspondences. Participants of the letter-sound training group received the same instruction program in letter-sound correspondences as the phonological linkage group. Children were instructed in grapheme-phoneme correspondences as described above. This training program period was spread over 10 weeks.

It should be noted that it was difficult to persuade kindergarten teachers to implement the letter-sound training program, because German kindergarten teachers normally reject and actively avoid any school-related activities such as letter teaching in kindergarten programs. This attitude certainly differs from that of British or American kindergarten teachers. Thus, only a comparably small number of 49 children-at-risk could be recruited for the letter-sound instruction program.

Results

In the following, analyses concerning the screening, pre- and posttest measures are reported first, followed by the findings for the metalinguistic transfer test and reading as well as spelling performance in grade 2.

Bielefeld Screening Battery. We expected no substantial differences between the experimental groups on the Bielefeld Screening subtests. Table 1 contains means and standard deviations for the three training groups on the various subtests of the Bielefeld Screening Battery.

A visual inspection of Table 1 indicates that the three training groups did not differ much on

Table 1
Means and standard deviations (in parentheses) for the three training groups (phonological awareness, phonological linkage, letter-sound training) on all measures of the Bielefeld Screening Battery

Variable	Group: Phonological awareness (*N* = 82)	Phonological linkage (*N* = 77)	Letter-sound training (*N* = 49)
(A) Phonological awareness			
Rhyme production (12)	4.22 (4.70)	3.92 (4.54)	5.25 (4.83)
Rhyme matching (12)	5.13 (4.01)	5.12 (3.54)	5.44 (3.67)
Syllable segmentation (12)	6.51 (3.03)	6.51 (2.91)	6.65 (3.20)
Phoneme word matching (12)	8.09 (3.24)	8.60 (2.65)	7.88 (2.34)
(B) Phonetic recording in working memory			
Rereating pseudowords (12)	6.16 (2.77)	5.67 (2.76)	5.54 (3.35)
(C) Speed of access to phonological information			
Rapid naming, uncoloured (in sec)	55.90 (22.39)	59.92 (23.31)	62.06 (23.07)
Rapid naming, coloured (in sec)	82.65 (29.86)	86.59 (33.88)	90.02 (37.27)
(D) Visual attention			
Word matching (12)	7.96 (2.83)	8.07 (2.72)	8.85 (2.52)

Note: Maximum score is given in parentheses after variable name.

the phonological processing and visual attention tasks. This impression was confirmed by subsequent statisitical analyses: One-way analyses of variance with subsequent Student-Newman-Keuls tests yielded no significant differences among the experimental groups on the Bielefeld Screening subtests. Although the screening subtests produce ceiling effects in normal populations, our at-risk children performed rather poorly on most phonological tasks, scoring below average on most phonological awareness tasks.

Pretest measures. Our assumption was that the children-at-risk of the experimental groups should show lower levels of performance than the 'normal' control group on the pretest measures assessing *phonological awareness* and *letter knowledge*. Table 2 presents means and standard deviations for the three experimental groups and the control group on all pretest measures.

Again, a visual inspection of the pretest findings indicates that all children-at-risk had difficulties with mastering the phonological awareness tasks, and that no significant differences between the experimental groups could be found. As expected, children-at-risk's level of phonological awareness seemed less developed than that of the control children.

This was confirmed by statistical analyses. One-way analyses of variance with subsequent Student-Newman-Keuls (SNK) tests indicated that the control group significantly outperformed the experimental groups on most subtests assessing phonological awareness, whereas the three at-risk groups did not differ from each other. The group effects ranged from $F(3, 350) = 4.44$, $p < .01$ for the end sound categorization task to $F(3, 350) = 26.58$, $p < .01$ for the initial phoneme task. Results for the end sound categorization task deviated from the typical

Table 2
Means and standard deviations (in parentheses) for the three experimental groups (phonological awareness, phonological linkage, letter-sound training) and the control group on all measures of the pretest

