Journal of Experimental Child Psychology **75,** 116–133 (2000)
doi:10.1006/jecp.1999.2525, available online at http://www.idealibrary.com on IDEAL®

Pseudoname Learning by German-Speaking Children with Dyslexia: Evidence for a Phonological Learning Deficit

Heinz Mayringer and Heinz Wimmer

University of Salzburg, Salzburg, Austria

In 2 experiments, German-speaking dyslexic children (9-year-olds) showed impaired learning of new phonological forms (pseudonames) in a variety of visual–verbal learning tasks. The dyslexic deficit was also found when phonological retrieval cues were provided and when the to-be-learned pseudonames were presented in spoken as well as printed form. However, the dyslexic children showed no name-learning deficit when short, familiar words were used and they also had no difficulty with immediate repetition of the pseudowords. The dyslexic children's difficulty in learning new phonological forms was associated with pseudoword-repetition and naming-speed deficits assessed at the beginning of school, but not with phonological awareness and visual–motor impairments. We propose that the difficulty in learning new phonological forms may affect reading and spelling acquisition via impaired storage of new phonological forms, which serve as phonological underpinnings of the letter patterns of words or parts of words. © 2000 Academic Press

Key Words: dyslexia; consistent orthography; word learning; long-term memory; phonology; vocabulary.

The present study investigating dyslexic children's difficulty with learning new words was triggered by an unexpected observation. When planning a study on cognitive deficits of German-speaking dyslexic children, we decided to use a new naming-speed task in addition to the standard rapid-*automatized*-naming tasks (Denckla & Rudel, 1976). The new task required a learning phase, in which the new phonological forms had to be associated with their referent pictures. In pretests, randomly selected 8-year-old children showed little difficulty in learning three pseudowords as names of three fantasy animals. When we started testing dyslexic children, immediate repetition of the pseudonames posed no problem, but slightly delayed recall—after only one or two interposed other naming

The research reported in this paper was part of the first author's doctoral thesis work in developmental psychology at the University of Salzburg. Financial support was provided by a grant from the Austrian Science Foundation (Grant P09911-HIS). Thanks are due to Karin Landerl for linguistic advice.

Address correspondence and reprint requests to Heinz Mayringer, Hellbrunnerstrasse 34, A-5020 Salzburg, Austria. E-mail: heinz.mayringer@sbg.ac.at.

0022-0965/00 $35.00
Copyright © 2000 by Academic Press
All rights of reproduction in any form reserved.

attempts—posed a major problem for the dyslexic children (Wimmer, Mayringer, & Landerl, 1998).

In fact, several studies document such difficulties in visual–verbal paired-associate learning by English-speaking poor readers (Aguiar & Brady, 1991; Gascon & Goodglass, 1970; Gathercole & Baddeley, 1990; Otto, 1961; Vellutino, Steger, Harding, & Phillips, 1975; Vellutino & Scanlon, 1987). A recent study by Vellutino et al. (1996) is particularly impressive, as it retrospectively examined the kindergarten deficits of reading-impaired first graders. These children showed difficulties in visual–verbal learning together with difficulties in verbal short-term memory (digit span), confrontational and rapid naming, and phoneme segmentation, with a tendency to more serious deficits in the difficult-to-remediate group. This pattern of deficits is in close correspondence with the dominant phonological deficit explanation of difficulties in learning to read (Shaywitz, 1996).

The present research attempted to replicate and examine in more detail our observation of a pseudoname-learning deficit in German-speaking dyslexic children. Establishing such a deficit is of relevance for the evaluation of the generality of the phonological deficit explanation. Most of the support for this explanation comes from studies with children who exhibit specific difficulties in learning to read English. However, learning to read English, with its highly inconsistent grapheme–phoneme relations (e.g., hear–bear, heard–beard), may well demand a higher level of phonological competence than learning to read languages with more typical alphabetic orthographies. German, for example, exhibits rather straightforward grapheme–phoneme relations. Most often a specific grapheme relates to only one phoneme (although two graphemes may map onto the same phoneme) and silent letters are rare. Therefore, the application of these rather simple grapheme–phoneme relations more or less guarantees successful word recognition via phonological recoding. Furthermore, reading instruction for German children makes heavy of this fact by relying predominantly on a synthetic phonics teaching approach. Not surprisingly, phonological recoding in word recognition—measured via reading of pseudowords—was found to be much easier for young German readers than for young English readers (Frith, Wimmer, & Landerl, 1998; Wimmer & Goswami, 1994; Wimmer, Landerl, Linortner, & Hummer, 1991). Similar findings were reported for other consistent orthographies such as Dutch (Wentink, Van Bon, & Schreuder, 1997), Spanish (Goswami, Gombert, & de Barrera, 1998, Experiment 3; Signorini, 1997), Portuguese (Pinheiro, 1995), Italian (Cossu, Gugliotta, & Marshall, 1995), Greek (Goswami, Porpodas, & Wheelwright, 1997; Porpodas, Pantelis, & Hantziou, 1990), and Turkish (Öney & Durgunoglu, 1997).

Language-related differences also extend to children with dyslexia. Landerl, Wimmer, and Frith (1997) compared German and English children with dyslexia and found that German children were much more accurate in phonological recoding. The distinctive reading problem of German dyslexic children is massively reduced reading fluency, often accompanied by poor orthographic spelling (Landerl, Wimmer & Frith, 1997; Wimmer, 1993, 1996). Again, this pattern of findings for dyslexic children is not limited to German, but was also found in other consistent orthographies such as Norwegian (Lundberg & Høien, 1990) and Dutch (Yap & Van der Leij, 1993).[1] The most direct interpretation of this pattern of impaired reading speed and poor orthographic spelling would be that in consistent orthographies, where phonological recoding is less of a problem, dyslexia may be due primarily to a dysfunction of visual/orthographic memory. In other words, dyslexic children in consistent orthographies typically may show an impaired ability to store the letter sequences for frequently occurring words or parts of words. Share and Stanovich (1995) have suggested this memory dysfunction as "one other cognitive 'sticking point' where reading acquisition can run aground" (p. 12). Direct experimental evidence that dyslexic children in a consistent orthography suffer from difficulties in storing the letter sequence of words was provided for Dutch (Reitsma, 1983) as well as Italian (Zoccolotti et al., 1997). Postulating a specific memory dysfunction for letter sequences as proximal cause of the reading difficulties of dyslexic children in consistent orthographies raises the question about the more distal cognitive impairments leading to the difficulty in storing letter sequences. Obviously, a more general visual memory dysfunction would be a plausible candidate. This theoretical possibility would be incompatible with the phonological deficit explanation of dyslexia. Another theoretical explanation of the dyslexic difficulty to store letter sequences of words or parts of words follows from Ehri's (1992) and Perfetti's (1992) theorizing on the orthographic lexicon. Both Ehri and Perfetti suggest that permanent memory of the letter sequences of words is achieved by connecting the letters with their corresponding segments in the phonological word form. An extension of this view would be that new phonological forms may be generated that closely follow the letter sequence, for example, when *choir* is remembered as "tshoaiar."

