

Spelling in Children With Dyslexia: Analyses From the Treiman–Bourassa Early Spelling Test

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We examined the oral and written spelling performance on the Treiman–Bourassa Early Spelling Test (Treiman & Bourassa, 2000a) of 30 children with serious reading and spelling problems and 30 spelling-level-matched younger children who were progressing normally in learning to read and spell. The 2 groups' spellings were equivalent on a composite measure of phonological and orthographic sophistication, representation of the phonological skeleton of the items, and orthographic legality. The groups showed a similar advantage for words over nonwords on the phonological skeleton and orthographic legality measures. The children with dyslexia and the comparison children also showed an equivalent advantage for written over oral spelling on the composite and phonological skeleton measures. Further analyses revealed that children with dyslexia made many of the same linguistically based errors as typically developing children but also pointed to some subtle differences between the groups. Overall, the spelling performance of children with dyslexia appears to be quite similar to that of normally progressing younger children.

Children with developmental dyslexia have great difficulty learning to read and write, despite normal intelligence, adequate learning opportunities, and no serious emotional or personality disorders. To illuminate the causes of these problems, re-

searchers have often compared children with dyslexia to younger, typically developing children of the same reading or spelling levels—a match that is often established through standardized tests. The main goal of the reading- or spelling-match design is to determine whether children with dyslexia show different patterns of performance than normally progressing children. If such differences exist, they could provide valuable clues to the nature and causes of reading and spelling problems in children with dyslexia.

Many researchers have used a reading-level match design to examine reading and reading-related skills in children with dyslexia. It is often argued that the difficulties experienced by children with dyslexia stem from deficits in phonological processing. Such children appear to have poor phonological awareness (e.g., Bradley & Bryant, 1978; Bruck, 1988; Bruck & Treiman, 1990), or awareness of and access to the individual sounds in words (Mattingly, 1972). Children who lack phonological awareness have difficulty on auditory tasks that require them to analyze spoken words, such as choosing the “odd word” in sets such as *bat*, *bin*, and *log* (e.g., Bradley & Bryant, 1983). If children do not understand that the spoken forms of words such as *bat* and *bin* begin with the same sound, they may not appreciate why their written forms begin with the same letter. To the extent that children with dyslexia have poor phonological skills, they will be disadvantaged in learning to read. They should have serious problems assembling pronunciations for unknown words, a task that places heavy demands on phonological processing. Many studies have found that children with dyslexia, as a group, have special difficulty decoding unfamiliar items (for reviews see Rack, Snowling, & Olson, 1992; van IJzendoorn & Bus, 1994). However, not all studies find this result (e.g., Treiman & Hirsh-Pasek, 1985).

If children with dyslexia have difficulty appreciating the phonological basis of written language, how do they make any progress in reading? One possible answer (e.g., Olson, 1985) is that they employ visual strategies to try to compensate for their phonological weaknesses. That is, children with dyslexia use their visual skills and word-specific knowledge to retrieve the identities of words from the mental lexicon. If children with dyslexia are aided by such a strategy, their knowledge of word-specific patterns and permissible letter sequences must be fairly good. Consistent with this idea, Siegel, Share, and Geva (1995) found that children with dyslexia, although poorer at nonword reading than reading-level-matched comparison children, performed significantly better on an orthographic choice task. This task involved choosing the more “wordlike” letter string from two alternatives, such as *moke* in the pair *moke–moje*. Although other researchers have not always found children with dyslexia to be better than younger children who do not have dyslexia on orthographic tasks, children with dyslexia are at least as good (e.g., Stanovich, Siegel, & Gottardo, 1997). As compared to reading-level-matched children who do not have dyslexia, then, children with dyslexia may have poor phonological skills but adequate orthographic skills. Their rela-

tively good orthographic skills allow them to perform similarly to the younger children without dyslexia on standardized word reading tests.

Most researchers have focused on the reading difficulties of children with dyslexia. However, individuals with dyslexia usually have serious problems with spelling as well (e.g., Boder, 1973; Critchley, 1975). The goal of our research was to better understand the spelling performance of children with dyslexia through the use of a spelling-level match design. Surprisingly little work has compared the phonological and orthographic characteristics of spelling performance by children with and without dyslexia to determine whether these aspects of spelling skill are dissociable in the manner that they appear to be for reading. We review the existing research on dyslexia and spelling before introducing our study.

If children with dyslexia have a phonological deficit that appears in spelling, then many of their spellings should fail to capture the phonological structure of the target words. Several researchers have attempted to test this idea by dividing misspellings into “phonetic” and “nonphonetic” categories. In phonetic errors, such as “klene” for *clean*, each phoneme is represented with a letter or letter group that may be used to symbolize that sound in English. Nonphonetic errors include “cene” for *clean* and “sak” for *sank*, in which a phoneme is omitted. A highly deviant spelling such as “fod” for *past* would also be a nonphonetic error. According to the phonological deficit hypothesis, children with dyslexia should produce a higher proportion of nonphonetic errors than spelling-level-matched children who do not have dyslexia. Some researchers have reported that nonphonetic errors are more frequent among children with dyslexia than younger children without dyslexia of the same spelling level (Bruck, 1988; Lennox & Siegel, 1996; Rohl & Tunmer, 1988). However, other researchers have not found such differences (Bradley & Bryant, 1979; Nelson, 1980; Pennington et al., 1986).

Unfortunately, the classification of spelling errors as “phonetic” or “nonphonetic” does not capture some important distinctions among errors (Bourassa & Treiman, 2001; Treiman, 1997). “Nonphonetic” spellings such as “fod” for *past* defy phonological explanation. They appear to reflect a lack of knowledge about sound-to-spelling correspondences, although they may reflect other types of knowledge, such as children’s knowledge about the letters in their own names (e.g., Treiman, Kessler, & Bourassa, 2001). “Nonphonetic” errors such as “cene” for *clean* and “sak” for *sank* have a phonological basis. Omissions of the interior consonants of initial and final clusters are relatively common among typical beginning spellers; these errors have a well-documented linguistic explanation (Treiman, 1991, 1993; Treiman, Zukowski, & Richmond-Welty, 1995). If individuals with dyslexia make many such errors, one cannot claim that they fail to appreciate the role of phonology in spelling. As this example shows, research on spelling in children with dyslexia should be informed by research on spelling in normal beginners. If it is not, then the conclusions may be invalid.

