

Developmental Variations in Spelling

Comparing Typical and Poor Spellers

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Most children acquire basic reading and writing skills during the first few years of elementary school. For some children, however, even the smallest advance toward learning to read and write requires extraordinary effort. Such children are often labeled delayed, disabled, or dyslexic. Many researchers (Brady, 1997; Frith, 1985; Goswami & Bryant, 1990; Liberman, Rubin, Duques, & Carlisle, 1985; Stanovich, 1992) suggest that deficits in phonological skill underlie these children's difficulties. In this chapter, we focus on children with dyslexia and beginning spelling development using this phonological deficit hypothesis as a framework. We begin with a short discussion of typical beginners' spelling development and the importance of phonological skills. We then consider studies that compare the phonological skills of children with dyslexia and typical children in tasks other than spelling. Studies that have compared children with dyslexia and typical children's spellings of real words and nonwords are then reviewed. That discussion leads to a consideration of orthographic knowledge

and its influence on spelling skill. The importance of interactions between phonological and orthographic skills for typical word-knowledge development is considered next. The chapter concludes with a discussion about possible inefficiencies in the interaction of phonological and orthographic skills for children with dyslexia.

Studies that have examined the spelling of children with poor reading and spelling skills often compare such children to younger children with similar levels of spelling or reading skill. We focus on studies that compare such skill-matched groups, because they are more informative than studies that compare same-age groups of children. In skill-matched comparisons, researchers can identify the similarities and differences between the skills of poor readers and spellers, and those of typical children. Age-matched comparisons primarily confirm the skill differences between children with dyslexia and their same-age peers; they do not show whether and how the pattern of performance for children with dyslexia differs from that of typical children. Indeed, Bryant and Impey (1986)

argued for skill-matched rather than age-matched comparisons when stating that “if the causes of a child’s reading difficulties are to be traced back to his or her peculiar reading patterns . . . then these patterns must be different from those of other children whose progress in reading is quite normal” (p. 123).

SPELLING DEVELOPMENT

To become a good speller, one must learn how the English writing system codes spoken words. Although the English system represents aspects of language in addition to phonology (see Kessler & Treiman, 2003), it is in large part an alphabetic code for the phonemes or individual sounds in words. Therefore, phonemic awareness is a critical foundation for skilled spelling and reading. Phonemic awareness includes skills such as isolating and manipulating the separate speech sounds represented by the writing system. In this chapter, we use the terms “phonemic awareness” and “phonological skill” to refer to children’s skill with English phonology.

Many studies have demonstrated a strong link between phonemic awareness and early performance in reading and spelling. For example, Juel, Griffith, and Gough (1986) found that beginning first graders’ ability to manipulate phonemes in words (e.g., segmenting, deleting, blending, and substituting phonemes in real words) predicted their reading and spelling achievement at the end of the first and second grades. A link between children’s phoneme segmentation ability at age 4 and their spelling achievement at ages 5 and 6 was also found by Muter, Hulme, Snowling, and Taylor (1998). Moreover, Byrne and Fielding-Barnsley (1989) demonstrated through a series of training experiments that preliterate children need some understanding that words are composed of identifiable, segmentable sounds, before they can use letter-sound associations to decode unknown words. Stated another way, young children must possess some phonological skill in order to grasp the alphabetic principle. As we will see, phonological skills play an important role in learning to spell.

Ehri (1997) discussed three processes by which words may be spelled—by memory, by analogy, or by invention. Spelling a word by memory requires that the speller already know the word’s spelling. Spelling a word by analogy requires the speller to recognize the phonological similarity between the target word and other known words. The parts of the known spelling that represent the similarity between the words are transferred to the new spelling. Finally, spelling by invention requires that spellers analyze words into phonemes and apply alphabetic knowledge of phoneme-grapheme correspondences to create spellings. Children who are just beginning to read and write have little knowledge of words’ spellings. They cannot spell many words using memory or analogy and must often rely on invention. Therefore, an understanding of how typical children invent spellings provides a foundation for studies of poor readers and writers. It allows us to determine whether the writing of children with dyslexia is appropriate for their level of development, even if it is inappropriate for their age. The following description of invented spellings introduces some of the characteristics of young children’s writing, as well as the components of word knowledge.

Many researchers (e.g., Durrell, 1980; Ehri, 1983, 1986; Gentry, 1982; Hender-son, 1985; Treiman & Kessler, 2003) have argued that children’s knowledge of letter names plays an important role early in spelling acquisition. The connection between letters and their names is thought to provide a foundation for knowledge about grapheme-phoneme correspondences, or alphabetic knowledge. Most children in literate societies can identify a number of letters of the alphabet before they begin formal schooling. For example, Worden and Boettcher (1990) found that U.S. 4-year-olds correctly named about 14 of the 26 letters, and 5-year-olds correctly named about 22. Letter-name knowledge, however, does not automatically elucidate the links between letters and their sounds. When Worden and Boettcher asked children about the sounds associated with the letters, the 4-year-olds were successful on about six letters and the 5-year-olds on about 8.

Although knowledge of letter names does not guarantee knowledge of letter sounds, it is useful for the majority of English letters. Consider Treiman's (1994) findings with preschoolers who attempted to spell syllables such as /gar/, /zɛf/ and /tib/.¹ Preschoolers who knew the letter names produced many single-letter spellings. The single letter that they used was often the consonant letter suggested by the letter name in the spoken syllable. For example, these preschoolers often spelled /gar/ as R, /zɛf/ as F, and /tib/ as T. (Children's spellings are in capital letters here and throughout the chapter.) Although spellings such as R for /gar/ appear very primitive, children who produce such spellings may appreciate that certain aspects of conventional print, such as the *r* in *car* and the *p* in *pizza*, make sense given words' phonological forms. Letter-name knowledge may thus help children take their first steps toward understanding that writing is connected to speech.

