Reading and Writing (2005) 18:27–49
DOI 10.1007/s11145-004-2345-x

How do the spellings of children with dyslexia compare with those of nondyslexic children?

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Abstract. Children with dyslexia are believed to have very poor phonological skills for which they compensate, to some extent, through relatively well-developed knowledge of letter patterns. We tested this view in Study 1 by comparing 25 dyslexic children and 25 younger normal children, chosen so that both groups performed, on average, at a second-grade spelling level. Phonological skill was assessed using phoneme counting and nonword spelling tasks. Knowledge of legal and illegal letter patterns was tested using a spelling choice task. The dyslexic children and the younger nondyslexic children performed similarly on all the tasks, and they had difficulty, for the most part, with the same linguistic structures. Supporting the idea that older dyslexics' spellings are quite similar to those of typical beginners, we found in Study 2 that experienced teachers could not differentiate between the two groups based on their spellings.

Key words: Dyslexia, Graphotactic Knowledge, Phonological skill, Spelling, Spelling-level match

Introduction

Much research describes the difficulties that young children experience with certain linguistic structures when they begin to read and spell. For example, children may have trouble segmenting consonant clusters into phonemes and symbolizing each phoneme with a separate letter (e.g., Read, 1986; Treiman, 1993). Most children overcome these initial difficulties and make progress in learning to read and spell. However, some children acquire literacy skills extremely slowly, even while doing well in other academic areas. These children are said to have a specific disability in reading and spelling, or developmental dyslexia.

Many researchers have argued that children with dyslexia have very poor phonological skills, even poorer than would be expected given their level of literacy. Individuals with dyslexia have difficulty

in phonological awareness tasks such as identifying the "odd word out" in sets such as *weed*, *need*, *deed*, and *peel* (e.g., Bradley & Bryant, 1978) and counting the number of phonemes in spoken words (e.g., Bruck, 1992). Other evidence points to deficient phonological processes in speech perception and memory for speech (see Share, 1996). Even those researchers who argue that there are distinct subtypes of dyslexia agree that most subtypes have a core problem in phonological awareness and that other deficits are sometimes present as well (e.g., Morris et al., 1998). Dyslexics' poor phonological skills, it is argued, make it hard for them to learn links between letters and phonemes and use these links to read and spell novel words (Rack, Snowling, & Olson, 1992; van IJzendoorn & Bus, 1994). Children with dyslexia may attempt to compensate for their phonological weaknesses by relying on knowledge of legal and illegal letter patterns, which we refer to as graphotactic knowledge.[1] This knowledge appears to be relatively well developed in children with dyslexia. Siegel, Share, and Geva (1995) found that children with dyslexia performed significantly better than younger nondyslexic children when asked to select the item that looked more like a word in pairs such as *clid-cdil*. In contrast to their good performance on this spelling choice test, the children with dyslexia were significantly worse at pronouncing nonwords than the nondyslexic children. This pattern of relatively good performance on tests of graphotactic knowledge coupled with poor performance on tests of phonological skill tasks has been found in several studies (e.g., Olson, 1985; Pennington et al., 1986; Stanovich, Siegel, & Gottardo, 1997), although children with dyslexia are not always superior to younger children of the same reading level in graphotactic knowledge.

In contrast to the many studies that have examined the phonological skills and reading skills of individuals with dyslexia, relatively few studies have looked at spelling. This is surprising given that dyslexics' spelling problems are often more severe and persistent than their reading problems (e.g., Boder, 1973; Pennington et al., 1986). If dyslexics have serious phonological problems, these problems should show themselves in spelling as well as reading. The findings reviewed above lead us to expect that dyslexics would be poor at representing the phonological forms of words in spelling, but that they would attempt to compensate for their phonological problems through use of graphotactic knowledge. That is, dyslexics' spellings may "look right" even when they do not represent the sounds of the target words. Several studies have tested these predictions by means of a spelling-level match design. In this design, researchers select older dyslexic children and younger normal children such that the

two groups perform at similar levels on a standardized spelling test. Researchers then compare the dyslexic and nondyslexic children's performance on tasks other than the real-word spelling task on which the groups were matched, attempting to determine whether the dyslexics show an atypical pattern of strengths and weaknesses. In particular, do the children with dyslexia make more errors on nonword spelling and phonological awareness tasks than the control children, and do they perform well in tests of graphotactic knowledge?

In one study using a spelling-level match design, Bruck and Treiman (1990) focused on word-initial consonant clusters. As mentioned earlier, typical beginners may have difficulty representing clusters as sequences of phonemes. They sometimes fail to spell the interior consonants of initial clusters, producing errors such as "pa" for *play* and "set" for *street*. Bruck and Treiman studied 23 dyslexic children (mean age 10 years, 2 months) and 33 first and second graders (mean age 7 years, 5 months). On average, both groups of children performed at a second-grade spelling level. The children with dyslexia, like the normally progressing children, sometimes failed to spell the second consonants of initial clusters. Both groups also had difficulties with clusters on phonological awareness tasks. Importantly, these difficulties tended to be more severe among the dyslexic children than the spelling-level matched younger children. This outcome supports the idea that the phonological skills of children with dyslexia are poorer than expected given their ability to spell real words.

Other studies using a spelling-level match design, in contrast, have reported few differences between older children with dyslexia and typical younger children. Several researchers have found that dyslexics and normals make similar proportions of phonologically motivated spelling errors (Bourassa & Treiman, 2003; Moats, 1983; Nelson, 1980). The proportions of graphotactically legal spellings have also been reported to be comparable for the two groups (Bourassa & Treiman, 2003; Nelson, 1980). When specific linguistic structures have been examined, similarities between the errors committed by older disabled spellers and those committed by younger normal spellers have been found in several studies (Bourassa & Treiman, 2003; Invernizzi & Worthy, 1989; Moats, 1983). However, these studies did not usually include enough instances of each linguistic structure to permit strong conclusions about each one. And some of the researchers, even while pointing to similarities in the error patterns of older dyslexic and younger normal children, noted subtle differences. For example, Bourassa and Treiman (2003) found in post hoc analyses that dyslexic children were more likely to include final *e*s in their spellings, and Moats (1983) suggested that dyslexics were better informed about certain spelling conventions.