Misspellings by children with dyslexia generally appear to be reasonable and linguistically motivated (e.g., “cene” for *clean*, “sak” for *sank*) rather than very unusual (e.g., “fod” for *past*; Bruck & Treiman, 1990; Kibel & Miles, 1994; Moats, 1983; see Treiman, 1997, for a review). Still, quantitative comparisons between children with dyslexia and younger normally achieving children might reveal a phonological deficit in those with dyslexia (Treiman, 1997). For example, Bruck and Treiman (1990) found that children with dyslexia were more likely than younger children without dyslexia of the same spelling level to omit the second consonants of word-initial clusters, as in “cene” for *clean*. This result suggests that the phonological processing skills of children with dyslexia may be poorer than expected given their scores on standardized spelling tests. Children with dyslexia may attempt to spell by sound, but they may fail to capture some of the phonemes in the target items.

If children with dyslexia attempt to compensate for their phonological problems by using visual memory and orthographic skills, then they should have particular difficulty spelling nonwords, which have no representation in memory and which therefore draw on phonological processes. The *lexicality effect*—the advantage for real words over nonwords—should thus be larger for children with dyslexia than for younger children of the same spelling level. As we noted earlier, studies using a reading-level match design have typically found a larger lexicality effect in children with dyslexia (see Rack et al., 1992; van IJzendoorn & Bus, 1994). The few studies that have examined the lexicality effect for spelling show mixed results. The children with dyslexia and the spelling-match comparison children studied by Bruck (1988) showed lexicality effects that were similar in size. Martlew (1992) found a larger lexicality effect for children with dyslexia than for spelling-match control children. However, the small number of participants and stimuli in the Martlew study make it difficult to draw strong conclusions.

Other studies have examined knowledge of orthographic patterns by individuals with dyslexia. As noted earlier, the performance by children with dyslexia on orthographic choice tasks appears to be as good as or even better than that of typically developing children who score at similar levels on standardized spelling tests (Siegel et al., 1995; Stanovich et al., 1997). Nelson (1980) found that adolescents with dyslexia and younger control children did not differ in the orthographic legality of their misspellings, and Pennington et al. (1986) reported that adults with dyslexia were as good as or better than spelling-level controls in their knowledge of orthographic patterns.

To summarize, the large body of research on dyslexia and reading provides reasonably strong support for the idea that individuals with dyslexia, as a group, have poor phonological skills. Such individuals compensate, to some extent, by using orthographic knowledge and word-specific memory. The relatively small body of research on dyslexia and spelling provides only weak support for this claim, however. Additional research on dyslexia and spelling is needed, research that is in-

formed by knowledge of spelling development in normally achieving children. We attempted to meet this need by investigating the performance of children with dyslexia and spelling-level-matched younger children on the Treiman–Bourassa Early Spelling Test (T–BEST; Treiman & Bourassa, 2000a). This test includes words and nonwords that vary in complexity and that contain a number of linguistic features that are problematic for typical beginning spellers. In their earlier study, Treiman and Bourassa scored the children’s spellings in three ways (see Methods section for further details). The *composite measure* was designed to capture the overall sophistication of the children’s spellings. This measure (see also Tangel & Blachman, 1992, 1995) goes beyond traditional classification schemes that miss a great deal of information by scoring spellings simply as correct or incorrect. Consider the errors “te” and “tak” for *tank*. Although both are incorrect, “tak” is more sophisticated in that it represents more of the phonemes in the target word. It therefore gains more points on the composite measure. The composite measure permits even finer discriminations among spellings. For instance, although neither “de” nor “se” includes any of the letters in the correct spelling of *tank*, the former would receive a higher rating because /t/ and /d/ are phonetically similar, differing only in voicing.¹ Spellings on the T–BEST were also examined for their phonological and orthographic characteristics. The *phonological skeleton* measure (see also Bruck, Treiman, Caravolas, Genesee, & Cassar, 1998) reflects children’s ability to symbolize the consonant–vowel structure of the items. The *orthographic accuracy* measure (see also Bruck et al., 1998) taps the legality of the letter strings that spellers use.

Treiman and Bourassa (2000a) found developmental differences among young normally achieving children (kindergarten through second grade) on the composite, phonological skeleton, and orthographic accuracy measures for the words and nonwords on the T–BEST. The test and its scoring procedures are thus sensitive to differences in skill among young children who are learning to spell at a typical pace. In our study, we tested for a lexicality effect on the T–BEST by having each child with and without dyslexia spell both the words and nonwords. This procedure differs from that of Treiman and Bourassa, who tested words and nonwords in separate experiments. If the lexicality effect is larger for children with dyslexia than for younger normally progressing children of the same spelling level, this would support the phonological deficit hypothesis. This hypothesis would also be supported if the scores of the children with dyslexia on the phonological skeleton

¹Sounds are represented using the alphabet of the International Phonetic Association (1996, 1999). Conventional spellings are given in italics, children’s spellings in quotes, and pronunciations in IPA symbols surrounded by slash marks. The values of most IPA symbols agree with those of the corresponding English letter, but the following require special attention: æ *apple*, ɒ *odd*, *car*, e *ape*, ɛ *edit*, ə *sofa*, ø *ladder*, ɡ *go*, i *eat*, I *it*, o *oat*, ŋ *sing*, ɹ *read*, ɾ *ladder*, ʌ *ugly*, ' precedes primary stress in items of more than one syllable.

measure were lower than those of the comparison children. If individuals with dyslexia compensate to some extent for their phonological weaknesses by using orthographic knowledge, then the scores of those with dyslexia on the orthographic measure should exceed the scores of the younger children.

