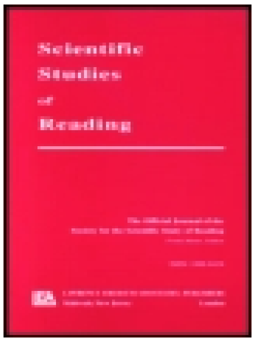

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Uta Frith , Heinz Wimmer & Karin Landerl

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Differences in Phonological Recoding in German- and English-Speaking Children

Uta Frith
Medical Research Council Cognitive Development Unit
and
University College London

Heinz Wimmer
University of Salzburg

Karin Landerl
University of Salzburg

Orthographic consistency in different languages is likely to have an effect on phonological recoding skills, which are basic to the acquisition of reading. To explore this issue, we investigated word and nonword reading in German- and English-speaking 7- to 12-year-old children. Comparability of the stimuli across the 2 languages was strictly controlled: The German and English words used were common to both languages. Nonwords were derived by exchanging consonantal onsets between short words and by recombining syllables in long words. An identical set of CVCVCV nonwords was also presented to both language groups. At ages 7, 8, and 9, English-speaking children made a higher proportion of errors than their German-speaking peers when reading nonwords and words of low frequency. This was the case even when word-recognition ability was equated between the 2 language groups. By age 12, both groups had equally fast nonword-recognition latencies, but English-speaking readers were still less accurate when recoding long and complex nonwords. Only the younger English-speaking readers made substantial numbers of errors with CVCVCV nonwords. Vowels, which are the most inconsistent feature of English orthography, were often mispronounced in English but hardly ever in German, where they are

Requests for reprints should be sent to Uta Frith, Medical Research Council Cognitive Development Unit and University College London, 4 Taviton Street, London WC1H 0BT, England. E-mail: u.frith@cdu.ucl.ac.uk

consistent. Word-substitution errors occurred more frequently in English than in German. We suggest that low orthographic consistency, as in English, necessitates the use of complex and error-prone strategies in phonological recoding, whereas high consistency, as in German, allows phonological recoding into syllables on-line. This makes the teaching of phonological recoding relatively straightforward and allows the acquisition of basic reading skills to proceed at a faster pace. Differences in the teaching of reading might in turn contribute to differences in recoding skills.

Phonological recoding—that is, "the ability to translate printed words independently into their spoken equivalents" (Share, 1995, p. 156)—is the essence of successful reading acquisition. This widely held view has been reconfirmed in two recent reviews of the field (Share, 1995; Share & Stanovich, 1995). Clearly, the success of phonological recoding depends on whether the word to be identified conforms to the code. In the case of irregular words, which are frequent in English, phonological recoding, if strictly applied, leads by definition to an incorrect word sound. Take the word *heart,* for example. If *heart* represents a new letter sequence for a child, then the following outcomes can be imagined: Recoding the *-ea-* as in the word *hear* results in *heert;* recoding the *-ea-* as in the word *heard* results in *hurt.* An American second-grade child quoted by Nyikos (1990) aptly characterized the problem: "When I sound it out, it comes out in a crazy word ... sometimes if it's not important, I just skip it. But sometimes if it's important, then I have to ask my teacher" (p. 79).

Learning to read and write in a consistent orthography should not lead to such difficulties. Here, grapheme–phoneme recoding is reliable, and the assembly of phonemes results in pronunciations close to that of the target word. Therefore, we expect that teaching and learning phonological recoding would be easier in consistent orthographies. Plaut, McClelland, Seidenberg, and Patterson (1996), in their update of the Seidenberg and McClelland (1989) connectionist model of reading acquisition, showed that phoneme–grapheme consistency is a major factor in network learning. Thus, there are good theoretical grounds for expecting that consistent, regular phoneme–grapheme relations result in faster learning than do irregular relations.