As children advance, they continue to employ their letter-name knowledge by using letters to represent the sounds of the letter's name. For instance, they may spell *car* as CR, using *r* to represent the entire /ar/ sequence. Letter-name spellings are more common for some consonant letters than others. For example, Treiman (1993, 1994) found that kindergartners and first graders used letter-name spellings most often for *r*, next most often for *l*, and least frequently for other consonant letters such as *m*, *n*, *f*, *s*, *t*, *p*, and *k*. Letter-name errors occur on vowels when children transcribe long vowels with the single vowel suggested by the letter name rather than with the appropriate final *e* or vowel digraph. Thus, children make errors such as HOM for *home*, BOT for *boat*, and AWA for *away* (Bissex, 1980; Gentry, 1982; Henderson, 1985; Read, 1986; Treiman, 1993).

According to the stage theories that are often used to describe spelling development (Ehri, 1983, 1986, 1997; Gentry, 1982; Henderson, 1985), letter-name spellings appear when children are at the partial-alphabetic and alphabetic stages of development. These stages are also sometimes called the semiphonetic and phonetic stages, respectively. Children at these spelling stages are

most often found in kindergarten, first, and second grade. Their spellings suggest that they understand that writing represents the sounds in words. However, the children's spelling attempts are often inaccurate, because their phonological skill is still rudimentary and their knowledge of the alphabetic system incomplete.

As well as producing letter-name spellings, young children at the partial-alphabetic and alphabetic stages commonly produce other kinds of errors. For example, children have problems with initial and final consonant clusters, as in *sled* and *jump*. Children sometimes write these words as SED and JUP, respectively, symbolizing only the first consonant of an initial cluster or the last consonant of a final cluster. Children also often fail to represent reduced vowels in spelling, omitting the second vowel in *carrot*. In addition, children often leave out the vowel when spelling words with a syllabic *r* or *l*, as in SPIDR for *spider* and LITL for *little*. These spellers represent the past tense ending *-ed* with *d*, *t*, or vowel + *d* according to its sound, as in PED for *pinned*, STAPT for *stepped*, and PLATID for *planted* (Bissex, 1980; Ehri, 1986; Gentry, 1982; Henderson, 1985; Read, 1986; Reece & Treiman, 2001; Treiman, 1993).

Errors such as these become less common as children progress, partially as a result of children's increased exposure to print. Through experiences with printed words, as in reading, children begin to develop orthographic knowledge. "Orthographic knowledge" refers to an understanding of the conventions of the writing system, including knowledge about spaces between words, acceptable and unacceptable letter sequences, and the various representations for certain phonemes, depending on such factors as their position in a word. This knowledge, in addition to phonology, then influences spelling.

Orthographic knowledge begins with very simple observations. For example, a child who spells *car* as CR may note that printed words in books usually contain a vowel letter. Such observations may lead the child to include vowels in words, but in the wrong place (Treiman, 1994). Consider the spelling GRE for the nonword /gar/. A

young child's belief that /ar/ is an indivisible phonological unit suggests that the unit be spelled with single *r*; the child's orthographic knowledge suggests that the word contain a vowel. The child solves this conflict by placing an *e*, which occurs as a silent letter in words such as *came* and *give*, at the end of the spelling (see Reece & Treiman, 2001). Thus, even early in the development of spelling, children notice what words look like and use this information when constructing their own spellings.

Young children also use morphological relations among words, to some extent, to guide their spelling. Although we focus on children's use of phonology in this chapter, it is important to discuss briefly the influence of morphology on children's spelling. Nunes, Bryant, and Bindman (1997) proposed that children's morphological spelling strategies may develop in stages. These researchers examined how children's use of the past tense spelling *-ed* changed over time. On three separate occasions over a 20-month period, the researchers asked children, ages 6.5–8.5 years at session 1, to spell regular verbs, irregular verbs, and nonverbs. They found that beginning spellers primarily relied on a phonetic spelling strategy, such as spelling *kissed* as KIST. As their spelling skills developed, the children began to use the *-ed* spelling. However, interestingly, they used the *-ed* spelling for /t/ and /d/ in regular verbs, irregular verbs, and nonverbs. For example, children spelled *kissed*, *slept*, and *soft* as KISSED, SLEPED, and SOFED. The children apparently realized that *-ed* sometimes spells /t/ and /d/, without understanding the spelling's connection with past-tense verbs. As the young spellers advanced further, they began to limit their generalization of the *-ed* spelling to regular and irregular verbs, apparently, as they began to understand the grammatical basis for the spelling. Nunes, Bryant, and Bindman suggest that young spellers' initial use of a phonetic spelling strategy provides opportunities for acquiring the new morphological strategy.

We also have obtained results suggesting that young children's awareness of morphology aids their spelling. In one study, we considered how the addition of the past-tense morpheme sometimes creates a final cluster,

as in *rained*. Earlier, we described how children often have difficulties spelling final consonant clusters. In our study, we reasoned that if children relied only on phonology to spell, omissions of consonants in final clusters should be equally likely for two-morpheme words, such as *rained*, and one-morpheme words, such as *brand*. However, we (Treiman & Cassar, 1996) found that children in kindergarten, first, and second grade made fewer errors on consonant clusters in two-morpheme than in one-morpheme words. For example, children were less likely to spell *rained* as RAD than to spell *brand* as BRAD. The children did not use morphology to the full extent possible, however, because they left out the *n* when spelling *rained* more often than when spelling *rain*. In a different set of studies, Treiman, Cassar, and Zukowski (1994) found that children in kindergarten, first, and second grade were able to use morphology to aid their spelling of flaps in two-morpheme words such as *dirty* and *waited*. However, as in the study just mentioned, the children were more likely to spell correctly the root words, such as *dirt* and *wait*, than the two-morpheme words. Thus, young spellers sometimes use morphology to override their phonological strategies, but phonology plays an important role.

To summarize, the typical errors of young spellers reveal their developing phonological skills. As children gain experience with printed words, their orthographic and morphological knowledge begins to have a larger influence on their spelling choices. Children's spelling performance, phonological skill, and alphabetic knowledge thus improve in concert. If phonological skill is poor, or if it does not interact appropriately with other types of knowledge, then improvement may be extremely slow. Given the importance of phonology, in the next section, we consider studies that have directly examined the phonological skills of poor and typical readers, and spellers using tasks other than spelling.