To summarize, evidence on the question of whether children with dyslexia show a different pattern of strengths and weaknesses than normally progressing younger children is mixed. Our study went beyond many of the previous studies in this area by examining three critical skills – spelling, phonological awareness, and graphotactic knowledge – in the same children. Also, we looked at a range of linguistic structures, using enough stimuli that we could draw conclusions about each structure. Children with dyslexia and typically developing children were carefully matched on a standardized spelling test involving real words. If children with dyslexia use a different mix of skills than typical children to reach the same level of real-word spelling performance, then they should perform worse on the phonological awareness and nonword spelling tasks than the control children, but better on tests of graphotactic knowledge.

Study 1: Method

Participants

Children with dyslexia. The children with dyslexia were recruited through four institutions: Michigan Dyslexia Institute, Beaumont Hospital Center for Human Development, Greenwood School, and Eton Academy. The first two institutions, which are located in the suburbs of Detroit, Michigan, provide evaluation and tutoring services to individuals with dyslexia. Greenwood School is a boarding school for boys with dyslexia located in Vermont. Eton Academy, in suburban Detroit, is a private day school for children with dyslexia and other learning difficulties. Administrators at each institution nominated children who had been identified as developmentally dyslexic as possible participants. Each institution followed standard clinical practices to identify individuals as dyslexic, and all of the children had been assessed as having normal intelligence. To be included in the final sample, a child had to perform below the fourth grade level on the spelling subtest of the Wide Range Achievement Test 3 (WRAT3) (Wilkinson, 1993). This criterion was adopted because the spelling errors of interest in the present study typically occur during the early years of elementary school. Because the WRAT has a fairly small number of words per grade level, we increased reliability by administering both forms of the test across two sessions and using the combined score. The spelling level of the children in the dyslexic group was required to be at least one standard deviation below the norm for their age group. Twenty-five of the

nominated children met the criteria and were included in the study. All of them were native English speakers.

The children with dyslexia ranged in age from 7 years, 9 months to 15 years, 10 months, with a mean age of 11 years, 7 months. Eighteen were boys and seven were girls. The children's mean grade level on the spelling subtest of the WRAT3 was 2.15 ($SD = 0.64$; range 1.3–3.9). The children with dyslexia were poor readers as well as poor spellers. On the reading subtest of the WRAT3, the children's mean grade level was 2.89 ($SD = 0.97$; range 0.7–4.9). The reading measure, like the spelling measure, was based on the children's combined performance on the two forms of the test.

Typical children. Twenty-five first graders from two schools in the suburbs of Detroit, Michigan, tested near the end of the school year, formed the control group. Thirty-one children were initially tested. The six children with the lowest scores on the WRAT3 spelling test were dropped. The resulting group of typical children closely matched the children with dyslexia in spelling level. None of the typical children had a reading, spelling, or learning difficulty according to their teachers and parents. Eighteen of the typical children performed within one standard deviation of the mean for their age group on the WRAT3 spelling test. The remaining seven children performed better than one standard deviation above the mean for their age group. All of the typical children were native English speakers.

The typical children ranged in age from 6 years, 4 months to 7 years, 4 months, with a mean of 6 years, 8 months. Fifteen were boys and ten were girls. Their mean grade level on the spelling subtest of the WRAT3 was 2.11 ($SD = 0.65$; range 1.2–3.7). Their mean grade level on the reading subtest was 2.49 ($SD = 0.80$; range 1.3–4.0). Because of the way in which the dyslexic and normal children were matched for spelling level, the two groups were extremely close on this measure. As it turned out, the two groups were quite similar in reading level as well. The small numerical superiority for the dyslexic children was not statistically significant ($P = 0.15$ by a two-tailed t test)

Materials

Nonwords for phoneme counting and nonword spelling tasks. Forty-four nonwords, each containing one or more linguistic features known to cause difficulty for beginning spellers, were constructed. The nonwords are listed in the Appendix. The linguistic features included word-initial

and word-final consonant clusters, consonant and vowel letter names, and reduced vowels in unstressed syllables.

The letter-name sequences /ɑɹ/[2] and /ɛl/ occurred in eight one-syllable and eight two-syllable nonwords, for example /dɑɹ/ and /ˈdɑɹəg/. Eight additional two-syllable nonwords that contained either /ɑ/, /ɹ/, /ɛ/, or /l/ served as controls. Examples are /ˈdɑzəb/ and /ˈgɛkəp/. All of the two-syllable nonwords had an unstressed, reduced vowel in the second syllable. Vowel phonemes that corresponded to the names of vowel letters occurred in ten one-syllable nonwords. These nonwords also contained initial consonant clusters, as in /dɹit/. Another ten nonwords contained final consonant clusters, as in /pɪlt/. Most of the final consonant cluster nonwords contained short vowels.

The 44 stimuli were divided into two lists. Each list contained an equal number of each type of stimulus. In each session, one list was used for the phoneme counting task and the other list for the nonword-spelling task.