Despite these rather obvious conclusions, the evidence is scarce and fraught with methodological problems Studies of nonword-reading skills in English-speaking children suggest that the acquisition of phonological recoding is slow and difficult. Mean error rates for nonword reading at the end of Grade 1 typically range from 40% to 80% (e.g., Jorm, Share, MacLean, & Matthews, 1984; Juel, Griffith, & Gough, 1986; Treiman, Goswami, & Bruck, 1990). In contrast, in Greek, an orthographically consistent language, first graders made just more than 10% errors when reading words and nonwords (Porpodas, 1989). Similarly, with German-speaking first graders, Wimmer and Hummer (1990) found that average students read both words and nonwords with fewer than 10% errors, whereas even seriously reading-delayed first graders made only about 35% errors. Cossu, Gugliotta, and Marshall (in press) found that Italian first graders made about 20% errors on one- and two-syllable nonwords and hardly any errors on words.

There have also been some direct comparisons. In an English–Turkish comparison, Oney and Goldman (1984) used nonwords derived from either Turkish or English words of one, two, and three syllables by changing the initial consonant(s) of the syllables. In the study, the Turkish first graders made 6% errors when reading nonwords, whereas the American first graders made 40% errors. Thorstad (1991) compared Italian children and English children who were taught either with the now obsolete initial teaching alphabet (ITA) system, which artificially regularizes English orthography, or with the conventional orthographic system. The regular orthography users, both Italian and ITA-taught English children, showed an advantage in word-recognition skills in the early stages of reading.

One methodological problem that tends to beset comparative studies is that children in different language communities are presented with different stimuli. This problem was controlled in an English–German word–nonword reading comparison. Wimmer and Goswami (1994) used number words (e.g., *two–zwei, three–drei*) and derived nonwords from number words by exchanging syllable onsets. This study showed a marked effect of orthography on nonword reading but not on number-word reading. Thus, English-speaking 7- and 8-year-olds made 30% errors on nonwords, whereas German-speaking 7-year-olds made just more than 10% errors. The English-speaking 9-year-olds still tended to produce more nonword-reading errors than the German 7-year-olds. A replication of this nonword–number word comparison with Dutch 7-, 8-, and 9-year-olds (Jansen, 1995) also showed low error rates for nonwords (15% errors for 7-year-olds), similar to the rates found for the German-speaking children.

These investigations suggest that there is at least a delay for nonword-reading skills in English-speaking children compared to children who learn to read an orthographically consistent language. What causes this delay? How do children learning to read English acquire a reliable phonological recoding strategy? Do they organize phonological recoding processes in a way that is qualitatively different? It seems unlikely that the differences obtained in previous studies are due to a selection bias, as different samples from different schools have been used as subjects, and comparisons have been made among several different countries. In cross-language comparisons, many variables will remain outside experimental control and cannot be easily disentangled. Fortunately, one particular type of control is possible for German–English written-word comparisons. Because of their partly common root, German and English share many words similar in spelling, pronunciation, and meaning. We capitalized on this phenomenon for this study, which attempted to provide a systematic investigation of phonological recoding in the two orthographies.

We investigated the ability to decode words and nonwords in children learning to read either English or German in England and in Austria. In particular, we explored the hypothesis that differences in orthographic consistency might favor different methods of teaching reading and thus might induce qualitatively different strategies in phonological recoding. To pursue this aim, we initially conducted a study with 7-, 8-, and 9-year-olds who were attending ordinary suburban schools in each of the two countries. The correspondence in age implies that the English-speaking children had about 1 year more of schooling, as they begin school at about age 5, whereas in Austria children have to be 6 years old in order to enter Grade 1. We asked the children to read our systematically constructed stimulus lists and recorded speed and accuracy of decoding.