Phonological Skill

Children who struggle at learning to read and write often have poor phonological skills. For example, Bradley and Bryant

(1978) asked poorly reading 10-year-olds and typical 6-year-olds of the same reading level to identify the word with the odd sound from lists of spoken words. The children heard words such as *weed*, *need*, *deed*, and *peel*, and were to identify *peel* as the odd word. The poor readers had more difficulty than the typical children identifying the odd words. The poor readers also had more difficulty with another phonological task, producing rhymes for words. Olson (1985) reported that older poor readers were worse than younger children of the same reading level at choosing nonwords that sound like familiar words. For example, the nonword *kake* sounds like a word, but *dake* does not. Siegel and Ryan (1988) found that poor readers were worse than their reading-level-matched peers at reading and spelling nonwords and choosing spellings for orally presented nonwords. Finally, Bruck (1992) found that children with dyslexia between the ages of 8 and 16 years performed more poorly than age-matched and reading-level-matched controls on six tasks tapping phonological skill—syllable counting, phoneme counting with nondigraph stimuli, phoneme counting with digraph stimuli, syllable onset deletion, phoneme deletion with nondigraph stimuli, and phoneme deletion with digraph stimuli. Digraphs are spellings that use two letters to represent one sound, as with *ph* for /f/ in *graph*. Bruck further reported that adults with dyslexia performed more poorly than reading-level-matched typical children on phoneme deletion and phoneme counting.

In each of these studies, the phonological skills of children with reading disabilities were inferior to those of younger typical children with the same level of reading ability. Other research aimed at uncovering subtypes of reading disabilities provides further evidence that phonological difficulties are a primary characteristic of children with reading problems. Morris et al. (1998) gave 234 children ages 7–9 years multiple measures of verbal and nonverbal skills. These measures fell into eight skill categories—phonological awareness, verbal short-term memory, rapid naming, lexical vocabulary, speech production, visuospatial skill, visual attention, and nonverbal short-term memory.

The researchers formed subgroups based on the children's strengths and weaknesses across the measures. Morris et al. had expected to uncover three disability subtypes—phonological awareness impaired, phonological-verbal-short-term memory impaired, and general cognitive impaired. However, three statistical clustering procedures revealed that 183 of the children consistently fell into seven rather than three deficit subtypes. Six of the seven subtypes were characterized by poor phonological skills. Slow picture naming, poor visual block pattern repetition, and poor word and nonword repetition characterized the seventh subtype, the rate deficit group. Morris et al. suggested, based on their results, that developmental dyslexia involves "a core problem in the development of phonological awareness skills" (p. 368). They argued that the variety of subtypes reflects the influence of phonological deficits on other skills, such as short-term memory.

Although the phonological skills of poor readers often appear inadequate given their ability to read real words, their skill may be commensurate with their performance on other tasks. Instead of comparing children with poor reading skills only to younger children matched on real-word reading, Metsala (1999) also matched groups for their ability to pronounce nonwords. This task of "sounding out" novel items likely relies more on phonological skill and knowledge of grapheme-phoneme correspondences than does real-word reading. Factors other than phonological skill, for example, rote memory and experience with print, contribute importantly to real-word reading skill. To measure phonological awareness, Metsala asked the children to delete the first or last phonemes from real words and say the remaining word. For example, the children were asked to say *crew* without the /k/. The children with poor reading skill, ages 6–14 years, performed significantly worse than the real-word reading-matched children on this task. However, there was no difference between the performance of the poor readers and the nonword reading-matched group. These findings, together with those described earlier, suggest that poor readers possess poorer phonological skills than typi-

cal children with similar levels of word-reading skill. The new finding is that poor readers may demonstrate phonological skills equal to those of typical children with similar levels of skill in nonword reading. In other words, poor readers' phonological awareness may be appropriate for their (low) level of phonological decoding skill. Another task that may track phonological skill is spelling. It may be that the phonological skills of children with poor reading and spelling skills are also commensurate with their level of spelling development.

As mentioned earlier, learning to spell requires an ability to segment spoken words into phonemes. Therefore, poor phonological skill should be linked to poor spelling ability. Phonological skill may actually relate more closely to spelling than to reading. Perin (1983) found that individuals who were good readers but poor spellers, and those who were poor at both reading and spelling, were worse than individuals with good reading and spelling skills at creating Spoonerisms, such as *Jon Dohnson* for *Don Johnson*, and counting phonemes in real and nonsense words. As mentioned earlier, children can apparently develop some real-word reading skill independent of phonology. Spelling, in contrast, may show minimal development in the absence of good phonological skills. Consistent with this view, longitudinal studies of children with poor reading skill show that their spelling typically lags behind their reading (Rourke & Orr, 1977; Rutter, Tizard, Yule, Graham, & Whitmore, 1976). In the studies discussed earlier, the children with poor reading skill had poorer phonological skills than reading-matched children. Given the link between spelling and phonological skill, it is likely that the children with poor reading skill were poorer spellers than the reading-matched children. Such a difference between reading skill and phonological and spelling skills may be especially likely in studies involving poor readers with more advanced reading skills.

The close relationship between phonological skill and spelling suggests that spelling-level-matched comparisons should find similar levels of phonological skill in children with dyslexia and younger spelling-level-matched typical children, even if reading-

level-matched studies do not; that is, if spelling relies primarily on phonology, then children with dyslexia should possess a level of phonological skill that is commensurate with their spelling ability. Supporting this notion, Cassar, Treiman, Moats, Pollo, and Kessler (2003) found that children with dyslexia between the ages of 8 and 15, and typical younger children, all with second-grade spelling skills, performed similarly on a phoneme counting task. The nonwords in the phoneme counting task contained either a phonological sequence that is a letter name, as in /dar/ or /vel/, or an initial or final consonant cluster, as in /blop/ or /fimp/. The children with dyslexia and the younger children counted the same numbers of phonemes and made the same types of errors on these nonwords. The children with dyslexia and the younger children differed only on one measure. The children with dyslexia were more likely to count the *r* letter-name sequence than the *l* letter-name sequence as one phoneme. The younger children made the *r* and *l* errors equally often. In general, however, the children with dyslexia and the younger children were very similar in their level of phoneme segmentation skill and the nature of their errors.