Another goal of our study was to examine the cognitive requirements of various spelling tasks and whether these differentially influence the performance of children with and without dyslexia. Previous work has found that older children (fourth through sixth grade; Jorm & Schoknecht, 1981) and adults (Stadtlander, 1996; Tenney, 1980) perform better in written spelling tasks than oral spelling tasks. Several factors may contribute to the superiority of written spelling for older children and adults. For one, the motor patterns for handwriting are well established by fourth grade. Because these motor skills demand little attention, they should not interfere with the processes of spelling. In addition, the reading lexicon (the store of words a person knows how to read) likely contains more words than the spelling lexicon (the store of words the person knows how to spell). People may sometimes decide on the correct spelling of a word by writing it down and attempting to read what they have produced (Simon & Simon, 1973). This is not possible with oral spelling. A further disadvantage of oral spelling is that people must rely on short-term memory to track where they are in spelling a word. In contrast, a writer can easily tell which letters have been produced and which remain to be written.

Treiman and Bourassa (2000a) compared written and oral spelling on the T-BEST for children in kindergarten through second grade, permitting an analysis of task differences in children younger than the fourth to sixth graders tested by Jorm and Schoknecht (1981). Treiman and Bourassa found no differences between oral and written spelling among kindergartners. However, an advantage for written spelling was observed among first and second graders. When spellings of real words were scored for correctness, the superiority for written spelling over oral spelling did not reach conventional levels of statistical significance for first graders but was reliable for children tested early in second grade. First and second graders showed a significant superiority for written spelling on the composite score on the T-BEST, both with real words and nonwords. Although the typically developing children more accurately captured an item's phonological skeleton when they spelled it on paper than when they spelled it aloud, written and oral spellings did not differ in orthographic accuracy. Treiman and Bourassa concluded that typically developing children can better analyze and represent phonology when they can symbolize the results in a lasting, visible form (written task) than when they cannot (oral task).

In the present study, we matched children with and without dyslexia on a standardized written spelling task with real words, the Wide Range Achievement Test (3rd edition; WRAT-3; Wilkinson, 1993). Given this match, both groups were expected to produce similar numbers of correct spellings of real words on the written

spelling task of the T-BEST. We asked whether the lack of a visible record of an item's spelling, as in the oral task, has a different impact on children with dyslexia than on typical children. The answer to this question may depend on the previously noted idea that, when spelling aloud, people rely on auditory short-term memory to track their performance. Individuals with dyslexia appear to have poor short-term auditory memory (e.g., Brady, 1997) and so may have particular difficulty with oral spelling relative to written spelling.

METHOD

Participants

Children with dyslexia. Children with dyslexia were recruited through three institutions—Michigan Dyslexia Institute, Center for Human Development, and Eton Academy. The first two organizations provide evaluation and tutoring services to children and adults with dyslexia. Eton Academy is a private day school for children with dyslexia and other learning difficulties. All three institutions are located in the suburbs of Detroit, Michigan.

Administrators at each institution nominated possible participants who had been classified as developmentally dyslexic. Permission to participate was granted for 42 children with dyslexia, all native speakers of English. To be included in the final sample, a child with dyslexia had to meet three criteria: (1) Full Scale Standard IQ score of at least 85 (Wechsler, 1991); (2) performance below the 25th percentile for the applicable age group on both the Spelling and Reading subtests of the WRAT-3 (Wilkinson, 1993), based on the combined performance across the two forms of each subtest;² and (3) performance below the fourth-grade level on the Spelling subtest of the WRAT-3, based on the combined performance across the two forms.

The selection procedures for our study are similar to those of many previous studies. The WRAT has often been used in the classification of individuals with dyslexia (e.g., Bruck, 1988; Bruck & Treiman, 1990; Pennington et al., 1986; Siegel et al., 1995), and studies of dyslexia typically rule out children with low IQs. Our use of a spelling percentile cutoff did not appear to create a sample that differed from that of other studies. Rarely is a child a poor reader but a good speller (e.g., Frith, 1980), and indeed no child who was referred for the dyslexia study

²The WRAT-3 (Wilkinson, 1993) Spelling and Reading subtests both have two alternate forms. Wilkinson recommends the use of both forms for a more comprehensive test of spelling and reading skills. Each child's spelling score is based on his or her combined (not averaged) score across the two spelling forms, and likewise for the reading score. The grade levels and percentiles we report are based on the Combined Age Norms listed in the WRAT-3 manual.

sample was excluded because he or she was above our spelling percentile cutoff but below our reading cutoff. We selected children who scored below the fourth-grade level on the WRAT-3 because the spelling test of interest, the T-BEST (Treiman & Bourassa, 2000a), is sensitive to individual differences in spelling skill among normally progressing children in early elementary school. Ceiling effects on this test would be likely among children with higher levels of spelling skill.

Thirty of the potential participants (21 boys) met all three criteria and took part in the study. These children ranged in age from 7 years 11 months to 14 years 7 months, with an average age of 11 years 1 month. Table 1 shows the participants' mean grade level and percentile scores for the Spelling and Reading subtests of WRAT-3. The mean Full Scale IQ was 100.17 ($SD = 8.17$, range = 85–123).

Children without dyslexia. Sixty-four kindergarten to third-grade children from four schools in suburban Detroit were given parental permission to participate. All were native speakers of English. To be included in the study, a control group child had to meet two criteria: (a) performance at or above the 25th percentile for the appropriate age group on both the Spelling and Reading subtests of the WRAT-3, based on the combined performance across the two forms of each subtest, and (b) performance below the fourth-grade level on the Spelling subtest of the WRAT-3, based on the combined performance across the two forms. Forty-three of the children met these criteria. These children had a mean spelling grade level of 2.39 ($SD = 0.83$, range = 1.0–3.9) on the Spelling subtest of the WRAT-3. To equate the dyslexia and control groups on sample size ($n = 30$), the data from 13 control children were removed from further analyses, with the constraints that the resulting group would remain closely matched to the dyslexia group in spelling level and number of children in each of the four counterbalance conditions (see our later discussion). (The results for the initial group of 43 and the final group of 30 were similar.) The final sample of 30 control children (16 boys) ranged in age from 6 years 2 months to 8 years 10 months, with a mean age of 7 years 5 months. Table 1 shows the mean grade level and percentile scores for the Spelling and Reading subtests of WRAT-3 for the control children. The dyslexia and control groups were very similar with respect to mean spelling and mean reading performance, with no significant group differences on these measures ($ps > .45$ according to t tests).