STUDY 1: CONTINUOUS READING OF WORDS AND NONWORDS

Method

Participants

Forty-five English-speaking children and 50 German-speaking Austrian children forming three age groups (7-, 8-, and 9-year-olds) participated as subjects. All of the English-speaking children came from a state school on the outskirts of London (Orpington, Kent). Children were tested at the end of primary Grades 2, 3, and 4, respectively. The Grade 2 children (8 boys, 6 girls) were mainly 7-year-olds (*M* age = 7:8[1] years; range = 7:2 to 8:2 years); the Grade 3 children (7 boys, 13 girls) had a mean age of 8:5 years (range = 7:11 to 9:0 years), and the Grade 4 children (5 boys, 6 girls) had a mean age of 9:6 years (range = 9:1 to 9:11 years). For the youngest group, reading-age scores (British Ability Scales, Word Recognition subtest) showed that reading performance spanned a wide range of ability but was at age level for the group as a whole (median reading age = 7:7 years; range = 6:0 to 11:3 years). All of the children who were available in these age groups and who agreed to participate were included in the study.

The school attended by the German-speaking children is located in a suburb of the city of Salzburg. Testing was carried out immediately after summer vacation, at the start of Grades 2, 3, and 4, respectively. The Grade 2 children (11 boys, 9 girls) were mainly 7-year-olds (*M* age = 7:8 years; range = 7:1 to 8:5 years), the Grade 3 children (7 boys, 13 girls) had a mean age of 8:8 years (range = 8:3 to 9:3 years), and the Grade 4 children (6 boys, 4 girls) had a mean age of 9:4 years (range

[1]7:8 means 7 years, 8 months. The format is the same throughout the article.

= 9:1 to 9:8 years). The Grade 2 children were tested with a standardized reading test. They also spanned a wide range of ability and showed a mean percentile rank of 55 (range = 15 to 90). Again, this sample included all of the schoolchildren who had agreed to participate.

Schooling background. Our German-speaking children had been introduced to reading by a synthetic phonics approach as described by Wimmer (1995). This approach emphasizes word recognition via sounding out and blending. All grapheme–phoneme correspondences (including double- and triple-letter graphemes) are initially presented one by one. Then, they are immediately used for practicing phonological recoding of simple words such as *Mama* and *Mimi.* Beginners are encouraged to sound out their attempts at recoding and blending and to allow the teacher to help and correct if necessary. Graphic syllable markers are often used at the early stages to make the units for blending obvious. In addition, the children are given sentences and simple stories containing the words that are used to practice phonological recoding.

Our English-speaking children were taught reading with a combination of methods, which included (a) practicing sounding out and blending and (b) recognizing whole words and word patterns taught in terms of families with the same beginning and rhyming sounds. All children were given a wide variety of storybooks and reading materials, and parents were encouraged to read with their children. Thus, the children were taught word-attack skills in the rich context of other reading activities. Although very different in the two countries, initial reading instruction provided by the two participating schools was typical, we believe, for the vast majority of ordinary schools in England and Austria.

Materials and Procedure

Participating children had to read four 6-word lists and four 6-nonword lists as quickly and accurately as possible (examples appear in the Appendix). Because only words with identical referential meaning in the two languages were used, we can assume that familiarity was similar for the English- and German-speaking children. Of the 24 English words, 19 are on Dale's list (Harrison, 1980) of children's 768 best-known words; 4 (*baker, guest, plough, swan*) are on the list of 3,000 best-known words; and 1, *thirst,* is not listed, but *thirsty* is among the best-known words. Of the 24 corresponding German words, all but 6 (*Rose, Gast, grün, Pflug, Schwan, grau*) were among the 2,000 words used most frequently by German-speaking 9- and 10-year-olds in written productions (Bamberger & Vanecek, 1984). About half of the English words were regular in their spelling (e.g., *baker*); the other half were irregular (e.g., *guest*).

Only words beginning with a single consonant or a consonant cluster were used. This enabled us to derive the nonwords by exchanging the initial consonant(s) between the words within each list of words. Therefore, the nonwords corresponding to the words of a certain list consisted of exactly the same letters as the words, and, further, these letters formed the same consonantal syllable onsets and syllable rimes as in the words. In the case of two-syllable words, both the rime of the first syllable and the rhyme of the word were preserved. For example, the nonword corresponding to *summer* was *rummer.*

The six items on each list were presented in a row, so that children could use their familiar, left-to-right reading strategy. The row was in the middle of an otherwise empty page. The eight test pages were combined into a booklet interleaved with blank pages, so that the experimenter could start each reading task by turning over the blank page. The eight test pages were presented in two different orders, each beginning with real words. In both orders, a word list was never followed immediately by the list of corresponding nonwords.