Other studies using a spelling-level-matched design do not support the idea that poor spellers' phonological skills are commensurate with their spelling ability. Rohl and Tunmer (1988) used a spelling-level-matched design to compare typical second and third graders, and poorly spelling fifth graders on their ability to count phonemes in nonwords. The older poor spellers performed significantly worse than the younger children. This result, in contrast to the one described earlier, suggests that poor spellers' phonological skills are even poorer than expected given their level of spelling performance.

Bruck and Treiman (1990) found mixed results when testing children with dyslexia who spelled at the second-grade level. The children with dyslexia were on average 10 years of age. In some cases, the children with dyslexia had more difficulty manipulating phonemes in nonwords than spelling-level-matched typical children, and in other cases they did not. The children with

dyslexia performed significantly worse than the typical children when asked to recognize a phoneme in the second position of a consonant cluster. For instance, the children with dyslexia had more difficulty than the typical children saying that /gli/ contained /l/. However, the children with dyslexia and the typical children performed similarly on word-initial targets, such as the /s/ in /spoi/ and /saip/, and second-phoneme targets in syllables without consonant clusters, such as the /l/ in /əli/. The children made very few errors on these items, however, which may explain the lack of differences. The children with dyslexia were significantly worse than the typical children at deleting the initial sound of a consonant cluster and stating the remaining nonword. For example, the children with dyslexia had more difficulty removing the /s/ from /staib/ to respond /taib/.

Bruck and Treiman concluded that their children with dyslexia generally had poorer phonological skills than the younger typical children with similar spelling levels. However, they noted that the phonological difficulties experienced by the children with dyslexia were qualitatively similar to those experienced by typical children. This is an important point. Both groups of children made the same types of mistakes in the phoneme recognition and deletion tasks; the children with dyslexia made more of them in some cases but not others.

The similar errors made by poor and typical spellers in the spelling-level-matched studies suggest that the phonological skills of children with dyslexia develop along the same lines as those of typical children. Both groups encounter difficulties with consonant clusters and other phonological features. The higher error rates of the children with dyslexia in some of the studies reveal the slowness of this development. This brings us to a discussion of the phonological and orthographic quality of the spellings of children with dyslexia, and how they compare with the spellings of typical children.

Comparing Poor and Typical Spellers' Word Spellings

A number of researchers have compared the spellings of children with dyslexia and typi-

cal children matched for level of spelling skill. These researchers analyzed the children's spellings of words and nonwords, examining the types of errors produced by the two groups and the frequency of the errors. Such analyses should help reveal whether the spellings of children with dyslexia differ from those of typical children. Researchers have also examined the children's misspellings more generally for phonological and orthographic accuracy. It is possible that, because of their phonological weaknesses, children with dyslexia rely more on an orthographic than on a phonological strategy when spelling. If so, the spellings of children with dyslexia should be higher in orthographic quality than those of typical children. However, the results that we review suggest that the spellings of children with dyslexia and typical children are very similar, at least at the early skill levels that have been the focus of most research.

Nelson (1980) compared the real-word spellings of children with second-grade spelling abilities. The children with dyslexia were on average age 11 years, and the typical children were on average age 7 years. Three types of spelling errors were examined—letter order errors, phonetically implausible spellings, and orthographically illegal spellings. A spelling contained a letter order error if the word's letters were all present but out of order, as in YSA for *say*. A phonetically implausible error omitted, added, or substituted a phoneme, as in OOTS for *its*. Finally, an orthographically illegal spelling contained a letter group that does not occur in that position or order in English, as in CKAK for *cake*. Nelson found no significant differences between the spellings of the children with dyslexia and the typical children on any of the measures, suggesting that the spellings of children with dyslexia at this level are quite similar to those of younger typical children.

Moats (1983) conducted a similar study of real-word spelling using an error classification scheme based on typical errors made by typical beginning spellers. The children studied by Moats, like those studied by Nelson (1980), spelled at a second-grade level. Moats compared her children with dyslexia and typical children on serial order errors

and phonetic accuracy. Spellings containing letter order confusions, letter duplications, or insertions were considered serial order errors, as in SRTUK for *struck*. A number of spelling patterns were examined to measure phonetic accuracy. For example, Moats investigated long-vowel letter-name spellings such as MAK for *make* and the use of *r* and *l* syllabically, as in LITTL for *little*. In addition, Moats classified spelling errors as either conventional or preconventional. The conventional scoring criteria considered whether an error conformed to English spelling-sound rules. The preconventional scoring criteria considered whether an error followed patterns frequently found with typical beginning spellers, which were discussed earlier. For example, LODE for *load* was a conventional error and the letter-name spelling LOD was a preconventional error. Moats found that the spellings of the children with dyslexia and the typical children were indistinguishable on each measure. These results suggest that the spelling errors of children with dyslexia performing at a second-grade level are similar in nature and quantity to those of typical younger children. Moats did not formally compare the orthographic accuracy of the spellings produced by the two groups further than the measure of serial order errors. However, she noted that the children with dyslexia appeared to be "better informed about spelling conventions" (p. 132) than the typical children. For example, the children with dyslexia were more likely to include vowels in syllabic endings, as when spelling *tiger*, and to double consonants when adding a suffix, as in *bigger*.

Lennox and Siegel (1996) examined children with dyslexia and typical children's misspelling of words from a standardized spelling test. The children in their study spelled at the second-grade level, as in the studies previously described. Lennox and Siegel scored the errors for constrained phonological accuracy, unconstrained phonological accuracy, and visual overlap with the intended word. The constrained phonological accuracy measure considered whether the spellings for the phonemes in a word were acceptable given the other letters in the word. The unconstrained phonologi-

cal accuracy measure considered whether the spelling contained an acceptable representation of each phoneme regardless of its acceptability in that letter context. For example, RECH for *reach* was acceptable using the unconstrained measure but not acceptable using the constrained measure. REECH or RECHE would be acceptable using the constrained measure. The visual overlap measure was based on whether the error spelling contained the correct letters and bigrams, considering letter order, for the target word. The children with dyslexia and the typical children produced similar percentages of spelling errors that were accurate using the constrained scoring measure and the visual overlap measure. However, the children with dyslexia produced fewer errors than the typical children that were accurate using the unconstrained phonological measure. In this study, then, there was some evidence that children with dyslexia were poorer than younger typical children at representing the phonological forms of words at the same overall level of spelling development. However, the ability of children with dyslexia to represent the orthographic forms of words was similar to that of the younger children.