Obviously this phonological explanation of the orthographic memory difficulty of German dyslexic children may gain credence when we can show that German dyslexic children show a deficit in learning pseudonames which—given the appropriate control conditions—can be shown to be a purely phonological memory task.

Two experiments will be reported. In both, dyslexic and age-level control children had to learn three pseudowords as names of pictorially presented

[1] In this overview of non-English studies we did not include French. The reason is that French orthography seems to be a special case due to the many rules which regulate the nonsounding of single letters or letter patterns in word-end position. Findings on pseudoword-reading ability of French children in Grade 1 differ somewhat, with means ranging from only about 50% correct (Goswami et al., 1998, Experiment 3) to quite high performance (Sprenger-Charolles & Siegel, 1997; Sprenger-Charolles, Siegel, & Bonnet, 1998). For dyslexic French children tested at the end of Grade 4, pseudoword reading was found to be quite difficult, with only about 50% correct (Genard et al., 1998).

referents (phonological learning in the following). After presentation of the names and their referents, a sequence of test trials was given. Children were asked to recall the name in response to the pictorial referent, and if they could not, the name was given again. Improvement over trials was monitored until the child reached the learning criterion or the end of the task. Several task versions were applied to limit the interpretation of the impaired learning performance of the dyslexic children. One version controlled for the possibility that dyslexic children's impaired associate learning is due to a general difficulty in forming visual–verbal associations. An additional question of Experiment 1 was whether dyslexic children's difficulty with pseudoname recall may in part be due to a failure with the self-generation of phonological retrieval cues. Therefore, in another version pseudoname recall was always cued with the first syllable.

EXPERIMENT 1

Method

Participants. The present study included 20 boys with poor reading abilities and 20 boys with good reading and spelling abilities. All had participated in our longitudinal study on precursors of poor reading acquisition. At the time of participation, the boys were about 9 years old and had just started their 3rd year in school. Based on both an earlier reading assessment in the middle of Grade 2 and current teacher ratings, a group of boys with below-average and a group with above-average reading achievement were selected. The final selection was based on the combined results of the Salzburg Reading and Spelling Test (Landerl, Wimmer, & Moser, 1997). As this test has norms for only the end of Grade 2 and the end of Grade 3, we had to apply the norms for the end of Grade 2. This resulted in a slight overestimation of the reading and spelling abilities in the first months of Grade 3, so we included only the worse half of the below-average group in the final sample. This selection was based on the combined results of the reading test (consisting of subtests for reading aloud a simple text and lists of frequent words and of pseudowords, respectively) and of the spelling test. On the same basis, the better half of the above-average group was selected. A further requirement for inclusion in either group was a nonverbal cognitive ability score of at least 85. This score was based on three nonverbal scales of the Primary Test of Cognitive Skills (Huttenlocher & Cohen Levine, 1990), which were administered as a group test at the end of Grade 1. The three scales were standardized in the large longitudinal sample. Subsequently the sum of these there variables was standardized again and scaled with a mean of 100 and a standard deviation of 15.

As Table 1 shows, the dyslexic children were characterized by a marked reading-speed problem. For example, their mean reading time on familiar words was about three times as long as in the control children. However, the dyslexic children read most words, text, and pseudowords correctly. As already noted, this reading-speed impairment in conjunction with rather high reading accuracy is

TABLE 1
Descriptive Characteristics of Dyslexic Children and Control Children

	Dyslexic children n = 20		Control children n = 20	
	M[*P*][a]	*SD*	*M*[*P*][a]	*SD*
Reading				
Frequent words				
Speed (seconds per word)	1.5 [7]	0.5	0.5 [90]	0.1
Accuracy (error percentage)	2.8	5.2	0.0	0.0
Text				
Speed (seconds per word)	1.4 [10]	0.5	0.4 [>90]	0.1
Accuracy (error percentage)	1.8	3.5	0.3	1.0
Pseudowords				
Speed (seconds per word)	3.1 [17]	1.0	1.6 [85]	0.7
Accuracy (error percentage)	19.2	12.9	6.0	10.5
Spelling				
Orthographic (error percentage)[b]	44.2 [15]	11.7	2.6 [>80]	4.2
Phonetic (error percentage)	5.6	7.3	0.8	2.1
Nonverbal cognitive ability	101.1	10.9	103.4	10.8
Age (years; months)	9;1	0;7	8;10	0;4

[a] Percentiles corresponding to group means.
[b] As orthographic errors, only those misspellings were counted that were phonetically acceptable transcriptions of the words.

typical of German-speaking dyslexic children (Landerl, Wimmer, & Frith, 1997; Wimmer, 1993).

As evident from Table 1, the poor readers also showed poor orthographic knowledge. Nearly half of their spellings were orthographically wrong, although most of these orthographically wrong spellings were phonetically acceptable. As evident from their normal nonverbal cognitive ability, the reading and spelling difficulties of the dyslexic children were not attributable to a general learning difficulty.