Children were introduced to the task by means of two practice lists (one of words, one of nonwords) and were told: "Here are some words [or 'Here are some words that don't make sense']. Please read them as fast as you can without making any mistakes." The children were always told whether the next list would contain real or nonsense words. A timer was started when the page was turned, and it was stopped when the child had finished pronouncing the last item on the list. Children were praised after each trial, regardless of their performance. Their readings were recorded by a second experimenter, who was a native speaker of the child's language.

Results

Reading Accuracy

Figure 1 shows the percentage of the children's reading errors obtained for the 24 words and their corresponding nonwords. In scoring the reading of the English nonwords, lenient criteria were used, so that all legally possible grapheme–phoneme relations (including context-inappropriate relations) were accepted as correct recodings. For example, in the case of *theart,* four different readings, varying in pronunciation of the vowel grapheme, were all scored as correct: Eight children pronounced the *ea* as in *heard,* 4 as in *heart,* 2 as in *hear,* and 2 as in *bear.* Differences in vowel length, including the silent-*e* rule, were disregarded. For example, in reading *saker* (intended analogy = *baker*), 9 children shortened the vowel to *sacker,* whereas, in the reading of *blan,* the vowel was occasionally lengthened to *blane* (3 children). In contrast to nonwords, words were scored strictly. For example, in the reading of *heart,* the recoding of *-ea-* in analogy to *hurt* was not accepted; readings of *baker* as *backer* were also not accepted.

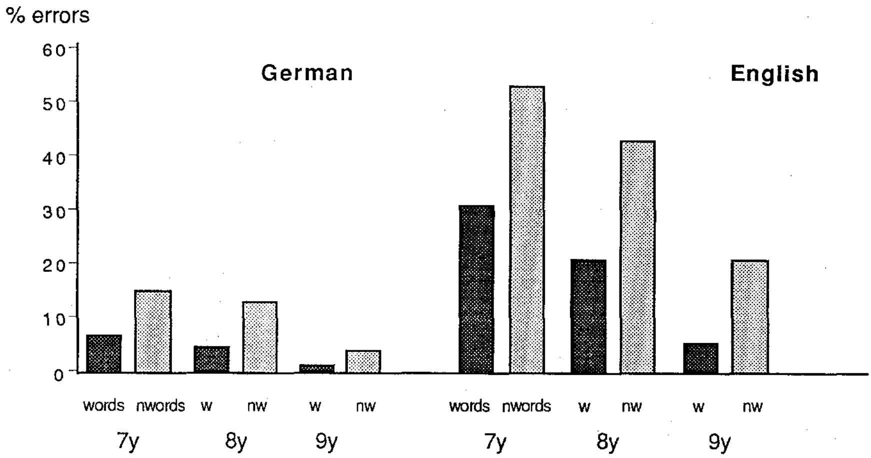

FIGURE 1 Mean error percentage for words and nonwords in Study 1. Comparison of German- and English-speaking 7- to 9-year-olds.

Errors were subjected to an analysis of variance (ANOVA) with Lexicality (Words vs. Nonwords) as a within-subjects factor and Orthography (English vs. German) and Age (7, 8, or 9 Years) as between-subjects factors. The main effects of orthography and lexicality were highly significant, and, importantly, so was the Orthography × Lexicality interaction, $F(1, 89) = 23.4$, $p < .001$. As evident from Figure 1, English-speaking children made more errors than German-speaking children on words (20% vs. 5%), but this difference was much larger for nonwords (41% vs. 12%). The number of errors decreased with age, $F(2, 89) = 9.1$, $p < .001$, but the Orthography × Age interaction was not significant, $F(1, 89) = 2.5$, $p > .05$. English- and German-speaking 9-year-olds performed at similar levels when reading words but not when reading nonwords.