Stimuli

Each child spelled two lists of items (List A and List B; see Appendix), each of which was derived from the word and nonword versions of the T-BEST (Treiman

TABLE 1
Wide Range Achievement Test (3rd ed.) Spelling and Reading Scores of Children With
Dyslexia and Spelling-Level-Matched Children Without Dyslexia

	<i>Group</i>					
	<i>Dyslexic</i>			<i>Nondyslexic</i>		
	<i>M</i>	<i>SD</i>	<i>Range</i>	<i>M</i>	<i>SD</i>	<i>Range</i>
Spelling grade equivalent	2.49	0.82	1.1–3.9	2.44	0.87	1.0–3.9
Spelling percentile	7.73	5.17	1–23	62.50	16.64	27–84
Reading grade equivalent	3.10	0.95	1.1–5.5	2.94	0.89	1.0–4.3
Reading percentile	9.50	5.82	0.1–23	70.10	20.03	25–95

& Bourassa, 2000a). Each list contained 10 words and 10 nonwords. For each child, one list was administered as an oral spelling test and the other as a written test. The words and nonwords on the two lists were similar in phonological structure and spelling patterns. The items on each list were presented in the same order to all children, the 10 words followed by the 10 nonwords.

Procedure

For the written spelling task, the child was told that he or she would be asked to spell some words and some “made-up words.” The experimenter first asked the child to spell his or her first name. One of the test lists, A or B, was then presented. For the word targets, the experimenter said each word, used it in a sentence, and then said the word again. The child was asked to repeat the target word. The child was given three chances to do so, and all children successfully repeated all target words. The child then wrote the word on his or her paper. The experimenter provided general encouragement but did not indicate whether a child’s spellings were correct. If the experimenter could not make out a letter the child had written, he or she inquired about the intended letter after the child had finished spelling the word. A poster on a nearby wall showed the upper- and lowercase forms of each letter. The procedure for nonwords was identical to that for words, except that the experimenter pronounced each nonword three times before asking the child to repeat and spell it. All children successfully repeated all target nonwords.

The procedure for the oral spelling task was like that for the written task except that the experimenter asked the child to spell each word aloud. Responses were tape recorded for later verification.

During the first session, each child spelled one list (A or B) in either the written or oral condition. During the second session, which took place an average of 7 days

after the first, the child spelled the other list in the other condition. The order of the written and oral conditions was balanced across children. The assignment of lists to conditions was also balanced. Four counterbalancing conditions were thus represented equally between the dyslexia and control groups: List A, oral, followed by List B, written (7 children from each group); List A, written, followed by List B, oral (7 children from each group); List B, oral, followed by List A, written (9 children from each group); List B, written, followed by List A, oral (7 children from each group).

RESULTS

Measures From Treiman and Bourassa (2000a)

In our first set of analyses, we used the measures developed by Treiman and Bourassa (2000a) to score the children's spellings.

Correctness. By this system, each word spelling was scored as conventionally correct or incorrect. Spellings that contained only some of the correct letters received no credit. Because the nonwords had several potential spellings, they were not scored as correct or incorrect.

Composite spelling score. The composite scoring system was designed to measure the overall sophistication of children's spelling attempts (see Treiman & Bourassa, 2000a, for details). It is called a composite scoring system because it reflects both phonological and orthographic features of the children's spellings. Primitive attempts that did not include any letters (e.g., spellings that included only numbers) or spellings that included some letters unrelated to the sounds in the word and some other symbols would receive scores of 0 and 1, respectively. However, no such spellings occurred in this study. Some spellings in this study comprised only letters, but the letters were not related to the sounds in the word. For example, one child produced "jjavi" for *locked*. These attempts received a score of 2. More points were given for spellings that represented some or all of the phonemes in the target words. For *dinner* and *supper*, for example, spellings that represented two (e.g., "dicv" for *dinner*), three ("sur" for *supper*), or four ("supr," "sapr," or "cupr" for *supper*) phonemes received 5, 6, and 7 points, respectively. Higher scores were reserved for spellings that followed orthographic conventions and had conventional consonant letter usage. For example, "super" for *supper* (use of "er" for /ə/) received 8 points, and "sopper" for *supper* (use of double consonant) received 9 points. Full points (between 8 and 11; see Appendix for maximum point value for

each item) were given for fully correct spellings. Longer and more complex words, like *supper*, had higher point values than short words, like *lap*.

Because the nonwords were phonologically similar to the real words, the scales were similar. The maximum point values for /bɪkt/ and /mækt/ were less than those for the phonologically similar words *packed* and *locked* because spellings such as “bict” and “makt” received as many points as spellings such as “bicked” and “macked.” In the case of *packed* and *locked*, the highest scores were reserved for spellings that ended with *ed*.

Phonological skeleton. To assess the phonological knowledge behind the children’s spellings, we determined whether each spelling captured the consonant–vowel structure of the target item. A spelling was considered to retain the phonological skeleton of the target if it had an appropriate sequence of consonant and vowel graphemes. Treiman and Bourassa (2000a) used this measure to assess the attainment of a basic level of phonological analysis. For example, one child in our study spelled *drip* as “drep.” Although incorrect, this spelling captures the consonant–consonant–vowel–consonant (CCVC) structure of *drip*. The child has presumably succeeded in analyzing the phonological structure of the word, and so the spelling was counted as correct by the phonological skeleton measure. “Duripe,” “dip,” and “dimp” for *drip* do not accurately reflect the word’s phonological skeleton and were scored as incorrect by this system.

Orthographic acceptability. A spelling was considered orthographically acceptable if it contained a sequence of graphemes that may occur in English. A spelling was orthographically unacceptable if it contained an illegal sequence. Treiman and Bourassa (2000a) used this system to assess children’s knowledge of and adherence to the orthographic patterns of English. The orthographic acceptability measure does not consider a spelling’s phonological acceptability, which is reflected in some of the other scales. For instance, “tambo” for *tomato* and “clen” for *clean* were counted as orthographically acceptable because they could be real English words. “Tmat” and “klmal” were orthographically unacceptable because they contain letter sequences that never occur in English; English words never begin with the bigram *tm* or the trigram *klm*.

Treiman and Bourassa (2000a) reported that the interrater reliability of the composite, phonological skeleton, and orthographic accuracy scoring systems for the T–BEST ranges from .84 to .99. Reliability for the correctness scale is 1.00 because children were asked to identify any unclear letters in their written productions and because a word’s correct spelling is unambiguous.