Spelling choice test. The spelling choice test was similar to that of Siegel et al. (1995) and Treiman (1993). It contained 60 pairs of four-letter nonwords, shown in the Appendix. Ten pairs tested knowledge about allowable vowel doublets. Each of these pairs contrasted a spelling containing a common medial vowel doublet, *ee* or *oo*, with a spelling containing a very uncommon medial vowel doublet, either *aa* or *ii*. Another ten pairs tested knowledge about allowable consonant doublets, contrasting *ff*, *ss*, *ll*, *tt*, and *pp* with the illegal or extremely uncommon *hh*, *vv*, *kk*, *ww*, and *jj*.[3] The consonant doublets occurred at the ends of the nonwords, as with *noss* vs. *novv*. Another ten pairs tested knowledge about acceptable initial consonant clusters. These pairs contrasted a spelling containing a common initial cluster (e.g., *dret*) with one containing an illegal or uncommon cluster (e.g., *gvet*). Ten additional pairs, such as *pilt* and *pibk*, tested knowledge about acceptable final consonant clusters. For the consonant cluster pairs, the incorrect answer was phonologically as well as graphotactically illegal. The final 20 pairs tested knowledge about acceptable positions for consonant doublets using legal consonant doublets (*ll*, *ff*, *ss*, *pp*, *tt*, *mm*, and *nn*). One item in these pairs contained a final consonant doublet (e.g., *pess*) and the other contained an initial consonant doublet (e.g., *ppes*). The 60 nonword pairs were divided into two randomly ordered lists of equal size, one list for each session.

Real-word spelling test. A spelling test consisting of 15 words was constructed to provide additional data about the children's spelling skills and to ensure that the dyslexic and typical groups were well matched

on ability to correctly spell real words. These words, shown in the Appendix, contained sequences that typical young children often misspell.

Procedure

Each child was tested individually in two sessions approximately one week apart. Each session began with one form of the WRAT3 spelling test. The children then carried out the phoneme counting task with one list of items. This task was introduced as a game using colored cardboard circles. The child was asked to repeat the ''made-up word'' stated by the experimenter and then count each sound in the item by putting a circle on the table while saying the sound aloud. The experimenter demonstrated the game using /bɪs/ and /vʌdz/. The child then counted the sounds in three additional practice nonwords with corrections and feedback given by the experimenter. The experimental nonwords followed. No feedback other than general encouragement about performance was given on these items. This portion of the experimental session was tape-recorded. Following the phoneme counting task, the child was given one form of the WRAT3 reading subtest.

The nonword spelling task was administered next. The child was told that he or she would be asked to write ''made-up words'' that had no right or wrong spellings. Children were instructed to repeat each nonword after the experimenter and then spell it. If a child mispronounced a nonword, the experimenter repeated it up to three times before asking the child to write it. The child was told to spell each nonword the way he or she thought it would be spelled if it were a real word.

The spelling choice test followed. Children were asked to look at the two ''made-up words'' in each space on their paper. They were instructed to look carefully at both spellings and then circle the one they thought looked more like real words should look. The experimenter and child did four practice pairs together, with the experimenter correcting or confirming the child's choices. The children then finished the spelling choice test on their own. The experimenter covered completed pairs to prevent comparisons to previous answers.

The same task sequence occurred in the second session with the real-word spelling test added at the end. For the real-word spelling test, the experimenter said each word, said it in a sentence, and then said the word again. The child was asked to write the word on a prepared answer sheet.

Results

Phoneme counting. Table 1 shows the mean proportion of nonwords that were segmented correctly in the phoneme counting task. To be scored as correct, the phonemes had to be reported in the correct order, except that vowels could vary, as when /ə/ was said for /ɑ/, and voicing changes on consonants were allowed. For the letter-name nonwords, there was no main effect of group ($F(1, 48) = 0.04$, $P = 0.83$). However, there were main effects of letter ($F(1, 48) = 11.17$, $P = 0.002$) and nonword type ($F(2, 96) = 63.39$, $P < 0.001$), as well as a three-way interaction involving group, letter, and nonword type ($F(2, 96) = 3.41$, $P = 0.037$). The children with dyslexia performed substantially more poorly on the one-syllable and two-syllable *r* letter-name nonwords than on the corresponding *l* letter-name nonwords. The typical children showed smaller differences between *r* and *l* letter-name nonwords.

For the cluster nonwords, there was no reliable difference between the children with dyslexia and the typical children in the accuracy of phoneme counting performance ($F(1, 49) = 1.77$, $P = 0.19$). Also, no significant difference between initial and final clusters was observed.

Nonword spelling. We examined the children's nonword spellings to determine how they represented letter names, reduced vowels, and consonant clusters. Spellings of letter-name sequences and the corresponding control sequences were categorized as VC, V, or C spellings. A VC spelling contained any vowel followed by an *r* or *l*, depending on the letter name in the nonword. A V spelling contained a vowel after the initial consonant(s), but the vowel was not followed by *r* or *l*. Lastly, a

Table 1. Mean proportion of nonwords of different types correctly segmented in phoneme counting task of Study 1 (standard deviations in parentheses).

	r letter name			*l* letter name			Cluster	
	one syll.	two syll.	*r*-control	One syll.	two syll.	*l*-control	initial	final
Dyslexic	0.46	0.12	0.27	0.71	0.29	0.26	0.53	0.52
	(0.34)	(0.21)	(0.28)	(0.34)	(0.35)	(0.36)	(0.34)	(0.38)
Typical	0.52	0.17	0.25	0.56	0.21	0.31	0.41	0.38
	(0.41)	(0.29)	(0.35)	(0.30)	(0.31)	(0.32)	(0.37)	(0.34)
Combined	0.49	0.15	0.26	0.64	0.25	0.29	0.47	0.45
	(0.37)	(0.25)	(0.31)	(0.32)	(0.33)	(0.34)	(0.36)	(0.36)

C spelling contained an *r* or *l* after the initial consonant(s). Fewer than 1% of the children's spellings did not fit into any of these categories, and these spellings were not included in the analyses. Table 2 shows the proportions of spellings in each category for each group and type of nonword. The analysis for each spelling type used the factors of group, letter, and nonword type. The three sets of findings are not independent because the VC, V, and C variables are related.