It was notable that the standard deviations were larger for English- than for German-speaking children. For example, the standard deviations for the error scores of the English-speaking 7-year-olds were 30% and 33% for words and nonwords, respectively, whereas those of the German-speaking 7-year-olds were only half as large (10% and 15%). The variance could be reduced by comparing only the better readers in the two languages regardless of age. Therefore, we conducted a second analysis based on the two easier stimulus lists, and only those 25 English- and 38 German-speaking children who were able to read all of the words in these lists without errors were included. For these good readers, the errors on the two corresponding nonword lists were subjected to an ANOVA with Orthography and Age as between-subjects factors. The same result was found as in the main analysis: The English-speaking children made more nonword-reading errors (22%) than the German-speaking children (8%), $F(1, 61) = 6.2$, $p < .001$.

Continuous Reading Speed

The combined time scores for the four word lists and the four nonword lists, regardless of errors, were subjected to two ANOVAs—one for untransformed time scores, one for log-transformed time scores—with similar results. Inspection of correlation coefficients (Spearman rank correlations between .61 and .95) showed that, for the English-speaking children, there was a strong positive association ($p < .01$) between number of errors and continuous reading speed, suggesting that there was no speed–accuracy trade-off. Just as in the case of performance accuracy, the main effect of orthography and the Orthography × Lexicality interaction were reliable, $Fs(1, 89) = 18.4$ and 14.3, $ps < .01$. German-speaking children read the word lists faster than English-speaking children (1.01 vs. 2.56 sec per item on average), and the difference was even larger for nonwords (1.41 vs. 4.10 sec). There was also a significant main effect of age, $F(1, 89) = 10.3$, $p < .001$, and an Orthography × Age interaction, $F(1, 89) = 4.4$, $p < .02$. English-speaking children showed greater improvement in reading speed with age than German-speaking children, and this was particularly marked for nonword reading. However, the three-way Orthography × Age × Lexicality interaction was not significant, $F(1, 89) = 2.4$, $p = .10$.

For the subgroup of good readers who made no errors on the two easy word lists, reading times were analyzed separately. Here, too, the Orthography × Lexicality interaction was significant, $F(1, 61) = 6.6$, $p < .02$. Post hoc tests showed that the English-speaking subgroup of good readers read the words faster than their German-speaking counterparts (0.62 vs. 0.82 sec per item; $p < .05$). However, they were slower when reading the corresponding nonwords (2.26 vs. 1.30 sec; $p < .05$).

Error Analysis

A direct reflection of the difference in orthographic consistency is the difference in the number of errors in which vowel letters were misread. Only word items were considered for this type of error because, in the case of the English nonwords, all possible pronunciations of vowel graphemes, however rare, were accepted as correct. Typical examples of misreadings of the vowel letter(s) in word items are 8 instances of *hurt* for *heart* and 4 instances of *backer* for *baker;* other cases were *swen* for *swan, lag* for *laugh, gust* for *guest, wood* for *word,* and *plug* or *pluff* for *plough.* Altogether, there were 170 errors with incorrect vowel sounds. The German-speaking children, in contrast, produced only 9 such errors in total. Examples are *Backer* for *Bäcker,* in which the vowel change indicated by the umlaut is neglected, and *Störcher* for *Säcker,* in which the visual similarity of *ö* and *ä* might be responsible for the error.

Another source of errors was the tendency to respond with an existing word or with a word combined with *-er* (e.g., *snaker* for *saker*). A German example for such errors is *blinken* for *glinken.* English-speaking children produced erroneous word responses to 12% of the words and to 21% of the nonwords, whereas German-speaking children produced corresponding percentages of 2% and 5%. An ANOVA of the number of erroneous responses to words and nonwords showed that the Orthography × Lexicality interaction was significant, $F(1, 93) = 7.1, p < .01$.

Study 1 Discussion

This study showed dramatic differences in phonological recoding in English- and German-speaking children. While based on better controlled stimuli, it confirms results reported in previous studies. When reading nonwords, our sample of English-speaking 7-year-olds made errors in the region of 55%, compared to 15% errors made by their German-speaking age peers. In both language groups, performance improved substantially with age, but differences still persisted at age 9. Differences in nonword reading were far more striking than those in word reading, which were in fact no longer significant in 9-year-olds. This suggests a prolonged and difficult period of acquisition for basic recoding skills over and above that of acquisition of word-recognition skills.