Pseudoname-learning tasks. Each child was presented with four visual–verbal learning tasks, distributed over two sessions separated by about 4 weeks. In the first session, one task involved learning three pseudowords of CVCVCV structure as names for three depicted children from foreign cultures. The second task of the first session required learning existing German first names instead of pseudonames. We chose actual names of similar syllabic complexity as the pseudonames, which, as a consequence, were rather unfamiliar (Hannelore–/‘hanεlo∂rε/, Eduard–/‘eduat/, Gerlinde–/gε∂‘lindε/). In the second session, the children again learned three pseudonames and three existing names. On the pseudoname task, however, the first syllable of the pseudoname was always given as a retrieval cue. The second task of the second session again required learning three existing names, but this time the existing names consisted of only two syllables and were highly familiar (Peter–/‘peta/, Susi–/‘susi/, Otto–/‘ɔtɔ/). These names are between two and six times more frequent than the existing three-syllable names, according to the Austrian electronic telephone directory.

The two sets of pseudowords were /‘sobilo/, /mɛ‘fo:sɛ/, /ti‘va:mi/ and /ro‘fe:mo/, /‘kasima/, /fɛ‘li:sɛ/. One set of pictures (colored paintings about 18 cm high) showed an African boy, an American Indian girl, and a Chinese boy; the other displayed a cowboy, an Eskimo girl, and a Japanese girl. The two pseudoword sets and the two picture sets were counterbalanced within each of the two pseudoname-learning tasks and within each of the two groups of participants.

As a general introduction to the pseudoname-learning tasks, the experimenter first explained that the names of three foreign children had to be learned. He then presented each foreign child individually by picture and name (e.g., “This is /‘sobilo/”). On the first trial, the child had to immediately repeat the name. If necessary, the name was given again until the pronunciation was accurate. Correct repetitions were confirmed (e.g., “Yes, /‘sobilo/”). On subsequent test trials, the three pictures were presented again one by one and the participant was asked to name the depicted children. For incorrect responses the experimenter gave the name again and asked the child to repeat the name. The order of the three pictures varied from trial to trial in the same fixed way for all children, with the constraint that the same picture never occurred twice in immediate succession. For the pseudoname-learning task of the second session, the procedure was the same except that the experimenter always provided the first syllable of the pseudoname as a retrieval cue (e.g., in the case of /‘sobilo/, “It starts with so“).

The maximum number of trials for each task was seven. Testing stopped if all three children were named correctly on two successive trials. This criterion was based on pretest observations, which indicated that children were easily bored with too many test trials.

Results

Immediate repetition of each of the three pseudonames on the name-introduction trial was easy. Combined over the two tasks, percentages of correct repetitions were 92% for the dyslexic and 95% for the control children. After the second presentation of the pseudoname (in the case of a repetition error), all repetitions were correct. Similarly, learning the familiar names /‘peta/, /‘susi/, and /‘ɔtɔ/ was very easy. All control children and 16 of the 20 dyslexic children showed correct naming after the first trial. Of the 4 remaining dyslexic children, 3 were incorrect on only one naming occasion and 1 child on two.

Figure 1 shows the learning curves for dyslexic and control children over the seven test-presentation trials for the pseudonames and for the complex existing names. The results for the two pseudoname-learning tasks were combined in Fig. 1, as a preliminary analysis revealed that the initial-syllable retrieval cues in the second task actually had a slight negative effect. Over all trials, the mean

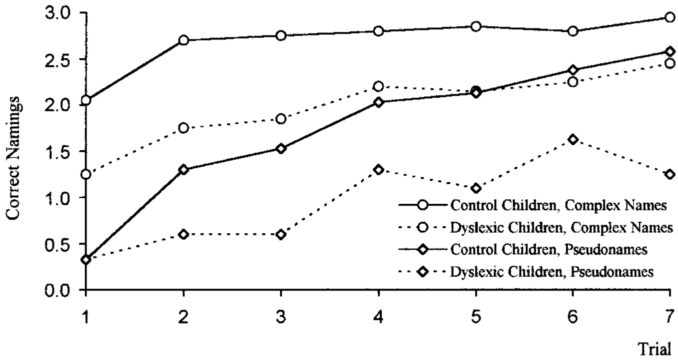

FIG. 1. Number of correct namings across test trials, separate for groups and learning conditions.

numbers of correct namings were 8.9 and 10.2 for the tasks with and without retrieval cues, respectively. The correlation between these two scores was .57.

From Fig. 1, it is obvious that learning existing names was easier than learning pseudonames, $F(1, 38) = 61.2$, $p < .001$, and that learning performance was much lower for dyslexic than for control children, $F(1, 38) = 24.9$, $p < .001$. Besides the effect of trial, $F(6, 228) = 54.1$, $p < .001$, there was a reliable interaction of task by trial by group, $F(6, 228) = 5.1$, $p < .001$. Separate ANOVAs for each of the two tasks showed the trial by group interaction to be reliable for learning pseudonames, $F(6, 228) = 7.7$, $p < .001$, but not for learning existing names, $F < 1$. The trial by group interaction in the pseudoword tasks is due to the fact that both the dyslexic and the control children started at the same level of accuracy. However, the control children improved steadily after the first test trial, whereas the dyslexic children did not.

The learning pattern was different for the task with existing names. There was already a lower performance of the dyslexic children on the first test trial. Despite improvement over the following trials, the dyslexic children did not even on the last trial reach the near-perfect performance shown by the control children on the second test trial.

An analysis of responses in the two pseudoname-learning tasks showed similar error patterns for the two groups. The highest proportions of errors were due to phonological distortions, with 62% and 55% for dyslexic and control children, respectively. Distortions ranged from near-hits (e.g., /ti‘ha:mi/ for /ti‘va:mi/) to pronunciations with low resemblance to the target (e.g., /‘kobɛ/ for /ti‘va:mi/). Refusals to respond accounted for 36% and 44% of failures of dyslexic and control children, respectively. Confusions of names occurred very infrequently. The highest proportion was 4%, shown by dyslexic children in the task without retrieval cues.

In the learning task with existing names, misnamings, refusals, and distortions accounted for about the same proportion of the dyslexic children’s errors.

Examples of phonological distortions in the case of existing names were /ge'lindϵ/, /ge'klindϵ/ for /gϵ∂'lindϵ/ or /'edua/ for /'eduat/. The existence of these distortions indicates that these names must have been unfamiliar to some of the children. The majority (64%) of the very few errors of the control children were refusals.