Table 2 shows the results for fully correct spellings of words. A 2 (task—written vs. oral) \times 2 (group—dyslexia vs. nondyslexia) analysis of variance (ANOVA)

revealed a main effect of task, $F(1, 58) = 12.66, p < .01$. Children produced more correct spellings in the written spelling task than the oral task. The main effect of group and the Task \times Group interaction were not reliable, $F(1, 58) = 1.93, p > .15$, and $F(1, 54) = 1.64, p > .20$, respectively. The lack of a significant group difference confirms that the groups were reasonably well matched in correct spelling of real words. The dyslexia and control groups performed similarly on the words of the T-BEST as well as the words of the WRAT-3.

The results for the composite scoring of words and nonwords appear in Table 3. To ensure that the scores for word and nonword stimuli were comparable, each participant's score in a given condition was calculated as a proportion of the maximum total points (93 for words, 92 for nonwords). A 2 (task—written vs. oral) \times 2 (group—dyslexia vs. nondyslexia) \times 2 (lexicality—words vs. nonwords) ANOVA revealed a main effect of task, $F(1, 58) = 44.27, p < .001$. Children received higher

TABLE 2
Mean Number of Correct Word Spellings Produced by Children With Dyslexia and Spelling-Level-Matched Children Without Dyslexia

	<i>Task</i>	
	<i>Written Spelling</i>	<i>Oral Spelling</i>
Dyslexic		
<i>M</i>	4.80	3.67
<i>SD</i>	2.71	2.76
Nondyslexic		
<i>M</i>	5.40	4.87
<i>SD</i>	2.74	2.46

Note. The maximum number of correct word spellings is 10.

TABLE 3
Mean Proportions for the Composite Measure for Spellings Produced by Children With Dyslexia and Spelling-Level-Matched Children Without Dyslexia

	<i>Stimulus Type</i>			
	<i>Words</i>		<i>Nonwords</i>	
	<i>Written Spelling</i>	<i>Oral Spelling</i>	<i>Written Spelling</i>	<i>Oral Spelling</i>
Dyslexic				
<i>M</i>	.86	.84	.87	.83
<i>SD</i>	.10	.09	.09	.11
Nondyslexic				
<i>M</i>	.89	.87	.89	.85
<i>SD</i>	.09	.09	.09	.08

TABLE 4
Mean Number of Spellings With Correct Phonological Skeleton for Children With Dyslexia and Spelling-Level-Matched Children Without Dyslexia

	<i>Stimulus Type</i>			
	<i>Words</i>		<i>Nonwords</i>	
	<i>Written Spelling</i>	<i>Oral Spelling</i>	<i>Written Spelling</i>	<i>Oral Spelling</i>
Dyslexic				
<i>M</i>	7.63	6.77	7.40	6.47
<i>SD</i>	2.34	2.34	2.54	2.74
Nondyslexic				
<i>M</i>	7.83	7.00	7.37	6.53
<i>SD</i>	2.21	2.39	2.91	2.47

Note. The maximum number of spellings with correct phonological skeleton is 10.

composite scores in the written task than the oral task. The Task \times Lexicality interaction was significant, $F(1, 58) = 4.73, p < .05$. Although written spellings of both words and nonwords received higher composite scores than oral spellings ($ps < .01$), the advantage of the written task over the oral task was larger for nonwords than for words. All other effects were nonsignificant ($ps > .25$).

Table 4 provides information about the children's ability to represent the items' phonological skeletons. An ANOVA using the factors of task, group, and lexicality revealed a main effect of task, $F(1, 58) = 26.98, p < .001$, with higher scores for written spelling than for oral spelling. The main effect of lexicality was also significant, $F(1, 58) = 5.55, p < .05$. The phonological skeletons of words were more likely to be correctly represented than the phonological skeletons of nonwords. No other effects were significant ($ps > .50$).

Table 5 shows the results of the orthographic scoring. An ANOVA using the factors of task, group, and lexicality showed a main effect of lexicality, $F(1, 58) = 19.23, p < .001$. The orthographic accuracy of the children's spellings was higher for words than nonwords. All other effects were nonsignificant ($ps > .30$).³

Some researchers have suggested that dyslexia sample groups consist of a mix of children with different subtypes of dyslexia (e.g., Boder, 1973; Curtin, Manis, & Seidenberg, 2001; Morris et al., 1998). If children with dyslexia show more variability in their skills and strategies than typically developing younger children,

³The high scores on the orthographic acceptability measure raise the question of ceiling effects. However, variability was sufficient to allow for a significant lexicality effect. Chi-square tests showed that similar numbers of dyslexia group and control group children achieved perfect scores of 10 in each of the spelling conditions (written spelling of words, oral spelling of words, written spelling of nonwords, oral spelling of nonwords; $ps > .10$). These results support the idea that the dyslexia and control groups did not differ in the orthographic accuracy of their spellings.

TABLE 5
 Mean Number of Orthographically Acceptable Spellings for Children With Dyslexia and Spelling-Level-Matched Children Without Dyslexia

	<i>Stimulus Type</i>			
	<i>Words</i>		<i>Nonwords</i>	
	<i>Written Spelling</i>	<i>Oral Spelling</i>	<i>Written Spelling</i>	<i>Oral Spelling</i>
Dyslexic				
<i>M</i>	9.17	9.03	8.63	8.67
<i>SD</i>	1.18	1.35	1.25	1.37
Nondyslexic				
<i>M</i>	8.70	8.93	8.27	8.40
<i>SD</i>	1.42	1.48	1.64	1.57

Note. The maximum number of orthographically acceptable spellings is 10.

then variance should be greater in the dyslexia group than the nondyslexia group. To examine this idea, we conducted tests of homogeneity of variance for group comparisons on all 14 measures shown in Tables 2 to 5. None of the differences was significant ($ps > .10$).