For VC spellings, the dyslexic and typical groups did not differ significantly ($F(1, 48) = 0.78$, $P = 0.38$). However, there were main effects of letter ($F(1, 48) = 18.34$, $P < 0.001$) and nonword type ($F(2, 96) = 11.21$, $P < 0.001$), as well as an interaction between them ($F(2, 96) = 5.55$, $P = 0.005$). The children produced substantially more VC spellings for *l* one-syllable and two-syllable letter-name nonwords than for *r* nonwords, a difference that has previously been noted for typical beginners (Treiman, 1993). The difference between two-syllable and control letter-name nonwords was larger for *r* than for *l*.

For V spellings, the main effect of group was again not significant ($F(1, 48) = 0.67$, $p = 0.42$). However, there was a main effect of nonword type ($F(2, 96) = 19.95$, $P < 0.001$). The children produced more

Table 2. Mean proportions of spellings of various types for letter names in nonwords of Study 1 (standard deviations in parentheses).

	One syllable			Two syllable			Control		
	VC	V	C	VC	V	C	VC	V	C
r letter name									
Dyslexic	0.73	0.01	0.25	0.56	0.05	0.38	0.73	0.11	0.14
	(0.39)	(0.05)	(0.37)	(0.43)	(0.12)	(0.41)	(0.27)	(0.19)	(0.15)
Typical	0.70	0.01	0.29	0.50	0.06	0.42	0.65	0.10	0.23
	(0.32)	(0.05)	(0.32)	(0.40)	(0.15)	(0.39)	(0.30)	(0.16)	(0.25)
Combined	0.72	0.01	0.28	0.53	0.06	0.41	0.69	0.10	0.21
	(0.35)	(0.05)	(0.35)	(0.41)	(0.15)	(0.40)	(0.28)	(0.18)	(0.22)
l letter name									
Dyslexic	0.92	0.01	0.06	0.76	0.06	0.18	0.80	0.09	0.09
	(0.23)	(0.05)	(0.17)	(0.28)	(0.13)	(0.25)	(0.26)	(0.16)	(0.17)
Typical	0.86	0.01	0.12	0.72	0.10	0.18	0.71	0.16	0.11
	(0.29)	(0.05)	(0.29)	(0.33)	(0.16)	(0.25)	(0.30)	(0.19)	(0.18)
Combined	0.89	0.01	0.10	0.74	0.08	0.18	0.76	0.13	0.11
	(0.26)	(0.05)	(0.25)	(0.30)	(0.15)	(0.25)	(0.28)	(0.18)	(0.18)

V spellings for the control nonwords, which did not contain a letter-name sequence, than for the letter-name nonwords.

For C spellings, we again found no reliable difference between the children with dyslexia and the typical children ($F(1, 48) = 0.56$, $P = 0.48$). As with VC spellings, there were main effects of letter ($F(1, 48) = 23.57$, $P < 0.001$) and nonword type ($F(2, 96) = 11.69$, $P < 0.001$), as well as an interaction between these variables ($F(2, 96) = 4.13$, $P = 0.02$). The children produced more C spellings for *r* nonwords than *l* nonwords and more C spellings for two-syllable letter-name nonwords than one-syllable and control letter-name nonwords. The difference between the nonword types was larger for *r* than for *l* nonwords.

We next examined children's spellings of the vowels in the initial cluster nonwords. These nonwords contained the phonemes that are the names of the vowel letters *a*, *e*, *i*, and *o*. The percentage of spellings that contained the vowel corresponding to the letter name and no other vowel letter (e.g., "dret" for /dɹit/) was 48% for the children with dyslexia and 53% for the typical children. These percentages did not differ significantly ($t(48) = 0.69$, $P = 0.49$, two tailed).

Next, we analyzed the proportions of two-syllable letter-name and control nonword spellings in which the reduced vowels were represented. If any vowel letter occurred between the second and third consonants in the child's spelling, as in "grot" for /ˈgɔɹət/, it was considered a spelling of the reduced vowel. An ANOVA using the factors of group (dyslexic vs. typical), nonword type (letter name vs. control), and letter (*r* vs. *l*) revealed no significant effect of group ($F(1, 48) = 0.03$, $P = 0.85$). Children with dyslexia represented the reduced vowels 71% of the time, and typical children represented them 72% of the time. The only significant effect was that of nonword type ($F(1, 48) = 14.57$, $P < 0.001$). This effect arose because children were more likely to spell the reduced vowel in the two-syllable letter-name nonwords (76%) than in the control nonwords (67%).

To examine the spellings for the initial and final consonant clusters in the nonwords, we categorized a spelling as CC if it contained two consonants for the cluster, C1 if it represented only the first consonant of the cluster, and C2 if it represented only the second consonant. The consonants had to be either a conventional spelling for the phoneme, a reversal of a conventional spelling, or a letter representing a change in voicing for the phoneme. In addition, *ed* was accepted as a spelling of final /d/. Table 3 shows the proportion of spellings that fell into each category. Fewer than 5% of the spellings did not fit into the preceding categories.

Table 3. Mean proportions of spellings of various types for initial and final consonant clusters in Study 1 (standard deviations in parentheses).