In summary, Experiment 1 showed that dyslexic children exhibited poor learning performance on visual–verbal paired-association tasks. For both complex existing names and pseudonames children learned more slowly and less consistently than children in the control group. This poor learning performance of the dyslexic children occurred despite nearly perfect performance with the immediate repetition of the pseudonames and despite almost perfect learning performance when short, familiar names were used.

Before we discussed the implications of these findings, it seemed advisable to replicate them with another sample and with a modified pseudoname-learning task. In selecting the control group we attempted to avoid the overrepresentation of good readers and spellers that had occurred in Experiment 1. In addition, to create an easier version of the pseudoname-learning task we used two-syllable pseudonames (instead of three-syllable pseudonames) and doubled the number of the learning trials so that even dyslexic children might reach the learning criterion. A new feature of Experiment 2 was that an auditory–visual condition of name presentation was contrasted with the auditory-only condition used in Experiment 1. In the auditory–visual condition, pronunciation of the name to be learned was always accompanied by the written rendition of the name.

EXPERIMENT 2

Method

Participants. The 32 children (16 dyslexic boys, 16 age-level control boys) of the present study came from the large longitudinal study on precursors of reading difficulties already mentioned; 3 dyslexic and 2 control children had participated in Experiment 1. The present assessment took place at the end of Grade 3. All the children had already served as dyslexic or control children in the middle of Grade 2 in another study of our group on cognitive deficits of dyslexic children (Wimmer et al., 1998). Children at that time were included in the dyslexic sample when the teacher's judgment of a specific reading difficulty was confirmed by a reading-speed percentile rank of below 20 for the frequent-words subtest and the text-reading subtest of the Salzburg Reading and Spelling Test (Landerl, Wimmer, & Moser, 1997). The 20 dyslexic and 27 control children of the Grade 2 study were contacted again for the present study. Of the children in the previous dyslexic group, 1 refused to participate and 3 were no longer exceptionally poor readers. The remaining 16 dyslexic children exhibited a reading-speed percentile below 20 for at least one of the three subtests which consist of existing words (high-frequency words, compound words, text).

To match group sizes, the control group was also reduced to 16 children. In

TABLE 2
Descriptive Characteristics of Dyslexic Children and Control Children

Variable	Dyslexic children $n = 16$		Control children $n = 16$	
	M [*P*][a]	*SD*	*M* [*P*][a]	*SD*
Reading				
Frequent words				
Speed (seconds per word)	1.3 [6]	0.6	0.6 [80]	0.1
Accuracy (error percentage)	3.8	6.3	0.2	0.8
Text				
Speed (seconds per word)	1.5 [5]	0.6	0.6 [55]	0.2
Accuracy (error percentage)	3.5	2.9	2.1	1.9
Pseudowords				
Speed (seconds per word)	2.3 [11]	0.8	1.4 [60]	0.4
Accuracy (error percentage)	15.2	14.4	3.3	3.2
Spelling				
Orthographic (error percentage)[b]	46.2 [5]	13.7	14.4 [50]	9.0
Phonetic (error percentage)	8.5	10.7	1.7	2.5
Nonverbal cognitive ability	101.6	15.0	102.4	14.9
Receptive vocabulary (WISC-R)	10.5	2.3	11.3	2.8
Age (years; months)	9;3	0;6	9;3	0;4

[a] Percentiles corresponding to group means.
[b] As orthographic errors, only those misspellings were counted that were phonetically acceptable transcriptions of the words.

doing so, we tried to match control children with the dyslexic sample for nonverbal cognitive ability (end of first-grade assessment; see Study 1) and vocabulary. Vocabulary was assessed at the end of Grade 2 with the German version of the WISC-R vocabulary scale (Tewes, 1983).

As evident from Table 2, the reading and spelling difficulties of the present dyslexic children were quite similar to those of the dyslexic sample of Experiment 1. Again the dominant reading problem was impaired reading speed, particularly for the short, high-frequency words. The characteristic spelling problem was orthographically wrong but phonetically acceptable spelling. An important aspect was that the dyslexic children scored in the normal range not only with respect to nonverbal cognitive ability but also with respect to vocabulary. With respect to reading and spelling performance, the control children of the present experiment were closer to average than the control children of Experiment 1 were.

Pseudoname-learning task. Children had to learn three pseudonames, using three fantasy animals as referents. The maximum number of test trials was increased to 14 and the learning criterion was set to three successively correct namings of the three animals. Names were introduced in the same way as in Experiment 1. For the auditory–visual condition, the experimenter pronounced the name, which was also printed above the picture. As in Experiment 1, on each test trial, the experimenter provided the correct name after the child's naming attempt—regardless of whether the child produced the correct name. However, to speed up the test trials, the child was not asked to repeat on each test trial the name provided by the experimenter. Furthermore, the time to respond on the test trials was limited to 5 s. For the auditory–visual condition, feedback was provided by always turning over to the next page, which showed the same animal and the name of the animal printed above the picture. As in the auditory-only condition, the name was auditorily provided by the experimenter. The combination of printed and spoken name was thus given not only on the introduction trials but also on each test trial. To ensure that the child had enough time to read the printed name, the feedback page was presented for about 3 s. The same feedback procedure was used for the auditory-only condition, with the exception that on the feedback page the animal was presented without the spelling of its name.

The reading time of 3 s for the printed names in the auditory–visual condition was chosen to ensure that even dyslexic children have enough time to link the letter sequence of the word to the spoken counterpart. As evident from Table 2, the dyslexic children exhibited a mean reading time for the word-analogous pseudowords of 2.3 s per pseudoword. So, the time required for self-reading of comparable pseudowords was less than the exposure time of the present names, which were read by the experimenter.

In Experiment 2, CVCV pseudonames were used. One set was /'gelo/, /'tafi/, /'bosa/, and the second set was /'sapo/, /'lutϵ/, /'rika/. Two sets of colored paintings of fantasy animals were used as referents. The two name and the two picture sets were counterbalanced over the two learning tasks within each of the two groups of participants. The order of the two learning tasks (with and without additional name spelling) was counterbalanced within each group. To minimize interference between the two tasks, the phonological word-identification task was administered between the two pseudoname-learning tasks.