	Group			
Variable	Phonological awareness (N = 82)	Phonological linkage (N = 77)	Letter-sound training (N = 49)	Control (N = 146)
(A) Phonological awareness				
Phoneme blending (8)	3.48 (1.59)	3.34 (1.59)	3.12 (1.73)	4.02 (1.82)
Phoneme segmentation (8)	0.29 (0.85)	0.18 (0.51)	0.35 (0.93)	1.61 (2.31)
Initial phoneme (8)	0.70 (1.45)	0.44 (0.94)	0.84 (1.66)	2.69 (2.93)
Phoneme deletion (8)	0.05 (0.35)	0.00 (0.00)	0.00 (0.00)	0.55 (1.51)
End sound categorization (10)	1.73 (2.22)	2.23 (2.64)	2.67 (2.93)	3.05 (2.98)
First sound categorization (10)	0.66 (1.30)	0.84 (1.68)	0.82 (1.63)	1.55 (2.12)
(B) Early literacy				
Letter name (26)	2.79 (4.31)	2.44 (3.89)	2.96 (3.66)	5.91 (7.17)
N of word read (7)	0.05 (0.22)	0.00 (0.00)	0.02 (0.14)	0.26 (1.11)

Note: Maximum score is given in parentheses after variable name.

pattern of findings in that the control group's performance differed significantly from that of the phonological awareness group but was comparable to that of the two other at-risk groups. However, findings for the end sound categorization task should be interpreted with caution because floor effects were found for this variable.

Subtests tapping *early literacy* skills also yielded significant differences among the experimental groups and the control group. On average, control children identified three more letters than the children-at-risk. The results on the word reading task confirmed the assumption that German kindergarten typically cannot read. Floor effects were found for all of the groups.

Taken together, the results confirm the hypothesis that our children-at-risk performed significantly worse on the phonological awareness and early literacy tasks at pretest than the 'normal' control children.

Posttest measures and pretest-posttest comparisons. We assumed that the trained children-at-risk would be able to reach the control children's level of phonological awareness and letter knowledge at posttest on those tasks which were explicitly practised in the different training versions. Thus, the hypothesis was that no substantial differences between the experimental groups and the control group should be found after completion of the intervention programs. Table 3 presents means and standard deviations for all posttest measures, as a function of group membership.

A visual inspection of Table 3 indicates that the three training groups managed to improve their level of phonological awareness and letter

Table 3
Means and standard deviations (in parentheses) for the three experimental groups (phonological awareness, phonological linkage, letter-sound training) and the control group on all measures of the posttest

	Group			
Variable	Phonological awareness (*N* = 73)	Phonological linkage (*N* = 75)	Letter-sound training (*N* = 45)	Control (*N* = 139)
(A) Phonological awareness				
Phoneme blending (8)	5.68 (1.71)	5.31 (1.64)	3.96 (1.51)	4.77 (1.96)
Phoneme segmentation (8)	4.23 (2.37)	3.05 (2.55)	1.38 (1.32)	1.89 (2.56)
Initial phoneme (8)	6.56 (2.25)	5.88 (2.43)	5.27 (2.37)	3.79 (3.14)
Phoneme deletion (8)	2.51 (2.57)	1.32 (1.80)	0.27 (0.69)	1.28 (2.31)
End sound categorization (10)	5.16 (2.73)	4.41 (3.06)	4.07 (2.94)	4.68 (3.09)
First sound categorization (10)	2.11 (2.42)	2.23 (2.40)	2.36 (2.38)	2.28 (2.62)
(B) Early literacy				
Letter name (26)	5.19 (5.32)	7.28 (5.85)	11.02 (3.53)	9.04 (8.11)
Letter sounds (26)	3.56 (3.57)	6.18 (5.00)	9.09 (2.85)	5.26 (5.41)
N of word read (7).	0.04 (0.20)	0.36 (1.08)	0.27 (0.84)	1.05 (2.06)

Note: Maximum score is given in parentheses after variable name.

knowledge during the intervention. In the following, the results for the phonological awareness tasks are described in more detail. One-way analyses of variance with subsequent Student-Newman-Keuls tests were conducted to examine the group differences.

On the *phoneme blending task* no substantial differences were found between the phonological awareness group and the phonological linkage group which both significantly outperformed the letter-sound training group and the control group, $F(3, 328) = 10.26$, $p < .01$. The control group was significantly ahead of the letter-sound training group, similar to the pretest findings. A 4 (group) x 2 (measurement point) repeated measures analysis of variance yielded significant main effects of group, $F(3, 328) = 5.94$, $p < .01$, and measurement point, $F(1, 328) = 164.49$, $p < .01$, qualified by a significant Group x Measurement point interaction, $F(3, 328) = 11.56$, $p < .01$. Whereas the three experimental groups were significantly worse than the control group at pretest, this pattern was dramatically changed after the training period. Although all groups made progress in blending phonemes, the greatest gains were observed for the phonological awareness group and the phonological linkage group. These two groups not only reached the control children's level but also surpassed it.