Cassar et al. (2003) also compared the phonological and orthographic accuracy of real-word spellings produced by children with dyslexia and typical children. As in the preceding studies, the children with dyslexia and the typical children performed at a second-grade spelling level. The children with dyslexia were on average 11 years of age. The words selected for the spelling test contained many of the patterns that typical beginning spellers find challenging. For example, children were asked to spell words containing letter names, as in *jar* and *enter*, long vowels, as in *money* and *people*, reduced vowels, as in *correct* and *heaven*, and initial and final consonant clusters, as in *spider* and *bump*. The children's spellings were analyzed for the typicality of errors for each spelling pattern. Examples of typical errors are JR, NTR (letter names), MUNE, PEPL (long vowels), KRET, HEVN (reduced vowels), and SIDR and BUP (consonant clusters). The spellings were also analyzed for phonological and orthographic accuracy more gen-

erally. Four scoring systems were used—phonologically correct–constrained, phonologically correct–unconstrained, phonological skeleton, and orthographic acceptability. The phonologically correct–constrained and phonologically correct–unconstrained measures were essentially the same as Lennox and Siegel's (1996) constrained phonological accuracy and unconstrained phonological accuracy measures, respectively. The measure of orthographic acceptability was similar to Nelson's (1980) measure of orthographically legal versus illegal spellings. The phonological skeleton scoring system assessed whether a spelling preserved the word's pattern of consonants and vowels. For example, HEVIN preserves the phonological structure of *heaven* even though it is incorrect. The children with dyslexia produced spellings that were statistically indistinguishable from those of the typical children on all measures. Even a measure of letter reversals, which have long been considered a common characteristic of dyslexia, and one that makes the errors of children with dyslexia qualitatively different from those of typical children (e.g., Vernon, 1957), showed similar results for the two groups. These results suggest that for children with dyslexia performing at the second-grade level, spelling errors are similar in both quality and quantity to those of younger, normally progressing typical children.

Bourassa and Treiman (2003) also compared children with dyslexia and younger typical children who performed at a second-grade level on a standardized spelling test. The two groups' spellings were statistically equivalent on a composite measure of phonological and orthographic sophistication, on representation of the phonological skeleton of the target items, and on orthographic legality. The children with dyslexia did not show more variability than the typical children, the same finding reported by Cassar et al. (2003). Again, the conclusion is that low-performing children with dyslexia produce spellings that are similar to those of typical beginners.

Pennington et al. (1986) also compared the spellings of individuals with dyslexia to those of nondyslexic individuals. Their dyslexics, in contrast to those in the studies

described so far, were adults. The adults with dyslexia, who averaged 33 years in age, were compared with age-matched typical adults and younger, spelling-matched children. The adults with dyslexia and the children spelled at a sixth-grade level. Pennington and colleagues found no differences between the adults with dyslexia and the children on measures of phonological spelling accuracy. The spellings of both the adults with dyslexia and the children were less phonologically accurate than the spellings of the typical adults. Pennington et al. also found no differences among the three groups on a measure of simple orthographic accuracy. This measure required a spelling to contain the correct initial and final letters, and no illegal letter sequences. On a measure tapping complex aspects of orthographic knowledge, however, Pennington et al. found group differences. This measure examined spellings for patterns such as vowel clusters, as in *courteous* and *believe*, and double consonants, as in *illogical* and *necessity*. The adults with dyslexia appeared to have less sophisticated knowledge of complex patterns than their age-matched peers but somewhat better knowledge than the spelling-level-matched children. This result differs from those of the previously described studies that found dyslexic and nondyslexic children to be similar on orthographic measures. One possible explanation for the difference stems from the idea that Pennington et al.'s adults with dyslexia had more experience with print and more opportunities to increase their orthographic knowledge than did the children with dyslexia in the studies described earlier. As the skills of spellers with dyslexia advance, their orthographic knowledge may surpass their phonological skill.

The spelling comparison studies demonstrate that the phonological accuracy of real-word spellings produced by children with dyslexia is often similar to that of younger children with the same level of spelling skill. Also, the types of errors made by low-performing children with dyslexia are similar to those made by typically developing children who are just learning to spell. A few studies suggest that the orthographic quality of the spellings is higher in children with dyslexia than in younger con-

trol children. Most studies, especially those examining children with dyslexia who have lower levels of spelling skill, do not find such differences. However, it may be premature to draw conclusions from data on real words only. The children with dyslexia, being older than the children with whom they are compared, may have had more experience with the words on which they were tested than the younger children. This may account for their occasionally higher levels of orthographic skill.

Another approach to uncovering whether children with dyslexia rely more on orthographic spelling strategies than do typical children is to compare their spellings of regular and irregular words. Bruck (1988) reasoned that if children with dyslexia do not use phonological strategies to spell words, regularity should not affect their performance. She compared the spellings produced by children with dyslexia and younger, spelling-matched typical children for five types of words that varied in sound-to-spelling regularity. The words included highly regular words (e.g., *sharp*), less regular words containing sounds with more than one legal spelling (e.g., *real* and *feel*), exceptions (e.g., *touch*, *such*), words with strange or rare spelling patterns (e.g., *busy*), and nonwords that were similar to the highly regular and less regular words (e.g., /lArp/, /bil/). The children with dyslexia were affected by regularity, as were the control children. Both the children with dyslexia and the typical children made fewest errors on highly regular words and fewer errors on less regular words than on exception and strange words. The children with dyslexia produced significantly fewer phonetically accurate misspellings of the real words than the younger children. This latter finding does not agree with the results of the studies reviewed earlier in which children with dyslexia and typical children produced similar rates of phonetically accurate spelling errors (Bourassa & Treiman, 2003; Cassar et al., 2003; Moats, 1983; Nelson, 1980). Bruck concluded that children with dyslexia use phonology to spell words and nonwords, but that they do so less efficiently than typical children. Although children with dyslexia do not totally bypass phonol-

ogy when they spell, it is possible that they rely less on phonology and more on other strategies than do typical children.