Results

Pseudoname-learning. In contrast to the results of Experiment 1, the immediate repetitions of the pseudonames led to perfect performance, even among the dyslexic children. The improvement of pseudoname recall over the 14 test trials is given in Fig. 2 for the two conditions. If a child reached the criterion of correct name recall on three successive test trials, he was credited with correct performance for the remaining test trials.

An ANOVA with reading level as between-subjects factor and condition and trial as within-subjects factors proved all three main effects reliable: reading level, $F(1, 30) = 15.3$, $p < .001$; condition, $F(1,30) = 8.1$, $p < .01$; and trial, $F(13, 390) = 28.6$, $p < .001$. As evident from Fig. 2, dyslexic children showed depressed performance over all trials of both conditions. The difference between the groups became smaller over trials, because the control children were at ceiling and the dyslexic children showed improved naming performance. The

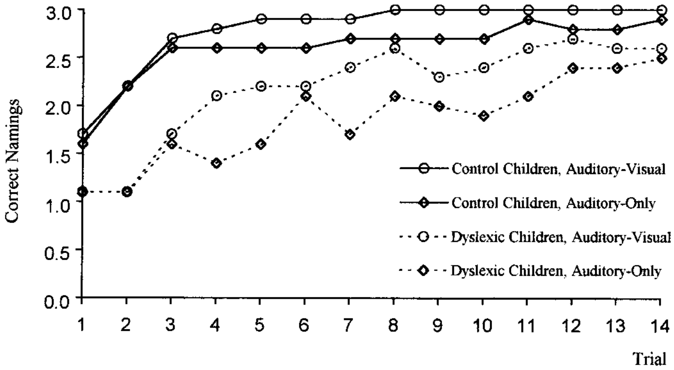

FIG. 2. Number of correct namings across test trials, separate for groups and tasks.

interaction between group and trial was reliable, $F(13, 390) = 2.4$, $p < .01$. The condition by trial interaction was not significant, $F(13, 390) = 1.4$, $p > .10$; nor was the group by condition interaction.

In a further step we analyzed the naming errors. We distinguished between phonological distortions as in /‘luta/ for /‘lutɛ/, refusals to respond, and misnamings, that is, giving one of the names in response to the wrong picture. Table 3 shows the means averaged over the two conditions. These means indicate how often a particular error type occurred in all the 14 naming responses required for a single name.

Only phonological distortions occurred often among dyslexic children. An ANOVA with type of naming error as within-subjects factor showed the interaction between group and error type to be reliable, $F(2, 60) = 7.6$, $p = .001$. Only for phonological distortions did dyslexic children’s errors exceed those of control children, $t(30) = 3.6$, $p = .001$. For refusals, $t(30) = 2.0$, $p = .05$, as well as misnamings, $t(30) = 1.8$, $p = .08$, group differences were of borderline significance.

Closer inspection of the phonological distortions showed that in about 80% of

TABLE 3
Means and Standard Deviations for Different Types of Naming Errors

	Dyslexic children		Control children	
Error type (errors/name, max = 14)	*M*	*SD*	*M*	*SD*
Distortions	3.0	2.3	0.8	1.0
Refusals	1.1	0.9	0.5	0.7
Misnamings	0.5	0.7	0.2	0.2

such errors in both groups the syllable structure of the target was preserved. That is, the child produced a CVCV name as an erroneous response (e.g., /‘rupe/ for /‘lutϵ/). An interesting error type was perseverations, that is, repetitions of an initial erroneous response on following trials. For example, a dyslexic child produced /‘rako/ instead of /‘rika/ and repeated this error two times on later trials. Overall, about 30% of all phonological distortions of dyslexic children were perseverations, in contrast to about 15% in the case of the normal readers.

In summary, using an easier pseudoname-learning task in Experiment 2, we replicated the main finding of Experiment 1. Despite success with the immediate repetition of the pseudonames, the dyslexic children showed substantially impaired learning performance. In contrast to Experiment 1, where both groups started with similarly low performance, now there were differences from the very beginning. Also replicating Experiment 1 was the finding that the majority of incorrect responses were not misnamings or refusals, but phonological distortions. Most of these distortions shared the syllable structure (CVCV) with the target and, therefore, were wrong with respect to the particular phonemes. An interesting additional observation was a tendency for error perseveration among the dyslexic children. Both groups profited from the additional presentation of the printed names.

Associations between visual–verbal learning performance and precursors of reading development. For this analysis, we created combined scores of pseudoname-learning performance by adding the number of correct namings across the two pseudoname-learning tasks of each experiment. The correlations between the pseudoname-learning scores for the two tasks were .57 and .70 for Study 1 and 2, respectively. Table 5 shows how these learning scores of Experiment 1 and 2 were associated with the precursor measures obtained at the beginning of Grade 1, and, in addition, it is shown for each measure whether the dyslexic group differed from the control group. A detailed description of the precursor measure is given in Wimmer et al. (1998). Detecting onsets (e.g., “Mutter–Nadel–Beeren: Which word starts with /m/?“) and rhymes (e.g., “What rhymes with Feld? Geld or Gold?”) were rather easy phonological awareness tasks. For the pseudoword-repetition task we used three-syllable items with the characteristic feature that the consonantal onsets of the syllables were easy to confuse (e.g., /‘fivofi/, /‘li∂ruli/). The visual naming-speed task was a version of the continuous naming tasks introduced by Denckla and Rudel (1976). Our version consisted of two tasks with 20 naming items each (5 different pictures, each repeated 4 times). In one task, the five words began with a different consonant cluster (Kran, Frosch, Blatt, Schloβ, Brot); in the other, they began with the same consonant (Buch, Bett, Bär, Baum, Ball). Articulation rate was measured via continued repetition of word triples for 10 s. Plural formation assessed the child’s knowledge of plural forms (e.g., *Frösche*). Visual search was a speeded match to sample task. In the peg-moving task (Annett, 1985) the child had to move quickly with one hand 10 pegs from one set of holes to another one. The nonverbal cognitive ability