A significant difference in nonword reading was found even when only those German- and English-speaking children whose word-reading performance was 100% accurate were selected. The selected German-speaking children only made 8% errors with nonwords, whereas their English-speaking counterparts made 22% errors. This particularly revealing comparison throws light on the question of whether there are qualitatively different phonological recoding processes. Even though the English-speaking children were able to read the target words without errors, they misread 1 in 5 nonwords. This is surprising because the nonwords were very similar to the words. They could have been read "by analogy," as they retained everything from the target word except for the consonant onset (e.g., *rummer* for *summer*). Our scoring system for nonwords not only was geared toward reading by analogy but also allowed for phoneme-by-phoneme recoding. This strategy would also have resulted in perfect performance. We suggest that the children in this sample relied far less on segmental recoding strategies and instead tended to rely on instant recognition of familiar words. The argument is that, had they used representations of phoneme or rime segments to recode words, they would have also recognized all of the corresponding nonwords. In contrast, we suggest that the German-speaking children used a recoding strategy that involved phoneme or rime representations. This made these children slower at word reading but faster and more accurate at nonword reading.

However, this is not the whole story. The results showed a consistent advantage for words over nonwords for both language groups. We assume that this advantage is due to the availability of representations for familiar words. During the early stages of learning, these would be representations of word sounds and syllable sounds, but eventually they would incorporate representations of word spellings. The universality of the word advantage rules out the possibility that phonological recoding in German involves only phonemic representations, which is theoretically possible with high orthographic consistency. If translation from print to sound proceeded purely by sounding out phonemes and blending them together in bottom-up fashion, then no difference between word and nonword reading would have been found. Instead, we suggest that phonological recoding involves not only the translation of letters into sounds but also the matching of a subsyllabic code with a syllabic code. If the latter is familiar, as in the case of short and frequent words, then this should lead to fast and accurate recognition (i.e., a word advantage).

We have no reason to postulate a different reason for the word advantage in English. However, we have to explain why the word advantage was so much larger. We suggest that this might be due to the low degree of orthographic consistency, which necessitates more complex strategies in phonological recoding. The difficulty of phonological recoding in nonwords is clearly demonstrated by the pattern of errors. First, errors (particularly vowel errors) were much more frequent. The rarity of vowel errors in German suggests that German-speaking children might well be able to use phonological recoding processes that allow them to blend together consonants and consistently pronounced vowels into syllables on-line. This is not possible in English because vowel pronunciation is strongly dependent on context. Second, English-speaking children showed a significantly stronger tendency to make errors that themselves were words. This suggests that lexical representations are frequently used in a top-down fashion to supplement error-prone bottom-up recoding processes.

The preliminary conclusion from the present findings is that orthographic inconsistency imposes a heavy burden on the beginning reader. The acquisition of phonological recoding in English is slower than in German. The strategies involved in phonological recoding might well be very different in the two language groups. But, to what extent can the present findings be generalized, and at what age would mastery of phonological recoding be equally automatic in English and German?

STUDY 2: WORD AND NONWORD READING WITH SINGLE-STIMULUS PRESENTATION

The main goal of Study 2 was to examine further the phonological recoding advantage of the German-speaking children (Study 1) using single-stimulus presentation, which permits measurement of naming latencies. We studied a new sample of children from different schools—8-year-olds and 12-year-olds. We proposed that, by age 12, differences in phonological recoding between the two language groups would have largely attenuated.

A new word–nonword reading task was devised with a broader and more varied set of stimuli. We included words of low and high frequency as well as short and long words and nonwords. Again we used English and German words similar in spelling, pronunciation, and meaning, and again we derived similar nonwords. In addition, we presented a set of identical nonwords to both groups, generally obeying a simple CVCVCV structure.