Another way to assess the relative use of orthographic and phonological spelling strategies by children with dyslexia is to compare their spellings of nonwords to those of younger spelling-matched children. Children have not been exposed to the nonwords prior to an experiment, and their novelty should encourage children to use a phonological spelling strategy, if they are able to do so. A few of the studies already discussed included comparisons of nonword spelling by older children with dyslexia and younger spelling-level-matched typical children. Bruck (1988), mentioned above, found that children with dyslexia and typical children spelled nonwords similarly. Bourassa and Treiman (2003) found that children with dyslexia and younger typical children performed similarly on nonwords, as well as words.

Bruck and Treiman (1990) and Cassar et al. (2003) asked their children with dyslexia and younger typical children to spell nonwords, as well as segment them, in phoneme counting tasks (the results of which were reported earlier). Recall that Bruck and Treiman's (1990) nonwords contained initial consonant clusters, as in /spoi/ and /staib/. Both children with dyslexia and typical children more often failed to spell the second consonants than the first consonants of initial clusters. Omission rates were higher for the children with dyslexia than for the typical children. This pattern of group differences in spelling was the same as that observed in the phoneme recognition task. In other words, the children's spellings of the initial consonant cluster nonwords closely mirrored their phonological skill. Cassar et al. (2003) included letter names, long vowels, reduced vowels, and initial and final consonant clusters in the nonwords that their children with dyslexia and typical children spelled. In this study, the only difference between the groups' nonword spellings was that the children with dyslexia were somewhat less likely than the typical children to omit the first consonants of final clusters. The groups' nonword spellings did not differ on any of the other spelling pat-

terns or on general measures of phonological and orthographic accuracy. Like Bruck and Treiman (1990), Cassar et al. (2003) found that both groups' spellings of the nonwords generally followed their phoneme counting performance. The one exception was that the children with dyslexia were much more likely to spell the /ar/ letter-name sequence appropriately, with a vowel letter and a consonant letter, than to count two phonemes for this sequence. That the children with dyslexia performed particularly poorly when counting the phonemes in /ar/ suggests that something other than phonological skill supported their spelling in this case. One possible explanation is that the children with dyslexia consider /ar/ as a single sound that is spelled with two letters, a digraph. This subtle difference may suggest that orthography and phonology interact differently in children with dyslexia than in normally progressing children. We have more to say about this possibility later.

To summarize, children with dyslexia produce spelling errors that are very similar to those of younger children with the same level of spelling skill. Even when children with dyslexia make more errors (Bruck, 1988; Bruck & Treiman, 1990; Lennox & Siegel, 1996), their errors are similar in nature to those of typical children. Children with dyslexia are influenced by phonology when spelling, just as are typical children. The similar orthographic accuracy of the spellings produced by children with dyslexia and typical children does not support the idea that children with dyslexia rely more on orthographic strategies than on phonological strategies when spelling. However, children with dyslexia may begin to rely disproportionately on orthographic knowledge as their spelling skills advance. Children with dyslexia may also possess more orthographic knowledge than is revealed in their spellings. In the next section, we consider the orthographic knowledge of children with dyslexia and typical children on tasks designed to assess this knowledge directly.

Orthographic Skill

As stated earlier, the phonological difficulties of individuals with dyslexia suggest that

they may rely heavily on orthographic knowledge to support their spelling. The studies reviewed in the previous section found few differences in the orthographic accuracy of spellings produced by children with dyslexia and typical children. However, both orthography and phonology undoubtedly influence spelling choices, and spelling is not a pure measure of orthographic knowledge. In this section, we consider research that assessed the orthographic knowledge of children with dyslexia and typical children using spelling recognition and spelling choice tasks. The studies reviewed employed reading-level, as well as spelling-level, matched comparisons. The results of these studies are mixed. In some cases, children with dyslexia perform better than typical children on orthographic tasks. In other studies, children with dyslexia and typical children are indistinguishable.

Olson (1985) asked children to choose the real words in pairs, such as *rain* (word) and *rane* (pseudohomonym). Olson argued that this pseudohomonym choice task taps orthographic knowledge, because the phonological forms of the items in each pair are alike. Seventh graders with reading disabilities and younger, reading-level-matched children performed equally well on the pseudohomonym choice task. However, these same children with reading disabilities demonstrated poorer phonological skill than the typical readers when reading nonwords. That the children with reading disabilities had better orthographic than phonological skill supports the idea that they rely more on orthographic than on phonological knowledge when reading.

The findings of Manis, Custodio, and Szeszulski (1993) also support the idea that children with dyslexia rely heavily on orthographic skills for reading. These researchers measured orthographic processing using two tasks. In the first task, the child heard a word, saw its spelling, and judged whether the spelling was correct. The spelling was either correct (e.g., *street*) or phonetically plausible but incorrect (e.g., *streat*). In the second task, the child heard a sentence using a homonym, saw a spelling for the homonym, and stated whether the spelling was correct. For instance, a child heard

"Monday is the first day of the week" and saw either *week* or *weak*. These two tasks require orthographic rather than phonological skill, because both spellings are phonologically acceptable. The children with dyslexia completed the tasks on two occasions spaced 2 years apart. At the time of first test, the children with dyslexia averaged 12 years of age and read at a fourth-grade level. By the second test, the children read at a sixth-grade level. The performance of the children with dyslexia was compared to that of separate groups of reading-matched typical children for each test. The performance of the children with dyslexia on the orthographic tasks, while not as good as that of the nondyslexic children, improved over the 2 years. The word-identification skills of the children with dyslexia also improved. However, the children with dyslexia made no progress over the same period in their ability to pronounce certain types of nonsense words, delete phonemes from nonwords, and spell irregular words. Manis et al. concluded that the increasing orthographic skill of the children with dyslexia contributed to their improvements in word identification.

The studies by Olson (1985) and Manis et al. (1993) assessed children's ability to distinguish conventional spellings of real words from phonetically plausible alternatives. These tasks tapped children's knowledge about the orthographic forms of the specific words that were tested. Orthographic knowledge, however, includes more than knowledge about the spellings of specific words. As we stated earlier, orthographic knowledge includes an understanding of writing conventions, acceptable letter sequences, and variations for representing phonemes. The studies we describe next assessed these broader aspects of orthographic knowledge.