TABLE 4
Correlations between Pseudoname Learning and Precursor Measures of Reading Development, and Dyslexic Children's Standardized Deficits on the Precursor Measures

	Experiment 1		Experiment 2	
Precursor measures	*r*	*z*[a]	*r*	*z*[a]
Onset detection	.28	−0.97**	.08	−0.15
Rhyme detection	.23	−0.96	.15	0.06
Pseudoword repetition	.39*	−1.36**	.49**	−1.13*
Visual naming speed	.50**	−1.61***	.51**	−1.12*
Articulation rate	.38*	−0.45	.44*	−0.49
Plural formation	.11	−0.48	.22	−0.28
Visual search	.12	−0.33	.15	−0.34
Peg moving	.24	−0.15	.16	−0.21
Nonverbal cognitive ability	.06	−0.21	−.14	−0.06

Note. All variables were poled in such a way that the higher the score the higher the performance.
[a] Scores express groups' mean differences relative to the standard deviations of the control group.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

measure consisted of three subtests of the Primary Test of Cognitive Skills described previously.

Table 4 shows that the phonological learning scores of Experiments 1 and 2 were reliably associated only with three precursor measures: pseudoword repetition, visual naming speed, and articulation rate. Table 4 also shows that the dyslexic children displayed a substantial deficit in pseudoword repetition and visual naming speed in both experiments. The standardized deficit scores in Table 4 were computed by dividing the difference between each child's score and the mean of the control group by the standard deviation of the control group. Apparently the association with the verbal speed measures was not due to a general speed factor, as the correlations with the visual–motor speed measures (visual search and peg moving) were rather low. It is also important to note that the correlation between the phonological learning scores and nonverbal cognitive ability was close to zero.

DISCUSSION

The Nature of the Difficulty in the Visual–Verbal Learning Task

Experiments 1 and 2 provide converging evidence that German-speaking dyslexic children show impaired phonological learning in a variety of visual–verbal paired-associate learning-task environments. The impairment was already found when existing names with multisyllable structures were used, which in some cases may have been of little familiarity for dyslexic children. However, the main finding has to do with learning of pseudonames, which, by definition, must be unfamiliar phonological forms. The pseudoname-learning difficulty was found for the longer CVCVCV names of Experiment 1 and also for the rather short CVCV pseudonames of Experiment 2. One may reason that the impaired learning performance of dyslexic children has to do with the fact that the items within a set of pseudowords shared the same syllable structure. However, this syllabic similarity of the pseudonames was not given in the original Wimmer et al. (1998) study, which used rather different pseudonames (/ʃpu∂k/, /‘filo/, /‘kog∂n/) but also found the dyslexic deficit. Furthermore, the presently observed phonological learning deficit of dyslexic children is not a new observation. As noted in the Introduction, a number of studies with English-speaking dyslexic children had already reported deficits in visual–verbal paired-associate learning paradigms (Aguiar & Brady, 1991; Gascon & Goodglass, 1970; Gathercole & Baddeley, 1990; Otto, 1961; Vellutino & Scanlon, 1987; Vellutino et al., 1975, 1996). Therefore, one can conclude that the difficulty of learning new phonological forms seems to hold for dyslexic children irrespective of whether the children are confronted with an easy transparent orthography such as German or a difficult opaque orthography such as English.

For the interpretation of the present dyslexic name-learning deficit several additional observations are important. First, in both experiments it was found that children had little or no difficulty with the immediate repetition of the pseudonames. This rules out that the difficulty of the dyslexic children could be due to faulty auditory perception, insufficient phonological short-term memory, or articulatory problems. A second important observation was that, in Experiment 1, dyslexic children were found to have little difficulty with the visual–verbal learning task when short, highly familiar names were used. This finding rules out that impaired memory for the associations between picture and name could be responsible for the poor dyslexic performance in the visual–verbal pair-association task. Vellutino et al. (1975) already had shown that dyslexic children had little difficulty to associate pictures with nonverbal sounds such as coughs. Also against impaired associative memory speaks the observation that few misnaming errors, that is, use of a correct name but for the wrong picture, occurred.

The findings that the visual–verbal learning deficit of dyslexic children was not reduced in the retrieval-cue condition of Experiment 1 and in the auditory–visual condition of Experiment 2 are further evidence for the generality of their phonological learning deficit. So neither the variations in the name-encoding phase (auditory–visual condition) nor those in the name-retrieval phase (retrieval-cue condition) had an effect on the dyslexic deficit. We conclude from this negative evidence that the main problem of dyslexic children with learning of new phonological forms must have to do with long-term memory for such forms. That the majority of their errors were phonological distortions also speaks for this conclusion. Of course, the expression *long-term memory* has to be qualified with respect to our learning task, as only two to four interfering trials occurred between the presentation of a specific name and the test for the specific name.

To interpret the difficulty of our dyslexic children with pseudoname-learning as a dysfunction of phonological long-term memory does not rule out a dysfunction of phonological short-term memory. Actually the finding that the dyslexic children showed impaired performance on the pseudoword-repetition task at school entry speaks for short-term memory difficulties. The present findings are in correspondence with those of Gathercole and Baddeley (1990), who found a substantial deficit on an experimental pseudoname-learning task for a group of 6-year-old children with poor performance on their nonword repetition test. As in the present study, Gathercole and Baddeley found that the learning deficit was specific to new phonological forms and not to familiar names. Nevertheless, it is important to note that the difficulty of our dyslexic children with the pseudoname-learning task cannot be explained with a dysfunction of the phonological loop as in Baddeley and Gathercole (1998). The correct immediate name repetitions indicate that the phonological loop had enough capacity to allow temporary storage and retrieval of the new phonological form.

The further longitudinal observation of a substantial association between early naming and articulation speed and later phonological learning is also interesting. No such association was given with early visual–motor speed. Therefore, the finding suggests that the speed with which existing long-term phonological memory traces can be accessed is of importance for learning new phonological forms. This interpretation is in line with the position of Hulme, Maughan, and Brown (1991) that long-term memory contributes to short-term memory span. One may also reason that the observed association has to do with speed differences in the rehearsal of new names in short-term memory (Hulme, Thomson, Muir, & Lawrence, 1984).