Results on the *phoneme segmentation task* showed that the phonological awareness group performed significantly better than the two remaining training groups and the control group, $F(3, 328) = 20.30$, $p < .01$. No significant differences between the children-at-risk instructed in letter-sound correspondences and the control children were found. However, these outcomes should be interpreted with caution because of floor effects.

To analyse changes from pre- to posttest, a 4 (group) x 2 (measurement point) repeated measures analysis of variance was carried out which yielded significant main effects for group, $F(3, 328) = 6.30$, $p < .01$, and measurement point, $F(1, 328) = 212.49$, $p < .01$, qualified by a significant Group x Measurement point interaction, $F(3, 328) = 47.35$, $p < .01$. Although all groups made significant progress from pre- to posttest, the greatest gain was observed for the phonological awareness group, followed by the phonological linkage group. These two groups performed significantly worse than the control group at pretest, but were significantly ahead of the control group at posttest.

Data analyses on the *initial phoneme task* showed substantial group differences at posttest, $F(3, 327) = 19.96$, $p < .01$. Subsequent SNK tests revealed that the trained children-at-risk were superior to the control children. Although the phonological awareness group performed significantly better than the letter-sound training group, there were no significant differences between the phonological linkage and the letter-sound training groups. The latter finding seems surprising but may be due to the fact that the identification of first sounds was part of all training programs. To assess differences in pretest-posttest changes, a 4 (group) x 2 (measurement point) repeated measures analysis of variance was carried out which yielded a significant main effect of measurement point, $F(1, 327) = 630.38$, $p < .01$ and a significant Group x Measurement point interaction, $F(3, 327) = 66.69$, $p < .01$. Whereas all groups improved their performance over time, the children-at-risk gained significantly more than the control children.

On the *phoneme deletion task*, floor effects were produced by all groups. Thus, these results should be interpreted with caution. Signicant group differences were found, $F(3, 327) = 11.07$, $p < .01$. Subsequent SNK test showed that the phonological awareness group performed significantly better than the other training groups and the control group. Whereas there were no substantial differences found between the phonological linkage group and the control group, the children-at-risk receiving letter-sound training scored significantly lower than the other trained children-at-risk and the control children.

To assess differences in pretest-posttest changes, a 4 (group) x 2 (measurement point) repeated measures analysis of variance was carried out, which yielded significant main effects for group, $F(3, 326) = 7.26$, $p < .01$, and measurement point, $F(1, 326) = 106.87$, $p < .01$, and a significant Group x Measurement point interaction, $F(3, 326) = 17.60$, $p < .01$. Overall, all groups improved their performance over time. However, the increases for the phonological awareness and phonological linkage groups were more pronounced than those of the letter sound training and control groups.

No significant group differences were found for the *end sound categorization task* at posttest. A 4 (group) x 2 (measurement point) repeated measures analysis of variance yielded a significant main effect of measurement point, $F(1, 328) = 147.20$, $p < .01$, and a significant Group x Measurement point interaction, $F(3, 328) = 7.80$, $p < .01$. Subsequent SNK test showed that the greatest increase was observed for the phonological awareness group which eventually reached the level of the control group at posttest.

Similarly, there were also no significant group effects on the *first sound categorization task*. A 4 (group) x 2 (measurement point) repeated measures analysis of variance only yielded a significant main effect of measurement point, $F(1, 328) = 60.16$, $p < .01$. Accordingly, all children improved their performance on this task. However, given that floor effects were produced even at posttest, the results should be interpreted with caution.

With regard to the *letter knowledge*, the pattern of findings changed from pre- to posttest. A 4 (group) x 2 (measurement point) repeated measures analysis of variance yielded significant main effects of group, $F(3, 327) = 7.25$, $p < .01$, and measurement point, $F(1, 327) = 336.20$, $p < .01$, which were qualified by a significant Group x Measurement point interaction, $F(3, 327) = 5.77$, $p < .01$. Subsequent SNK tests showed that although letter knowledge increased in all groups, the progress of the phonological linkage and letter-sound training groups was significantly better than that of the remaining groups. More specifically, children-at-risk in the letter-sound training group improved significantly more on *letter names and letter sounds* than the children-at-risk in the phonological awareness training group. The letter-sound training group also outperformed the control group regarding knowledge of letter-sound correspondences; however, the group difference concerning the correct identification of letter names did not reach statistical significance. The phonological linkage group did not differ significantly from the control group in the *identification of letter sounds*, but did significantly surpass the phonological awareness group.