Siegel, Share, and Geva (1995), instead of tapping word-specific knowledge by using real words, examined children's more general knowledge of acceptable letter patterns. Children with dyslexia and younger typical children matched for reading level were asked to select the item that looked more like a word from pairs of nonwords such as *clid-cdil*. The groups each contained similar

numbers of children reading at first-through eighth-grade levels. As a group, the children with dyslexia performed significantly better than the typical children. Siegel et al. also found that the children with dyslexia were significantly worse than the typical children on nonword reading. Comparisons for the children at each specific reading level were not reported. The researchers suggested, on the basis of the results, that children with dyslexia rely more on orthographic than on phonological knowledge when reading.

Stanovich, Siegel, and Gottardo (1997) asked children with reading disabilities and typical children with second-grade reading levels to complete the same orthographic choice task used by Siegel et al. (1995). The average age of the children with reading disabilities in this study was 9 years. The study, designed to explore possible reading disability subtypes, also included phonological tasks. The results suggested that the children with reading disabilities experienced phonological difficulties of various degrees. However, the children with reading disabilities and reading-level-matched typical children performed nearly identically on the word-likeness task. This result differs from that of Siegel et al., who found that dyslexic children performed better than typical children on the orthographic choice task. The different results may reflect the fact that Siegel et al. examined the combined performances of first- through eighth-grade readers. The children studied by Stanovich et al. (1997), in contrast, were all reading at the second grade level. Taken together, the findings support our earlier suggestion that children with dyslexia begin to show superiority on orthographic tasks when they achieve more advanced reading levels.

Cassar et al. (2003) also examined what children with dyslexia and typical children know about acceptable letter patterns. The children, all with second-grade spelling levels, were asked to choose the "made-up word" that they thought looked most like a real word from pairs of nonwords. Each pair contrasted a spelling containing a common letter sequence with a spelling containing an uncommon or illegal sequence. The nonword pairs contrasted common and un-

common consonant doublets, as in *jull* and *jukk*, common and uncommon vowel doublets, as in *geed* and *gaad*, common and illegal word-initial consonant clusters, as in *skad* and *mkad*, common and illegal word-final consonant clusters, as in *pilt* and *pibk*, and word-final and word-initial consonant doublets, as in *pess* and *ppes*. On each type of pair, the children with dyslexia and the typical children chose the common item significantly more often than expected by chance. Performance of the children with dyslexia was slightly better than that of the typical children, but the group differences were not statistically significant.

Thus, children with dyslexia possess orthographic knowledge about words and letter patterns that is at least commensurate with their level of reading and spelling skill. As we saw earlier, some of the spelling comparison studies suggest that children with dyslexia rely more heavily on this information than do normally progressing children. However, the majority of the spelling data suggest that the relative use of phonological and orthographic strategies is similar in children with dyslexia and typical children.

Interactions between Phonological and Orthographic Knowledge

In addition to considering children's orthographic and phonological strategies separately, we must consider how the two types of knowledge interact. Although children with dyslexia appear to have orthographic skills commensurate with their reading and spelling skills, their phonological skills have often been found to lag behind. This evidence can be taken to suggest that their orthographic knowledge does not interact with phonological knowledge in the same way that it does in normally progressing children. Exposure to word spellings when reading helps typical children learn about the separate sounds in words (e.g., Thompson, Fletcher-Flinn, & Cottrell, 1999). Knowledge about word spellings can even cause children to overestimate sounds for words in phoneme counting tasks. This occurs when knowledge of spellings containing silent letters leads children to count extra phonemes for words, a phenomenon

referred to as "overshoot errors." For example, Ehri and Wilce (1980) demonstrated that 9-year-olds judge a word such as *pitch* to contain more phonemes than a word such as *rich*, even though the *tch* in *pitch* and the *ch* in *rich* correspond to the same phoneme. Ehri and Wilce also examined the effect of spelling on phoneme counting performance with nonwords. One group of children learned nonword spellings that contained "extra" letters, as in *zitch* for /zitʃ/. Another group of children learned spellings for the same nonwords that did not contain extra letters, as in *zich* for /zitʃ/. The children who had learned the extra letter spellings tended to make overshoot errors on the nonwords. Tunmer and Nesdale (1982) also found that even 6-year-olds in first grade sometimes made overshoot errors when segmenting nonwords containing digraphs. Both Tunmer and Nesdale and Ehri and Wilce (1980) concluded that children's segmentation is influenced by their spelling knowledge, and that this can lead to errors in certain cases.

Are children with dyslexia, like typical children, influenced by spelling when counting phonemes and performing other phonological tasks? Landerl, Frith, and Wimmer (1996) examined the phoneme counting performance of children with dyslexia and younger, spelling-level-matched typical children on three types of words—phonologically transparent words, such as *ham* and *hot*, digraph words, such as *roof* and *bath*, and silent-letter words, such as *lamb* and *half*. The typical children were much more likely than the children with dyslexia to make overshoot errors on words with digraphs and silent letters; that is, the phonological performance of the children with dyslexia was less influenced by their knowledge of spelling.

Results similar to those of Landerl et al. (1996) have been found with nonwords. In the reading-level-matched study discussed earlier, Bruck (1992) included digraph and nondigraph nonwords in the phoneme counting task. The nondigraph nonwords were most naturally spelled without digraphs, as with /tisk/. The digraph nonwords contained phonemes that were conventionally spelled with two letters, as with

the vowel of /lim/. The children with dyslexia were less likely than the typical children to make overshoot errors on the digraph nonwords.

The results of Bruck (1992) and Landerl et al. (1996) suggest that the performance of children with dyslexia on phonological tasks is not influenced by orthographic knowledge to the same extent as that in typical children. We suggested earlier that children's experience with print gradually leads them from phonetic spellings to mature, conventional spellings. As this occurs, typical children's conceptions of spoken words are shaped by their knowledge of the words' spellings. This causes errors in certain cases, as when counting phonemes in words that are spelled with digraphs, but it usually helps children divide words into smaller units. If the phonological systems of children with dyslexia are less influenced by print learning, then their phonological skills would often appear underdeveloped in spite of their adequate orthographic skills. This is the result we have seen in a number of the studies reviewed here.