That a substantial proportion of the errors of dyslexic children on the pseudoname-learning task were phonological distortions of the pseudonames and not misnamings points to a specific impairment with the establishment of reliable long-term memory traces for new phonological forms. The detailed error analysis of Experiment 2 further pinpointed the problem at the segmental level, as the large majority of the phonologically distorted name recalls respected the syllabic structure of the names (two open syllables). The segmental errors could not be due to perceptual difficulties, as they did not occur in immediate repetitions. The error pattern observed here—correct syllable structure, but some wrong phonemes—was also frequently observed in studies examining object-naming abilities of dyslexic children and adults (Cantwell & Rubin, 1992; Katz, 1986; Rubin & Liberman, 1983).

The Theoretical Link to the Reading and Spelling Difficulties

The question here is how a deficit in forming long-term memory traces for new phonological forms may affect reading acquisition in consistent orthographies. As noted in the Introduction and demonstrated in the Participants section, the present German dyslexic children are rather accurate, but very slow readers and their spellings, although orthographically wrong, tend to be phonetically correct. In particular, the very slow reading of high-frequency words and the poor orthographic spelling suggest that part of the problem is long-term memory storage of word-specific letter sequences. Such entries in the orthographic lexicon would allow automatic word recognition in reading and orthographically correct spelling. As noted in the Introduction there are two different possibilities to explain the poor orthographic lexicon of dyslexic children. It could be seen as caused by a general visual memory dysfunction or—in line with the phonological deficit explanation—as caused by a phonological problem. The present findings of a long-term memory problem for pseudonames of German dyslexic children clearly speak for the phonological deficit explanation of the orthographic lexicon problem. Of course, the present findings do not specify the exact role of phonology in the formation of orthographic memories. A direct link would be that dyslexic children have difficulties forming long-term memories for spelling pronunciations (e.g., "tshoaiar" for *choir*) or forming long-term memories for the letter-sound sequence of a word. Of course, there are less direct interpretations of the link between presently observed phonological learning impairment and the characteristic reading and spelling problems of German-speaking dyslexic children. One is that both impairments are subserved at least partly by the same deficient brain structures. That our dyslexic children exhibited not only impaired phonological learning performance but also impaired naming-speed earlier on would certainly be in line with this perspective.

REFERENCES

Aguiar, L., & Brady, S. (1991). Vocabulary acquisition and reading ability. *Reading and Writing,* **3,** 413–425.

Annett, M. (1985). *Left, right, hand and brain: The right shift theory.* Hillsdale: Erlbaum.

Baddeley, A., & Gathercole, S. (1998). The phonological loop as a language learning device. *Psychological Review,* **105,** 158–173.

Bowers, P. G. (1995). Tracing symbol naming-speed's unique contributions to reading disability over time. *Reading and Writing,* **7,** 189–216.

Bowers, P. G., & Wolf, M. (1993). Theoretical links between naming-speed, precise timing mechanisms, and orthographic skill in dyslexia. *Reading and Writing,* **5,** 69–85.

Cantwell, A., & Rubin, H. (1992). Object naming ability of adults with written language difficulties. *Annals of Dyslexia,* **42,** 179–195.

Cossu, G., Gugliotta, M., & Marshall, J. C. (1995). Acquisition of reading and written spelling in a transparent orthography: Two non-parallel processes? *Reading and Writing,* **7,** 9–22.

De Jong, P. F. (1998). Working memory deficits of reading disabled children. *Journal of Experimental Child Psychology,* **70,** 75–96.

Denckla, M. B., & Rudel, R. G. (1976). Rapid 'automatized' naming: Dyslexia differentiated from other learning disabilities. *Neuropsychologia,* **14,** 471–479.

Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In P. B. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 107–143). Hillsdale, NJ: Erlbaum.

Frith, U., Wimmer, H., & Landerl, K. (1998). Differences in phonological recoding in German- and English-speaking children. *Scientific Studies of Reading,* **2,** 31–54.

Gascon, G., & Goodglass, H. (1970). Reading retardation and the information content of stimuli in paired associate learning. *Cortex,* **6,** 417–429.

Gathercole, S. E., & Baddeley, A. D. (1990). The role of phonological memory in vocabulary acquisition: A study of young children learning new names. *British Journal of Psychology,* **81,** 439–454.

Genard, N., Mousty, P., Content, A., Alegria, J., Leybaert, J., & Morais, J. (1998). Methods to establish subtypes of developmental dyslexia. In P. Reitsma & L. Verhoeven (Eds.), *Problems and intervention in literacy development* (pp. 163–176). Dordrecht: Kluwer.

Goswami, U., Gombert, J. E., & de Barrera, L. F. (1998). Children's orthographic representations and linguistic transparency: Nonsense word reading in English, French, and Spanish. *Applied Psycholinguistics,* **19,** 19–52.

Goswami, U., Porpodas, C., & Wheelwright, S. (1997). Children's orthographic representations in English and Greek. *European Journal of Psychology of Education,* **12,** 273–292.

Hulme, C., Maughan, S., & Brown, G. D. A. (1991). Memory for familiar and unfamiliar words: Evidence for a long-term memory contribution to short-term memory span. *Journal of Memory and Language,* **30,** 685–701.

Hulme, C., Thomson, N., Muir, C., & Lawrence, A. (1984). Speech rate and the development of short-term memory. *Journal of Experimental Child Psychology,* **38,** 241–253.

Huttenlocher, J., & Cohen Levine, S. (1990). *Primary Test of Cognitive Skills.* Monterey, CA: Macmillan/McGraw–Hill.

Katz, R. B. (1986). Phonological deficiencies in children with reading disabilities: Evidence from an object-naming task. *Cognition,* **22,** 225–257.

Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: A German–English comparison. *Cognition,* **63,** 315–334.

Landerl, K., Wimmer, H., & Moser, E. (1997). *Salzburger Lese- und Rechtschreibtest: Verfahren zur Differentialdiagnose von Störungen der Teilkomponenten des Lesens und Schreibens für die 1. bis 4. Schulstufe.* Bern: Huber.