	Initial cluster			Final cluster		
	CC	C1	C2	CC	C1	C2
Dyslexic	0.81	0.16	0.02	0.71	0.03	0.24
	(0.26)	(0.20)	(0.06)	(0.25)	(0.05)	(0.21)
Typical	0.71	0.29	0.00	0.56	0.01	0.40
	(0.32)	(0.32)	(0.02)	(0.31)	(0.03)	(0.29)
Combined	0.76	0.22	0.01	0.64	0.02	0.32
	(0.29)	(0.27)	(0.05)	(0.29)	(0.04)	(0.26)

For CC spellings, no significant effect of group ($F(1, 48) = 2.85$, $P = 0.10$) was found, although the tendency was for more CC spellings by the children with dyslexia. There was an effect of position such that children produced more CC spellings for initial clusters than final clusters ($F(1, 48) = 10.97$, $P = 0.002$). For C1 spellings, there was again no significant main effect of group ($F(1, 48) = 2.00$, $P = 0.16$). We did find a main effect of position ($F(1, 48) = 30.54$, $P < 0.001$) and an interaction of group and position ($F(1, 48) = 4.24$, $P = 0.04$). The children produced more C1 spellings for initial clusters than for final clusters, with this difference larger for the typical children than for the children with dyslexia. For C2 spellings, we found main effects of group ($F(1, 48) = 4.29$, $P = 0.04$) and position ($F(1, 48) = 71.83$, $P < 0.001$), as well as an interaction between these variables ($F(1, 48) = 5.86$, $P = 0.02$). Both groups of children produced more C2 spellings for final consonant clusters than for initial consonant clusters. However, the typical children produced substantially more C2 spellings than the children with dyslexia.

The idea that letter reversals are a salient feature in the spellings of children with dyslexia may be traced to early theories about reading disability (Vernon, 1957), although it has not received support in more recent studies (e.g., Moats, 1983; Nelson, 1980). To further test this idea, we examined the frequency of reversal errors in the children's nonword spellings. A written letter was counted as a reversal if it was a mirror image of the correct letter or a letter that, if reversed, was an appropriate representation of the phoneme, such as *d* for *b* in words with /b/. The mean number of reversals was 2.40 for the children with dyslexia and 1.92 for the typical children, not a significant difference

($t(48) = 0.53$, $P = 0.60$). Twelve of the children with dyslexia produced at least one letter reversal and seventeen of the typical children did so. When the children were divided into four frequency categories according to the number of reversals they produced (0, 1–3, 4–6, and 7 or more), no significant difference was found between the two groups of children ($\chi^2(3) = 4.81$, $P = 0.19$).

Finally, we classified the children's nonword spellings for phonological appropriateness and use of legal letter patterns. We used four scoring systems developed in previous studies (see Bourassa & Treiman, 2003; Bruck, Treiman, Caravolas, Genesee, & Cassar, 1998). For the first system, the phonologically correct–constrained scoring system, we considered whether each letter in the spelling was acceptable for the phoneme in its word position and environment. For example, a phonologically correct-constrained spelling for /dɹaɪk/ is "drike;" "drick" is not acceptable by this system because /aɪ/ is never conventionally spelled with single *i* in this context. In the phonologically correct-unconstrained scoring system, the phoneme's position and environment were not considered. In this system, "drick" was accepted for /dɹaɪk/. In addition, spellings that omitted the vowel of a letter-name sequence were accepted (e.g., "grup" for /ˈgɑɹəp/). For the phonological skeleton scoring system, we considered whether the spelling preserved the pattern of consonants and vowels in the nonword. For instance, "jrac" preserves the CCVC pattern of the nonword /dɹaɪk/ whereas "dite" does not. The scoring system based on graphotactic acceptability considered whether the sequence of letters is permissible in English. For example, neither "dort" nor "dakc" represents the phonological structure of /dɹaɪk/, but "dort" is a legal sequence of letters whereas "dakc" is not.

Each nonword spelling was scored using these four systems. Because a spelling scored as correct using the phonologically correct-constrained system would also be correct using the unconstrained system, only those spellings counted as incorrect under the constrained system were scored using the unconstrained system. Table 4 shows the proportions of spellings that were correct using each system. No significant differences were observed between the children with dyslexia and the typical children on any of the measures (phonologically correct-constrained: $t(48) = 0.70$, $P = 0.49$; phonologically correct-unconstrained: $t(48) = 0.07$, $P = 0.95$; phonological skeleton: $t(48) = 0.93$, $P = 0.36$; graphotactic acceptability: $t(48) = 1.58$, $P = 0.12$).

Spelling choice task. Table 5 shows the proportions of correct responses for the children with dyslexia and the typical children on the various

Table 4. Mean proportions of correct nonword spellings in Study 1 according to different scoring systems (standard deviations in parentheses).

	Phonologically correct–constrained	Phonologically correct–unconstrained	Phonological skeleton	Graphotactic acceptability
Dyslexic	0.44	0.17	0.69	0.85
	(0.25)	(0.10)	(0.23)	(0.13)
Typical	0.39	0.17	0.62	0.79
	(0.23)	(0.09)	(0.26)	(0.13)

Table 5. Mean proportion correct on spelling choice task of Study 1 as a function of pair type and group (standard deviations in parentheses).

Pair type	Dyslexic	Typical
Allowable vowel doublets	0.87	0.83
	(0.17)	(0.21)
Allowable consonant doublets	0.90	0.84
	(0.18)	(0.18)
Allowable initial clusters	0.84	0.82
	(0.17)	(0.23)
Allowable final clusters	0.85	0.79
	(0.18)	(0.21)
Doublet position	0.92	0.83
	(0.13)	(0.19)
Total	0.88	0.82
	(0.13)	(0.17)

types of pairs in the spelling choice task. Both groups performed significantly above chance (0.50) on each pair type ($P < 0.001$). Although there was a small numerical superiority for the children with dyslexia, an ANOVA using the factors of group (dyslexic vs. typical) and pair type (common consonant, common vowel, position, final cluster, or initial cluster) found no reliable main effect of group ($F(1, 48) = 1.53$, $P = 0.22$). There were no other significant effects.