Specific Measures

The analyses reported so far, which use the measures developed by Treiman and Bourassa (2000a), reveal no statistically significant differences between the spellings of the children with and without dyslexia. To probe further, we took advantage of the fact that the T-BEST includes many of the features that researchers such as Read (1975) and Treiman (1993) have found to be problematic for children who do not have unusual difficulties in learning to spell. Table 6 shows the features that we examined, as well as the number of items on the T-BEST that contained each one. The results are pooled over words and nonwords and over written and oral spelling, except for past tense /t/, where only words were examined. Because there were relatively few items with each feature, these analyses suggest areas for further investigation but do not permit strong conclusions.

In the category of phonetically based errors on consonants, we looked at spellings of intervocalic flaps with *d*. For example, the flap of *tomato* is spelled as *d* in "tomado." Four items on the T-BEST—*tomato*, *potato*, /və'metə/, and /bə'mitə/—contain a flap. For those in the dyslexia group, 24% of all spellings of these items included a *d*. The figure was 33% for normally progressing children. Given the small number of items with this and other specific features, we used chi-square tests to determine whether the two groups of children differed significantly. As Table 6 shows, the group difference was not reliable in the case of flaps.

TABLE 6
 Proportions of Spellings With Particular Characteristics Produced by Children With Dyslexia and Spelling-Level-Matched Children Without Dyslexia, Pooled Over Written and Oral Tasks

<i>Type of Spelling</i>	<i>Number of Items With Feature</i>	<i>Proportion of Spellings With This Characteristic in Dyslexic Children</i>	<i>Proportion of Spellings With This Characteristic in Nondyslexic Children</i>	<i>p Value for Difference by Chi-Square Test</i>
Phonetically based errors on consonants				
Flap spelled as <i>d</i>	4	.24	.33	<i>ns</i>
Affrication of /t/ and /d/ represented before /i/	4	.03	.07	<i>ns</i>
Past tense /t/ spelled with <i>t</i>	2	.25	.35	<i>ns</i>
Vowel omissions				
Omission of /ə/	6	.25	.17	<i>ns</i>
No vowel letter before <i>r</i> in spelling of /ə/	4	.08	.22	<i>p</i> < .01
Problems with interior consonants of consonant clusters				
Initial consonant clusters	12	.14	.13	<i>ns</i>
Final consonant clusters	8	.22	.19	<i>ns</i>
Letter-name spellings				
Consonant letter-name sequence spelled with consonant letter, no vowel in appropriate position	8	.12	.14	<i>ns</i>
Vowel letter name spelled with vowel letter only	20	.40	.43	<i>ns</i>
Spellings with final <i>e</i>				
C(C)VC with short vowel spelled with final <i>e</i>	12	.16	.04	<i>p</i> < .001
C(C)VC with long vowel spelled with final <i>e</i>	4	.28	.20	<i>ns</i>
Consonant doubling problem				
Intervocalic consonant after short stressed vowel spelled with single consonant letter	8	.61	.45	<i>p</i> < .001

We also examined /t/ and /d/ before /ɪ/, where normally developing children sometimes symbolize the affrication of the stop in spellings such as “jrip” for *drip*. A small proportion of spellings of items with initial /tɪ/ or /dɪ/ began with *c(h)*, *h*, *g*, or *j*, and the children with and without dyslexia did not differ significantly in this regard. The final phonetically based consonant error that we examined involved the

use of *t* rather than *ed* to represent the past tense in *packed* and *locked*. Spellings that included a *t* were fairly common in both groups of children, and the groups did not differ significantly in these errors.

The second category of errors involved failures to spell vowels. One such error, reported by Read (1975) and Treiman (1993), was the omission of unstressed /ə/. For example, one normally achieving child in our study spelled *tomato* as “tmado,” omitting the first vowel. Similar errors occurred among the children with dyslexia, and the errors did not differ significantly in frequency for children in both study groups. When we looked at vowel omissions in the spelling of /ɜ/, however, we found a reliable difference between the groups. For the nondyslexia group children, 22% of all spellings of the relevant items included an *r* with no vowel before it. For example, several normal spellers wrote *dinner* as “dintr,” an error similar to those reported by Read and Treiman. Such errors were significantly less common among the children with dyslexia, occurring 8% of the time in this group of children. The children with dyslexia were more likely than the typical children to produce spellings such as “diner” for *dinner*, which include a vowel. Although only four items contained /ɜ/, the control group children made more vowel omissions than the dyslexia-group children on all four. The T-BEST does not include any items with the stressed version of /ɜ/, so we could not determine whether the groups differed here as well.

Normally developing young children have difficulty spelling consonant clusters, sometimes failing to symbolize the second consonant of a two-consonant initial cluster or the first consonant of a two-consonant final cluster (Treiman, 1991, 1993; Treiman et al., 1995). Bruck and Treiman (1990) found that children with dyslexia omitted the second consonants of initial clusters more often than younger comparison children. We looked at spellings of initial clusters in which children represented the first consonant of the cluster in a phonetically reasonable manner but did not immediately follow it with the appropriate letter for the second consonant. Examples are “tip” for *trip* (second consonant of cluster omitted) and “duripe” for *drip* (vowel inserted between consonants of cluster). As Table 6 shows, such errors were not significantly more frequent among children with dyslexia than among normally progressing children of the same spelling level. We also examined spellings of final clusters in which children symbolized the second consonant of the cluster in a reasonable way but did not immediately precede it with an appropriate spelling of the first consonant. Examples include “matt,” “mad,” and “matk” for /mækt/. These errors did not differ in frequency between the two groups.

Under the category of letter-name spellings, we examined cases in which a child represented a sequence of phonemes that was the name of a consonant letter with that consonant letter alone, with no vowel letter in the appropriate position. Some such errors occur among normally progressing beginners, especially with *r* and *l* (e.g., Treiman, 1993). The children in this study sometimes used a conso-

nant-*r* sequence rather than a consonant-vowel-*r* sequence at the beginning of *jar*, spelling it as “jr” or “jre.” Similar errors occurred with *l*, as in “ble” for *belly*. The two groups did not differ significantly in the frequency of these consonant letter-name errors. We also looked at how often children spelled a vowel phoneme that was the name of a letter with only the corresponding letter, as in “clen” for *clean* and “flop” for /flop/. Vowel letter-name spellings did not differ in frequency between the two groups.