Leinonen, S., Leppänen, P. H., Aro, M., Ahonen, T., & Lyytinen, H. (1998). *Heterogeneity in oral text reading in adults with familial dyslexia: Relations to word recognition, phonological awareness, verbal short-term memory, and reading habits.* Manuscript submitted for publication, University of Jyväskylä.

Lindgren, S. D., de Renzi, E., & Richman, L. C. (1985). Cross-national comparison of developmental dyslexia in Italy and the United States. *Child Development,* **56,** 1404–1417.

Lundberg, I., & Høien, T. (1990). Patterns of information processing skills and word recognition strategies in developmental dyslexia. *Scandinavian Journal of Educational Research,* **34,** 231–240.

Öney, B., & Durgunoglu, A. Y. (1997). Beginning to read in Turkish: A phonologically transparent orthography. *Applied Psycholinguistics,* **18,** 1–15.

Otto, W. (1961). The acquisition and retention of paired associates by good, average, and poor readers. *Journal of Educational Psychology,* **52,** 241–248.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In P. Gough, L. C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 145–174). Hillsdale, NJ: Erlbaum.

Pinheiro, A. M. V. (1995). Reading and spelling development in Brazilian Portugese. *Reading and Writing,* **7,** 111–138.

Porpodas, C. D., Pantelis, S. N., & Hantziou, E. (1990). Phonological and lexical encoding processes in beginning readers: Effects of age and word characteristics. *Reading and Writing,* **2,** 197–208.

Reitsma, P. (1983). Printed word learning in beginning readers. *Journal of Experimental Child Psychology,* **75,** 321–339.

Rubin, H., & Liberman, I. Y. (1983). Exploring the oral and written language errors made by language disabled children. *Annals of Dyslexia,* **33,** 111–120.

Share, D. L., & Stanovich, K. E. (1995). Cognitive processes in early reading development: Accommodating individual differences into a model of acquisition. *Issues in Education,* **1,** 1–57.

Shaywitz, S. E. (1996, November). Dyslexia. *Scientific American,* 98–104.

Signorini, A. (1997). Word reading in Spanish: A comparison between skilled and less skilled beginning readers. *Applied Psycholinguistics,* **18,** 319–344.

Snowling, M. J., Goulandris, N., & Defty, N. (1996). A longitudinal study of reading development in dyslexic children. *Journal of Educational Psychology,* **88,** 653–669.

Sprenger-Charolles, L., & Siegel, L. S. (1997). A longitudinal study of the effects of syllabic structure on the development of reading and spelling skills in French. *Applied Psycholinguistics,* **18,** 485–505.

Sprenger-Charolles, L., Siegel, L. S., & Bonnet, P. (1998). Reading and spelling acquisition in French: The role of phonological mediation and orthographic factors. *Journal of Experimental Child Psychology,* **68,** 134–165.

Tewes, U. (1983). *Hamburg-Wechsler-Intelligenztest für Kinder–Revision 1983.* Bern: Hans Huber.

Van Bon, W. H. J., & Van der Pijl, J. (1997). Effects of word length and wordlikeness on pseudoword repetition by poor and normal readers. *Applied Psycholinguistics,* **18,** 101–114.

Vellutino, F. R., & Scanlon, D. M. (1987). Phonological coding, phonological awareness, and reading ability: Evidence from a longitudinal and experimental study. *Merrill–Palmer Quarterly,* **33,** 321–363.

Vellutino, F. R., Scanlon, D. M., Sipay, E. R., Small, S. G., Pratt, A., Chen, R. S., & Denckla, M. B. (1996). Cognitive profiles of difficult-to-remediate and readily remediated poor readers: Early intervention as a vehicle for distinguishing between cognitive and experiential deficits as basic causes of specific reading disability. *Journal of Educational Psychology,* **88,** 601–638.

Vellutino, F. R., Steger, J. A., Harding, C. J., & Phillips, F. (1975). Verbal vs. non-verbal paired-associates learning in poor and normal readers. *Neuropsychologia,* **13,** 75–82.

Wentink, H. W. M. J., Van Bon, W. H. J., & Schreuder, R. (1997). Reading development in elementary school: Do syllables play a role in phonological decoding? In C. K. Leong & R. M. Joshi (Eds.), *Cross-language studies of learning to read and spell* (pp. 195–212). Dordrecht: Kluwer.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics,* **14,** 1–33.

Wimmer, H. (1996). The nonword reading deficit in developmental dyslexia: Evidence from children learning to read German. *Journal of Experimental Child Psychology,* **61,** 80–90.

Wimmer, H., & Goswami, U. (1994). The influence of orthographic consistency on reading development: Word recognition in English and German children. *Cognition,* **51,** 91–103.

Wimmer, H., Landerl, K., Linortner, R., & Hummer, P. (1991). The relationship of phonemic awareness to reading acquisition: More consequence than precondition but still important. *Cognition,* **40,** 219–249.

Wimmer, H., Mayringer, H., & Landerl, K. (1998). Poor reading: A deficit in skill-automatization or a phonological deficit? *Scientific Studies of Reading,* **2,** 321–340.

Wolf, M. (1997). A provisional, integrative account of phonological and naming-speed deficits in dyslexia: Implications for diagnosis and intervention. In B. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 67–92). Mahwah, NJ: Erlbaum.

Wolf, M., Pfeil, C., Lotz, R., & Biddle, K. (1994). Towards a more universal understanding of the developmental dyslexias: The contribution of orthographic factors. In V. W. Berninger (Ed.), *The varieties of orthographic knowledge I: Theoretical and developmental issues* (pp. 137–171). Dordrecht: Kluwer.

Yap, R., & Van der Leij, A. (1993). Word processing in dyslexics. An automatic decoding deficit? *Reading and Writing,* **5,** 261–279.

Zoccolotti, P., De Luca, M., Di Pace, E., Judica, A., Orlandi, M., & Spinelli, D. (1997). *Markers of developmental surface dyslexia in a language (Italian) with high grapheme–4phoneme correspondence.* Manuscript submitted for publication, University of Rome.

Received August 17, 1998; revised July 30, 1999