Real-word spelling tests. The mean percentage of correct spellings for the children with dyslexia was 45% ($SD = 25\%$). For the typical children, the mean was 44% ($SD = 26\%$). The small difference was not statistically significant ($t(48) = 0.15$, $P = 0.88$). This result confirms that

the two groups were well matched on ability to produce correct spellings of words. The children with dyslexia tended to produce more letter reversals than the typical children (mean frequencies 0.84 and 0.32 respectively) when spelling words, but the difference was not statistically significant ($t(48) = 1.49$, $P = 0.14$).

Additional analyses of children's spellings. Additional analyses were carried out to follow up on an apparent difference between dyslexic and normal children's spelling that was reported in post hoc analyses by Bourassa and Treiman (2003). In that study, final *e* intrusions on items that contained a short vowel followed by a single consonant phoneme (e.g., "nape" for *nap*) were significantly more common for the children with dyslexia than for the typical children. The children with dyslexia also tended to produce more final *e*s for items with long vowels followed by a single consonant, but this difference was not significant. In the present study, the children with dyslexia included a final *e* 9% of the time in their spellings of one-syllable items from the real-word spelling test, the WRAT3, and the nonword spelling test that contained the short vowel /ɪ/, /ɛ/, /ʌ/, /æ/, or /ɑ/ followed by a single consonant phoneme, and where an *e* is not required by the final consonant letter (as it is in *give*). The corresponding figure was 7% for the typical children. When spelling monosyllables or word-final syllables that contained the long versions of these vowels but that were otherwise similar in structure, the children with dyslexia used a final *e* 37% of the time, as compared to 35% for the typical children. An ANOVA by items showed a main effect of vowel type, $F(1, 35) = 53.71$, $P < 0.001$, such that children used final *e* more often for long vowels than for short vowels. There were no significant effects involving group, indicating that the children with dyslexia and the typical children did not differ in their ability to distinguish long and short vowels in spelling.

Tests for homogeneity of variance. Finally, we compared the variability of the dyslexic and typical groups' performances on the variables from the phoneme counting, nonword spelling, spelling choice, and real-word spelling tasks. Comparisons were conducted for 57 variables. On 4 variables, the performance of the children with dyslexia varied more than the typical children's performance as judged by Cochran's *C,* Bartlett-Box *F,* and Hartley's $F_{\max}$. These were C2 spellings for initial consonant clusters, C1 spellings for final consonant clusters, and letter reversals in nonword and real-word spellings. C2 spellings of initial consonant clusters and C1 spellings of final consonant clusters were very infrequent for both groups of children, and few children made

any such errors. For letter reversals, three children with dyslexia produced more than eight reversals on nonwords. These same children each produced more than four reversals on real words. None of the typical children produced more than seven reversals on nonwords or more than three reversals on real words. On another 4 variables the typical children's performance varied significantly more than that of the children with dyslexia according to the criteria listed above. These variables were C spellings of *r* letter-name control nonwords, C spellings of one-syllable *l* letter-name nonwords, C1 spellings of initial consonant cluster nonwords, and proportion correct on position nonword pairs of the spelling choice test. In each case, the typical children tended to perform more poorly than the children with dyslexia did and some typical children performed especially poorly. In general, then, there is little evidence that the children with dyslexia were more variable than the typical children. The only area in which this may be the case involves letter reversals, where a few children with dyslexia made a disproportionate number of such spellings.

Discussion

Study 1 compared older children with dyslexia and younger typical children, closely matched on ability to spell real words, on a variety of other tasks. These included nonword spelling, phoneme counting, and graphotactic knowledge. We asked whether children with dyslexia experience difficulties with the same linguistic structures that are problematic for typical beginners, and we also asked whether the phonological difficulties are more severe in the children with dyslexia than the typical children. A further question was whether children with dyslexia have better knowledge of legal and illegal spelling patterns than would be expected given their ability to spell real words.

The children with dyslexia had difficulties with the same phonological structures that cause problems for typical first graders. Both groups of children had difficulty segmenting and spelling sequences of phonemes that matched a letter name (especially *r*), reduced vowels, and consonant clusters. These similarities suggest that the phonological awareness and spelling problems experienced by children with dyslexia are similar in nature to the problems experienced by typical beginners. With regard to severity, the children with dyslexia were not consistently worse than the younger typical children on the nonword spelling and phoneme counting tasks. Only sporadic differences appeared. The children with dyslexia had particular difficulty counting the phonemes in the *r* letter name sequence in nonwords. In contrast, the children with

dyslexia made fewer errors spelling initial and final consonant clusters than typical children. This latter outcome fails to replicate the finding of Bruck and Treiman (1990) that children with dyslexia perform more poorly on initial consonant clusters than typical children. The children with dyslexia did not significantly outperform the typical children on tests of graphotactic knowledge, as some previous researchers have reported (e.g., Siegel et al., 1995). Nor were the dyslexics' spellings significantly more likely to consist of legal letter sequences. These results do not support the idea that children with dyslexia possess relatively well-developed knowledge of letter patterns that they use to compensate, to some extent, for their poor phonological skills.

Study 2

As researchers, we were unable to find clear differences between the spellings of older children with dyslexia and younger typical children in Study 1. The few differences were sporadic and mixed, and we did not replicate several differences that have been noted in past studies. Given the differences between dyslexic and typical children that have been reported in the literature, we wondered whether there were certain subtle effects that our measures failed to pick up. We addressed this issue in Study 2 by asking whether experienced teachers could distinguish the two groups based on their spellings. Could teachers judge whether a speller was an older child with dyslexia or a younger typical child in the absence of information about the child's handwriting, age, or educational history?