Interactions between phonological and orthographic skills are a critical feature of several theories about children's developing word knowledge. In the next section, we discuss these views about how phonological and orthographic skills interact throughout development to serve reading and spelling skill.

THEORIES OF WORD KNOWLEDGE DEVELOPMENT

The theories discussed in this section describe how children develop mental representations for words. Mature word representations are proposed to contain the phonological information for a word linked to its orthographic information. One important feature of the theories is the interaction of phonological and orthographic knowledge during development. As children learn about the orthographic forms for words, this knowledge influences their phonological representations. The inefficient interaction between knowledge bases may provide an explanation for disabled speller's poor phonological skill.

Ehri (1997) proposes that the word representations that serve reading and spelling develop in four phases. The first phase is a logographic, or visual cue phase, in which a child relies on salient graphic features to recognize a word. For example, a child may "read" a fast-food logo or traffic sign based on the colors of the letters and the background but does not yet know that the letters are related to the words' pronunciations (also see Frith, 1986). When children begin to learn about the names and sounds of letters, they enter the second phase. In this partial-alphabetic phase, children begin to form connections between the letters they see in words and the sounds they detect in pronunciations. However, children have only rudimentary knowledge about the letter-sound relations. For example, a child in this second phase might guess "dog" and then "dad" when confronted with *door*, only able to use letter-sound relationships for the word's first letter. These children employ letter-name strategies when spelling and have difficulty representing all of a word's sounds with letters, as discussed in the earlier section on spelling development. Ehri suggests that, as phonemic segmentation and reading skills develop, all the letters in words become linked to phonemes. At this point, learners are in the third phase, the full-alphabetic level. Children now create more complete word spellings. Finally, at the consolidated-alphabetic level, children develop full visual-phonological representations of word spellings. These representations link individual letters with their sounds and also link groups of letters with groups of phonemes (e.g., *eam* with /im/). Ehri proposes that spellings and pronunciations merge such that the "orthographic image" of a word influences how a child judges its phonemic structure. This merger usually helps children to make accurate phonological judgments, but it can lead to overshoot errors on digraphs, as discussed earlier.

Perfetti's (1992, 1997) notions add to Ehri's (1997) by further specifying how representations of words change with development. Perfetti's description begins when a word exists in the learner's spoken vocabulary. The existing pronunciation may

change or become elaborated as the written form is learned. According to Perfetti, two principles characterize the development of word representations—precision and redundancy. A precise or fully specified representation contains all the letters in the printed word, together with their exact phonemic values. Before it becomes fully specified, a word's representation contains variables. Some letters are well specified, such as initial letters, and others are variable or indistinct, such as vowels. The lesser precision of vowel representations in English reflects the complex phoneme-grapheme mappings for vowels. As word representations become better specified, the information within the representation becomes more redundant. Mappings are created between letters and phonemes, between larger orthographic and phonemic strings, and between the complete spelling and the pronunciation. This redundancy leads to a strong and memorable bond between the word's spelling and its sound. The phonological and orthographic representations merge into a single representation and are no longer separate entities.

Ehri (1997) and Perfetti (1992, 1997) stress the interactions between phonology and orthography that occur in the development of reading and writing. They suggest that phonological and orthographic knowledge do not develop in isolation. Each supports and interacts with the other. For Ehri and Perfetti, phonological and orthographic information combine into unitary word representations. The theorists suggest that one knowledge base cannot develop properly if the other is inadequate.

The evidence reviewed in this chapter suggests that children with dyslexia have phonological skills that are weak, whereas their orthographic skills are adequate for their level of literacy development. As the preceding theories predict, this imbalance in skills retards the progress of children with dyslexia in both reading and spelling. Why does the imbalance exist? The theories suggest that improvements in one type of knowledge should result in improvements in the other. An imbalance in the two types of skills suggests a problem with the interaction of the knowledge bases. Some evidence

for such a problem was presented earlier in the contrast between the spellings and phoneme counting for /ar/ produced by children with dyslexia (Cassar et al., 2003) and their phoneme counting for words and non-words with silent letters and digraphs (Landerl et al., 1996; Bruck, 1992). If the information about word spellings that children with dyslexia encounter has little effect on their representations of the words' sounds, then the development of phonological skills may be delayed.

CONCLUSIONS

Because the majority of studies comparing children with dyslexia and typical children have focused on children at early stages of spelling development, our conclusions must be limited to this group. Children with dyslexia, we have seen, are slow to develop phonological skills. Nevertheless, the linguistic stumbling blocks encountered by children with dyslexia are much the same as those encountered by typical children, and children with dyslexia appear to employ strategies based on sound when they try to spell. As a result, children with dyslexia produce misspellings that are very similar to those of younger typical children. Despite these similarities, the time and effort expended by the children with dyslexia to acquire their spelling ability is much greater than the time and effort expended by typical children. One possible explanation for this difference is that orthographic and phonological knowledge do not support one another in children with dyslexia to the same extent that they do in typical children; that is, the interaction between the two types of knowledge may be weak. It may be possible to bridge this gap by explicitly teaching children with dyslexia to break spellings apart and to break pronunciations apart. Children with dyslexia should benefit from the explicit pairing of visual and verbal word components. Such teaching may help to ensure that what children with dyslexia learn about orthography affects their knowledge of phonology and vice versa, allowing each type of skill to support the other.

NOTE

1. Key to notation: /i/ as in *bee*, /ai/ as in *buy*, /o/ as in *toe*, /a/ as in *father*, /ɛ/ as in *bed*, /ɪ/ as in *bit*, /oi/ as in *boy*, /ə/ as in *sofa*, /b/ as in *bib*, /d/ as in *did*, /f/ as in *fluff*, /g/ as in *gag*, /k/ as in *kick*, /l/ as in *lull*, /m/ as in *mime*, /p/ as in *pup*, /r/ as in *roar*, /s/ as in *sassy*, /ʃ/ as in *show*, /tʃ/ as in *church*, /v/ as in *verve*, /z/ as in *zoo*.

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