Additional analyses focused on children’s use of final *e* when spelling words and nonwords with the phonological form of initial consonant or cluster, vowel, and following consonant (C(C)VC). A final *e* often appears in conventional English when the vowel is long, as in *tone* and *snake*. With short vowels, only such unusual words as *done* and *have* are written with final *e*. Normal beginners sometimes mistakenly include a final *e* with short vowels (Beers, Beers, & Grant, 1977; Reece & Treiman, 2001). We found some such errors among our control group children. However, these errors were significantly more frequent among the dyslexia group children, with 10 of the 12 of the relevant items giving rise to more such errors among the children with dyslexia than among the normally progressing younger children. The difference between the groups was not significant for the relatively few long-vowel items on the T-BEST. The results suggest that children with dyslexia, more than younger children who are learning to spell at a typical pace, have difficulty understanding the function of the silent final *e*.

Finally, we looked at children’s use of double consonants. English bisyllabic words with a short stressed vowel in the first syllable are often spelled with a double medial consonant, as in *supper* and *dinner*. Single consonants, as in *lemon* and *habit*, are less common with short vowels. With long vowels, single-consonant spellings are virtually the rule, as in *super* and *diner*. An understanding of the relationship between vowel type and consonant doubling emerges slowly among children who are learning to spell at a typical pace (e.g., Cassar & Treiman, 1997). Suggesting that this understanding is even more delayed among individuals with dyslexia, those in the dyslexia group in this study produced significantly more single-consonant spellings of items like *supper* than the comparison children. This pattern held for six of the eight relevant items, with one item showing a tie and the other a reversal. The T-BEST does not contain any items with long vowels, for which single-consonant spellings would be appropriate. Thus, we cannot assess the degree to which the children with dyslexia and the normally developing children used consonant doubling to differentiate between short and long vowels.

DISCUSSION

Our results replicate the basic findings of Treiman and Bourassa (2000a) and, importantly, provide new information about the spelling skills of children with dys-

lexia. Like Treiman and Bourassa, we found that children are more likely to spell words correctly when they write the spellings on paper than when they say them aloud. A new result was that the written spelling advantage was equivalent for children with dyslexia and younger children who have reached the same spelling level more quickly. For the composite scores for words and nonwords, we replicated Treiman and Bourassa's finding of a written spelling advantage. Again, the written spelling advantage was similar in size for children with dyslexia and normally achieving children. Another interesting finding among our dyslexia and nondyslexia groups was the larger written spelling advantage for nonwords than for words. This result suggests that a written record is especially helpful when phonological skills are stressed, as in computing spellings for nonwords. We found a reliable written spelling advantage on the phonological skeleton measure but not on the orthographic accuracy measure. These findings replicate those of Treiman and Bourassa and suggest, again, that children can more accurately analyze the phonological structure of an item when they are able to represent the results of their analyses in a visible form. A new finding was the advantage of words over nonwords on both phonological and orthographic measures. Somewhat surprising was the absence of a lexicality effect in the composite measure; it is not clear why this effect was not observed. Nonetheless, the lexicality effect in the phonological and orthographic measures suggests that children use word-specific memory to aid their spellings of real words.

The effects summarized here show that the T-BEST is sensitive to differences in spelling performance. Despite this, we found no differences between children with dyslexia and spelling-level-matched children without dyslexia on any of the measures developed by Treiman and Bourassa (2000a). The dyslexia group and the nondyslexia group were statistically indistinguishable in terms of correct spellings of real words. Moreover, the two groups performed at similar levels on measures that were designed to tap the phonological and orthographic processes involved in spelling. These latter results do not support the phonological deficit hypothesis. According to that hypothesis, spellings by children with dyslexia should rank lower in phonological accuracy and higher in orthographic accuracy than the spellings of younger children without dyslexia. Our finding that the dyslexia group did not show a larger lexicality effect than comparison children also fails to support the hypothesis that children with dyslexia, as a group, have a specific phonological deficit that appears in spelling.

Our comparisons between written and oral spelling also failed to distinguish between children with dyslexia and spelling-level-matched normal children. In the introduction to this article, we raised the possibility that, because oral spelling draws heavily on auditory short-term memory, it should be particularly difficult for children with dyslexia. This was not the case. The dyslexia and nondyslexia groups showed equivalent advantages for written spelling over oral spelling on the correctness, composite, and phonological skeleton measures of the T-BEST but

no such advantage on the orthographic accuracy measure. This result supports the hypothesis of Treiman and Bourassa (2000a) that was described earlier: Children can more accurately analyze and represent phonology when they can symbolize the results in a lasting, visible form (written spelling) than when they cannot (oral spelling). This is so whether or not the children are learning to read and spell at a normal pace.

Curtin et al. (2001) suggested that certain previous studies (e.g., Moats, 1983; Nelson, 1980) may have failed to find differences between the spellings of children with dyslexia and younger children without dyslexia because of unexplored heterogeneity within the dyslexia group. However, we found no evidence that children with dyslexia were more variable than younger, normally achieving children on the measures discussed here. Individual differences in phonological and orthographic skills are found among both children with dyslexia (e.g., Boder, 1973; Curtin et al., 2001) and normally progressing children (e.g., Castles, Holmes, & Wong, 1997; Treiman, 1984). Our findings suggest that the differences are no larger among children with dyslexia than among normally progressing younger children.

Our analyses of particular spellings on the T-BEST showed, for the most part, similarities between the children with dyslexia and the typical younger children. As expected, the young children in the comparison group produced many of the spellings that have been documented in previous studies of early spelling, including phonetically influenced errors on consonants, omissions of unstressed vowels, and single-letter spellings of phonemes and phoneme sequences that correspond to letter names. The children with dyslexia, although on average more than 3½ years older than the comparison children, produced the same kinds of spellings. This result supports the idea that spelling performance of children with dyslexia is similar in nature to that of normally progressing younger children, not qualitatively different. Most of the specific spellings that we examined occurred at similar rates in the dyslexia and nondyslexia groups. This was true for errors on initial consonant clusters, contrary to the findings of Bruck and Treiman (1990), and for many other types of spellings as well.