Method

Participants. The participants were 44 volunteers who had first-hand experience working with children with serious reading and spelling difficulties. They worked in a range of settings, including public schools, private practices, and reading clinics. These individuals were solicited through an Internet mailing list and personal contacts. We included data from those respondents who were native speakers of English, lived in the United States, and had at least a bachelor's degree in education, psychology, or a related field.

Materials

We included spellings for words from the real-word spelling test and the WRAT3 spelling subtest that all of the children in Study 1

attempted, and we excluded the word *cat*, which all of the children spelled correctly. This yielded 39 spellings for each child. Each child's spellings were typed in lower-case letters on a separate page, with the child's spellings down the left side of the page and the conventional spelling of each word to the right. At the top right side of each answer sheet were two boxes labeled "typical child" and "dyslexic child." The answer sheet included a scale on which the participant was asked to rate his or her confidence in the dyslexic/typical decision on a scale from 1 ("not at all confident") to 5 ("extremely confident").

The 50 children from Study 1 were divided into two groups, one containing 12 children with dyslexia and 13 typical children and the other the reverse. Each participant in Study 2 saw the spellings produced by one group of children in a randomized order. Participants were randomly assigned to groups. Participants were informed in writing that about half of the children whose spellings they would see were typical 6- and 7-year-olds, and that the other half were older children who had serious difficulties in learning to spell and read. They were asked to look at each child's spellings, make a decision about the child's status, rate their confidence in that choice, and then indicate which aspects of the child's spellings led to their decision.

Results and Discussion

The first row of Table 6 shows the mean proportion of correct responses and the mean confidence ratings for all 44 participants. As a group, the participants did not score higher than the 0.50 that would be expected by chance, and they were not highly confident in their responses. We also examined the responses for those 10 individuals who had the most experience, at least 7 years, teaching children with reading and spelling disabilities. Finally, we examined the results for those 10 participants who reported at least one year of experience (beyond student teaching or internship) as a teacher in a regular classroom with children between kindergarten and third grade, in addition to their experiences with reading-disabled children. Arguably, these latter individuals would be in the best position to compare typical and disabled students. For both of the subgroups, as for the group as a whole, performance did not differ significantly from chance.

Judging from the participants' comments, they held many of the hypotheses that have been put forward in the literature about how the spellings of children with dyslexia might differ from those of typically developing younger children. Perhaps the most widespread view was that children with dyslexia are especially poor at representing the

Table 6. Mean proportion of correct responses and mean confidence ratings for participants in Study 2 (standard deviations in parentheses).

	Proportion correct	Confidence rating
All participants ($N = 44$)	0.49 (0.09)	3.36 (0.67)
Participants with most teaching experience with children with serious reading and spelling problems ($N = 10$)	0.51 (0.08)	3.55 (0.48)
Participants with teaching experience with typically progressing children in early elementary school as well as dyslexics ($N = 10$)	0.50 (0.12)	3.39 (0.87)

phonological structure of spoken words in spelling. Thus, many of the respondents considered difficulties with consonant clusters, omissions of unstressed syllables, and nonphonetic substitutions to be indicators of dyslexia. Some respondents stated that "orthographically sophisticated" spellings were more common among children with dyslexia than among typical younger children. However, other participants considered spellings with illegal letter sequences, such as word-initial *ck*, to indicate dyslexia.

To summarize, even the most experienced teachers could not reliably determine, based on a child's spellings alone, whether that child was a typical beginner or an older child with dyslexia. The teachers' poor performance, rather than reflecting poorly on them, shows that the two groups of children indeed produce very similar spellings. The results of Study 2 do not support the idea that children with dyslexia have a different pattern of strengths and weaknesses than typical younger children that manifests itself in spelling and that causes dyslexics' spellings to differ systematically from those of typically developing younger children.

General discussion

Children with dyslexia are poor spellers. The dyslexic children in the present study, who averaged about 11 1/2 years old, were no better at spelling real words than normally developing first and second graders. Despite this abnormally low level of performance, the children with dyslexia were more normal than might have been expected in several respects. For one, the dyslexics had difficulty with the same linguistic structures that were problematic for typical beginners.

These included consonant clusters, unstressed vowels, letter-name vowels, and vowel-consonant sequences that correspond to letter names. Another way in which the children with dyslexia were less abnormal than had been expected was in their pattern of strengths and weaknesses. The dyslexics' performance on a phoneme counting task was commensurate with their spelling level, as was their performance on tests of graphotactic knowledge. This outcome does not fit with the view (e.g., Siegel et al., 1995) that children with dyslexia show extremely poor phonological skills, worse than would be expected given their level of literacy, coupled with relatively good knowledge of legal and illegal letter patterns. Supporting the idea that older children with dyslexia and younger typical children have similar profiles of strengths and weaknesses and produce similar kinds of spellings, teachers who had extensive first-hand experience with children with dyslexia could not reliably distinguish their spellings from the spellings of typical beginners. All in all, the older children with dyslexia were remarkably similar to the typical beginners in their spelling, phonological skills, and knowledge of legal and illegal letter patterns.

Our finding that beginning spellers with dyslexia have typical phonological and graphotactic skills for their level of spelling ability is surprising given the results of studies using a reading-level match design. Many such studies have found clear differences between the groups in reading skills, such that children with dyslexia rely more on knowledge of specific words, whereas typical readers rely more on decoding and phonology (for reviews see Rack et al., 1992; van IJzendoorn & Bus, 1994). The present results suggest a different state of affairs for spelling. Our results are consistent with the idea that phonology, although important for all aspects of literacy learning, is even more critical in learning to spell than in learning to read (e.g., Ehri, 1998; Frith, 1985; Goswami, 1992; Perfetti, 1992). According to this view, knowledge about the spelling patterns of a language is laid over a phonological foundation. If that phonological foundation is weak, knowledge of spelling patterns cannot develop sufficiently to support good spelling. Because of their poor phonological skills, children with dyslexia do not readily grasp the basis of an alphabetic writing system and do not acquire a sizable store of written spellings. This, in turn, means that they do not have a good database from which to learn about the letter patterns of the language. If phonology is the foundation on which spelling rests, with graphotactic knowledge built upon it, then children with phonological weaknesses will lag behind their age mates in both graphotactic and phonological skills. When children with dyslexia are

matched with typical younger children for ability to spell real words, the two groups will show similar phonological and graphotactic skills, as we found here. When children with dyslexia are matched with typical younger children for reading only, the dyslexics may be poorer spellers than the normal children and may show deficits in phonological skills.