Finally, on the *word reading task*, the control group was significantly ahead of the training groups, similar to the outcomes on pretest, $F(3, 325) = 9.12$, $p < .01$. Floor effects in all groups indicated that word reading skills were hardly developed before children entered school.

Overall, the intervention programs turned out to be rather effective. As predicted, the children at risk for dyslexia benefitted considerably from instruction in phonological awareness and letter-sound training. Particularly strong effects were found for the phonological awareness and the phonological linkage training groups. Although the gain in levels of phonological awareness was largest for the phonological awareness training group, it should be noted that only the phonological linkage training group caught up with or even outperformed the control group regarding both phonological awareness and letter knowledge.

Metalinguistic transfer test. As noted above, a transfer test of phonological abilities was included to assess long-term effects of the training programs. Children were tested with new measures of phonological awareness about four months after completion of the training period, that is, at the beginning of grade 1.

The group differences found for the metalinguistic transfer test are given in Table 4.

Table 4
Means and standard deviations (in parentheses) for the various measures of the metalinguistic transfer test, as a function of group (max = 10)

Variable	Group			
	Phonological awareness (N = 73)	Phonological linkage (N = 75)	Letter-sound training (N = 45)	Control (N = 139)
Initial phoneme	6.37 (2.55)	7.04 (2.07)	6.11 (2.59)	5.79 (2.74)
End sound	4.92 (2.69)	5.54 (2.29)	4.61 (2.61)	5.26 (2.84)
Word length	5.84 (1.92)	5.62 (2.20)	4.00 (1.57)	5.40 (2.46)
Phoneme analysis	2.47 (2.03)	2.85 (2.09)	1.31 (1.55)	2.96 (3.03)
Initial consonant	6.20 (3.26)	5.39 (3.44)	5.08 (0.28)	5.03 (3.95)
Vowel substitution	1.34 (2.57)	1.17 (2.10)	0.28 (0.66)	2.28 (3.40)

Outcomes for the various subtests were linearly combined to establish a sum score indicating the general level of metaphonological skills. As summarized in the table, two of the three training groups (i.e., the phonological awareness and the phonological linkage groups) performed at about the same level as the control group, whereas the letter-sound trainining group scored lower than all of the other groups. However, a one-way analysis of variance did not yield a main effect of group, $F(3,268) = 2.41$, $p < .07$. Thus, the difference between the letter-sound training group and the other groups was just short of being significant. Separate analyses for the various variables revealed that the letter-sound training group performed worse than the other groups on most subtests. However, significant differences were only found for the word length and phoneme analysis tasks. Overall these findings prove long-term effects of the training program, confirming the assumption that lasting training effects can also be obtained for children at risk for dyslexia.

Reading at the end of grade 2. The means and standard deviations obtained for the Würzburg reading test (WLLP; Küspert & Schneider, 1998) are provided in Table 5. Before getting to the group analyses, we should note that one problem with comparing the acquisition of literacy in the four groups was that significant group differences in nonverbal IQ were observed. That is, the control group scored significantly higher than all other groups which did not differ from each other. Given this problem, an analysis of covariance using IQ as covariate was carried out to assess performance differences in reading speed at the end of grade 2. The analysis yielded a significant effect of group, F(1, 4.07, $p < .01$, and also a significant effect of the covariate, $F(1, 268) = 4.36$, $p < .01$. The control group outperformed the phonological training and letter-sound training groups, but was not significantly better than the phonological linkage training group. The latter scored higher than the letter-sound training group, with the difference just short of being significant ($p < .06$).

Spelling at the end of grade 2. Mean performance and standard deviations obtained for the Diagnostische Rechtschreibtest DRT 2 (Müller, 1982) are also given in Table 5. Given that the covariate IQ was not significant for spelling, only the findings from a one-way analysis of variance are reported below. A main effect of group was found, $F(3, 268) = 7.39$, $p < .01$. The control group and the phonological linkage training

Table 5
Means and standard deviations (in parentheses) for the reading and spelling tests, as a function of group

Variable	Group: Phonological awareness (N = 73)	Phonological linkage (N = 75)	Letter-sound training (N = 45)	Control (N = 139)
End of grade 2				
Reading test (words correct)	66.19 (15.46)	70.69 (13.80)	63.31 (16.87)	75.70 (19.92)
Spelling test (words correct)	15.04 (5.44)	16.65 (5.27)	14.14 (5.23)	18.49 (6.34)

group did not differ from each other. However, the control group outperformed the two other training groups. Although the phonological linkage training group scored higher than the two other at-risk groups, the difference was only significant in case of the letter-sound group.