On several features, we *did* find significant differences between the children with dyslexia and the comparison children in our post hoc analyses. Two of the differences involve *es* that do not represent a separate phoneme—those in words like *supper*, where no separate vowel occurs in the second syllable of the word's spoken form, and those in words with long vowels, where the *e* signals the quality of the vowel but does not itself symbolize a phoneme. The dyslexia group children in our study, perhaps because they were older and more experienced with printed words than the comparison children, were more likely to include such *es* in their spellings. However, the dyslexia group children did not appear to have a good understanding of the function of the *e* in such cases. Errors such as “tripe” for *trip*, which include an inappropriate final *e* with a short vowel, point to a lack of understanding. The other specific difference that we found between children with dyslexia and comparison

children—the greater tendency of the children with dyslexia to use a single consonant in words like *dinner*—may also reflect a lack of understanding of how English marks the difference between long and short vowels. However, we cannot draw strong conclusions because the T-BEST contained relatively few items of each type and because some relevant types of items (e.g., long vowel words such as *diner*) were not included. Additional work is needed to follow up our findings and determine whether the spellings of children with dyslexia indeed differ subtly from those of younger children who are learning at a typical pace.

Although the spellings of older children with dyslexia may differ in certain subtle ways from those of younger normal children, our results suggest that the processes and strategies used by individuals with dyslexia are quite similar to those of children who are learning to spell and read in a normal fashion. Children with dyslexia lag behind typically developing children in learning to spell, but they show the same general patterns of performance and make similar kinds of errors. Our findings support the idea that the misspellings of children with dyslexia are reasonable and linguistically motivated; they are not dramatically different from those of typical children (e.g., Bruck & Treiman, 1990; Kibel & Miles, 1994; Moats, 1983).

As we outlined earlier, a number of researchers have found that, as compared to reading-level-matched control children, children with dyslexia are poor at pronouncing nonwords but possess as good or better orthographic knowledge (e.g., Rack et al., 1992; Siegel et al., 1995; Stanovich et al., 1997). Such results suggest that children with dyslexia have a phonological deficit for which they compensate to some degree through the use of orthographic or visual strategies. The logic is that the two groups—children with dyslexia and younger comparison children—achieve the same level of reading skill in rather different ways. The children with dyslexia rely more heavily on orthographic skills, whereas the younger normal children primarily use phonological skills. A nonword reading test reduces children's opportunity to use orthographic skills, exposing the phonological weaknesses of the children with dyslexia. Although a number of studies suggest that this is true for reading, our results suggest that it is not true for spelling. Because our study did not examine children's patterns of reading performance, we cannot be sure that the present children with dyslexia showed a specific deficit in the reading of nonwords, as has been found in other studies. If differences between reading and spelling appeared in a study that examined both skills in the same children, one potential explanation would be that spelling draws more heavily on phonological processing than does reading. Children can achieve some success in reading via whole-word memorization. In contrast, they can make little progress in spelling without an ability to use systematic sound–print relationships. If phonology is critical for the spelling of real words as well as for the spelling of nonwords, then equating children with dyslexia and comparison children on real-word spelling ability (as measured by a test such as the WRAT-3) will cause their nonword spell-

ing to be very similar. If phonology is less critical for reading, then groups matched on word reading ability may differ in nonword reading performance.

The view just described is consistent with the suggestion (e.g., Ehri, 1998; Share, 1995) that phonological and orthographic skills are strongly related. Share suggested that literacy is built on a phonological foundation and that orthographic skills derive from this foundation. This may be particularly true of spelling. If phonology is the base on which spelling rests, with orthographic knowledge derived from it, then children with weak phonological systems will lag behind normally achieving children in orthographic skills as well as phonological skills. Children with dyslexia who are matched with younger children for real-word spelling ability will show a profile of performance that is quite similar to that of the typical children. The spelling-level-match design, in this view, does not provide the hoped-for leverage in uncovering the nature and causes of spelling problems for children with dyslexia.

Our conclusions are discouraging in some ways. We have not found unusual spelling errors or highly atypical patterns of performance that occur only among children with dyslexia and that can serve as markers of dyslexia. In other ways, however, our results are encouraging. The findings suggest that individuals with dyslexia will benefit from instruction that is based on knowledge of typical spelling development. We have argued elsewhere that linguistic factors must be considered in such instruction (Bourassa & Treiman, 2001; Treiman, 1997). Because both children with dyslexia and typically developing children have difficulty with particular linguistic structures, such as consonant clusters, teaching that targets these structures should benefit both groups. Indeed, remediation is beginning to follow these principles. For instance, Apel and Masterson (2001) described a successful intervention program for a 13-year-old student with spelling difficulties. The method begins with an analysis of the child's spellings of a sample of items. Difficulties on particular linguistic structures are then targeted for intervention. The intervention is designed to increase the child's understanding of various aspects of language. The child described by Apel and Masterson had trouble with the interior consonants of final consonant clusters—for example, spelling *camp* as “cap.” Apel and Masterson were able to remediate such difficulties through intensive phonemic segmentation training.

Much remains to be learned about the spelling of children with dyslexia. Researchers are beginning to emphasize that spelling development involves the interaction of various strategies and sources of information along the developmental spectrum (e.g., Rittle-Johnson & Siegler, 1999; Treiman & Bourassa, 2000b; Varnhagen, McCallum, & Burstow, 1997). An understanding of the development of each of these strategies and sources of information, and how they interact, is an important step toward a full understanding of spelling development and disability.

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APPENDIX

Stimuli for the Treiman–Bourassa Early Spelling Test
in Order of Presentation

List A

Words: nap (8), jar (8), belly (9), tomato (11), trip (9), sank (9), cream (9), packed (10), dinner (10), snowing (10)

Nonwords: /næm/ (8), /dɑː/ (8), /'mɛli/ (9), /və'merə/ (11), /flʌm/ (9), /pæŋk/ (9), /tɒp/ (9), /bɪkt/ (9), /'gæɪlə/ (10), /'spino/ (10)

List B

Words: lap (8), bar (8), jelly (9), potato (11), drip (9), tank (9), clean (9), locked (10), supper (10), blowing (10)

Nonwords: /væm/ (8), /lɑː/ (8), /'pɛli/ (9), /bə'mɪrə/ (11), /tɪʌm/ (9), /gæŋk/ (9), /flop/ (9), /mækt/ (9), /'dɪlə/ (10), /'steno/ (10)

Note. Maximum point value for each item on composite spelling scale shown in parentheses.