Our results suggest that the linguistic difficulties that are beginning to be understood among children who are progressing at the expected rate in learning to spell and read, including difficulties with consonant clusters, reduced vowels, and so on, are also found among children who are making extremely slow progress. What we learn about the sources of these linguistic difficulties and how to overcome them should apply to all children. The similarities between children with and without dyslexia suggest that the two types of children do not need qualitatively different kinds of spelling instruction. Children with dyslexia clearly require more direct assistance to develop their phonological and spelling skills. But good instruction that focuses on the kinds of difficulties that are experienced by typical children should help all children.

Acknowledgments

Marie Cassar, Psychology Department, Saginaw Valley State University; Rebecca Treiman, Psychology Department, Washington University; Louisa Moats, Sopris West Educational Services; Tatiana Cury Pollo, Psychology Department, Washington University; Brett Kessler, Psychology Department, Washington University.

This work was supported, in part, by grants from the March of Dimes Birth Defects Foundation (12-FY98-204, 12-FY99-674, 12-FY00-51) and the National Science Foundation (SBR-9807736, BCS-0130763). We thank Christina Passejna, Andrew Yiu, and Margo Bowman for assisting with recruitment and data collection for Study 1 and Jeremy Cohen for helping tabulate the results of Study 2. We also thank the parents, teachers, administrators, and children at The Michigan Dyslexia Institute, The Greenwood School, The Beaumont Hospital Center for Human Development, Eton Academy, St. Vincent Ferrar Elementary School, and Huron Elementary School for their cooperation.

Notes

1. "Orthographic" has been used ambiguously to mean either correct spelling in general or, more specifically, rules about which letters can stand next to one another regardless of sounds. We use "graphotactic" as an unambiguous label for the latter.

2. Phonemes are represented using the alphabet of the International Phonetic Association (1996, 1999). The values of most IPA symbols agree with those of the corresponding English letter, but the following require special attention:/aɪ/ ***ai***sle, /æ/ ***a***pple, /ɑ/ ***o***dd, c***a***r, /e/ ***a***pe, /ɛ/ ***e***dit, /ə/ sof***a***, /g/ ***g***o, /i/ ***ea***t, /ɪ/ ***i***t, /o/ ***oa***t, /ŋ/ si***ng***, /ɔ/ d***aw***n, /ɹ/ ***r***ead, /u/ r***u***de**,** /ʊ/ p***u***t, /ʌ/ ***u***gly,' precedes primary stress in items of more than one syllable.
3. A few of the consonant doublets that we investigated, including *pp*, occur in the middle positions of words but rarely at the ends. The pattern of results did not change in a separate analysis that excluded these items.

Appendix

Nonwords for phoneme counting and nonword spelling tasks of Study 1

Practice nonwords for phoneme counting task: /bɪs/, /vʌdz/

One-syllable letter name: /dɑɹ/, /gɑɹ/, /sɑɹ/, /vɑɹ/, /kɛl/, /vɛl/, /gɛl/, /pɛl/

Two-syllable letter name: /'dɑɹəg/, /'gɑɹəp/, /'sɑɹət/, /'vɑɹəb/, /'kɛləp/, /'vɛləg/, /'gɛlət/, /'pɛləb/

Two-syllable control: /'dɑzəb/, /'gɔɹət/, /'sɑfəg/, /'tʊɹəp/, /'kɛdət/, /'vuləb/, /'gɛkəp/, /'pɪləg/

Initial cluster: /dɹit/, /tɹeg/, /dɹes/, /spaɪb/, /stob/, /sked/, /tɹip/, /dɹaɪk/, /tɹoz/, /blop/

Final cluster: /pɪlt/, /vʌnd/, /sɔnt/, /geŋk/, /tæld/, /fɪmp/, /zɔɹk/, /dɔɹt/, /kʌmp/, /bɪŋk/

Nonword pairs for spelling choice task of Study 1

Practice: *kos gnd, nas oau, vilo eoyu, baso rsmt.*

Vowel doublet: *heek haak, geed gaad, feep fiip, meer miir, jeet jaat, sook saak, bood biid, noop niip, woor wiir, goot gaat.*

Consonant doublet: *gatt gaww, noss novv, dett devv, viss viww, cepp cejj, jull jukk, naff nakk, soll sohh, teff tehh, dapp dajj.*

Initial cluster: *dret gvet, trag dzag, dras bfas, spib wpib, stob pdob, skad mkad, trep vcep, drik wgik, troz fjoz, blop kjop.*

Final cluster: *pilt pibk, vund vudk, gank gakj, sunt sutb, tald tacf, fimp fipg, zork zovn, dort dosr, kump kutk, bink bimh.*

Doublet position: *pess ppes, latt llat, lopp llop, tiss ttis, tull ttul, tunn ttun, foll ffol, femm ffem, piff ppif, luss llus, mott mmot, minn mmin, nall nnal, neff nnef, fapp ffap, pomm ppom, nupp nnup, simm ssim, saff ssaf, senn ssen.*

Real-word spelling test of Study 1

home, help, money, farm, raced, city, cart, bump, tent, people, trip, jar, dime, spider, kicked

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