General discussion

The training study focused on two important aspects: First, children-at-risk's level of phonological awareness and letter knowledge should be significantly improved in order to prevent the development of difficulties in subsequent reading and spelling acquisition. Second, we evaluated the phonological linkage hypothesis for the German language, claiming that maximal long-term training effects on literacy acquisition can be obtained by using a combined intervention program emphasizing the integration of training in phonological awareness with training in letter-sound correspondences.

Results concerning the Bielefeld Screening procedure indicated that the children-at-risk had some difficulties with identifying and manipulating larger phonological units such as rhymes or syllables. In accord to that, pretest findings showed that children-at-risk were hardly able to handle smaller phonological units like phonemes. They had great difficulties to blend, categorize or segment phonemes in different tasks. Therefore the probability that these children would develop difficulties in reading and spelling at school would have been very high (Marx, Jansen, Mannhaupt, & Skowronek, 1993).

The phonological awareness training program was developed to enhance at-risk children's insight into units of speech (see Lundberg et al., 1988). To test the assumption that phonological awareness is necessary but not sufficient for literacy acquisition, the phonological awareness training was combined with a training in letter-sound correspondences. The combined training program was expected to have the greatest long-term effects on subsequent reading and spelling skills (cf. Hatcher et al., 1994).

Posttest measures assessing phonological awareness skills and letter knowledge proved that children at risk for dyslexia can be effectively trained in the last year of kindergarten. The training effect regarding phonological awareness was particularly strong for those children belonging to the phonological awareness group. In general, they not only reached the control children's level but also outperformed the control children on several tasks. On the other hand, however, the children-at-risk of the phonological awareness group did not improve their letter knowledge much during the training period. In this regard, the greatest gain was observed for the letter-sound training group who significantly outperformed the other training groups and the control group. As expected, children of the letter-sound training group made less progress in the phonological awareness tasks, compared to the other training groups. Substantial improvements on both phonological awareness tasks *and* tasks assessing knowledge of letter-sound correspondences were only observed for those at-risk children who participated in the phonological linkage training that emphasized the connection between grapheme-phoneme correspondences and phonological awareness. These findings replicated and confirmed those by Hatcher et al. (1994).

One other major finding of the present study was that the phonological linkage hypothesis applies to children at risk for dyslexia. Although the phonological linkage group did not gain as much phonological awareness as the phonological awareness group, it was only the phonological linkage training group that equalled literacy development in the control group. Overall, there is no doubt that the 'normal' control group showed better reading and spelling performance than the three groups of children at risk. This may be partly due to the fact that the control group differed from the three at-risk groups in more aspects than phonological processing (e.g., IQ, letter knowledge). Given these initial group differences, it seems impressive that the phonological linkage training group almost caught up with the control children. The difference between the two groups was nonsignificant for the spelling test and also nonsignificant for the reading speed test after individual differences in IQ had been controlled for. However, the control group performed consistently better than the two other trained groups of children, regardless of task and measurement point. Thus, combining phonological awareness training with teaching letter-sound correspondence rules yielded the best long-term results, confirming the validity of the phonological linkage hypothesis for at-risk kindergarten children.

Moreover, it is not the mere amount of training units but the qualitative (linkage) aspect of the intervention that seems to determine the outcome. Although the phonological awareness training group received more training units in phonological awareness and consequently scored higher on those tests after training, the increased amount of phonological awareness training did not materialize in subsequent reading and spelling performance. This outcome clearly supports the conclusion provided by Bus and van Ijzendoorn (1999) that phonological awareness is an important but not sufficient condition for learning to read and spell.

In sum, then, the present study provides evidence for the fact that the phonological linkage hypothesis can be generalized across different orthographies and holds for both kindergarten and school children. Our findings confirm those reported by Ball and Blachman (1991), Bradley and Bryant (1985), Hatcher et al. (1994), indicating that phonological awareness and letter knowledge can be successfully trained in German children at risk for dyslexia. One indicator of success not mentioned before concerns the percentage of children at risk that did not turn into problem children at school. In each group of trained children, at least 80% did not develop any serious reading or spelling problems (the respective percentage in the phonological linkage group was 94 and thus especially high). That is, the broad majority of these children did not belong to the lowest quartile of the achievement distribution but showed average performance, indicating the particular usefulness of early prevention programs in the field of literacy acquisition.

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