Method

Participants

The 36 German-speaking and 40 English-speaking children described in Table 1 served in another study as reading-level controls or as age-level controls in a comparison of dyslexic German- and English-speaking children (Landerl, in press; Landerl, Wimmer, & Frith, 1997). Most (15 of 18) of the younger German-speaking children were tested immediately after the summer vacation at the beginning of Grade 3, which means that they had experienced 2 years of schooling. Three

TABLE 1
Descriptive Characteristics (Means and Ranges) of English- and German-Speaking 8- and 12-Year-Olds Participating in Study 2

	Age (Years) and Sex Ratio	*n*	*Reading Percentile*[a]	*Spelling Percentile*[b]	*Raven IQ Standard score*[c]
English 8-year-olds					
M	8:3[d]	21	52	51	106
Range	7:4–9:1		19–82	30–71	97–130
	57% boys				
German 8-year-olds					
M	8:8	18	55	N/A	107
Range	8:4–9:5		8–90		99–132
	56% boys				
English 12-year-olds					
M	12:7	19	56	48	106
Range	11:6–14		33–97	16–96	91–124
	58% boys				
German 12-year-olds					
M	1:7	18	N/A	46	100
Range	10:4–13:2			2–91	91–145
	56% boys				

[a]English: British Ability Scales (BAS) Word Recognition test (Elliot, Murray, & Pearson, 1983). German: Salzburger Lesetest (Landerl, Wimmer, & Moser, 1997). (This test has not been standardized for 12-year-olds.) [b]English: BAS Spelling scale (Elliot, 1992). German: Diagnostischer Rechtschreibtest (DRT) 4–5 (Seyfried, Klauser, & Weyermüller, 1987). No spelling test was available for the 8-year-olds. [c]Raven Standard Progressive Matrices (Raven, 1987). [d]8:3 means 8 years, 3 months.

children were tested at the beginning of Grade 2 and thus had only experienced 1 year of schooling. Eleven of the younger English-speaking children were tested in the middle of Grade 3, and another 10 were tested in the middle of Grade 4, which means that they all had a minimum of 2½ years of schooling.

Table 1 shows that nonverbal intelligence, tested by Raven's (1987) matrices, was well matched across countries. Further, spelling performance on standardized educational tests was similar: On average, the children performed at the appropriate grade level. It should be noted that the reading tests used were not the same in the two countries. The English-speaking children received a graded word-recognition test, the younger German-speaking children received a test based on word- and text-reading speed, and there was no standardized reading test available for the older German-speaking children.

The English-speaking children attended state schools in London; the German-speaking children attended a school in Salzburg. All of the schools served primarily middle-class neighborhoods. Information provided by the schools in London indicated that a mixed approach was used for reading instruction—an approach similar to that described earlier. In Salzburg, a standard phonics approach was used.

Materials and Procedure

Words and nonwords. For each of three item lengths (i.e., one, two, and three syllables), 32 English and German words were selected. As in Study 1, these words were similar in spelling, pronunciation, and meaning (e.g., *boat–Boot, motor–Motor, quality–Qualität*). The nonwords for one- and two-syllable items were again derived by exchanging the consonantal onset letters. For example, the English nonword *hoat* was derived from *hand* and *boat;* equivalently, the German nonword *Hoot* was derived from *Hand* and *Boot.* In the case of the three-syllable nonwords, the nonwords were constructed by rearranging the syllables of the words. For example, the English nonword *ralective* was constructed by combining the first syllable of *radio,* the second syllable of *electric,* and the third syllable of *positive;* the German equivalent of this nonword was *Ralektiv.*

Thorndike and Lorge's (1944) count of occurrences in magazines was used to subdivide the 32 English one-syllable words and the 32 English two-syllable words into two subsets, each of 16 low- and 16 high-frequency words. The low-frequency words all had counts below 220 (median = 84.5). The high-frequency words all had counts of more than 300 (median = 659). For the 32 three-syllable words, no such differentiation was possible because, with only 2 exceptions, they were all of low frequency (counts below 500). The same division was used for the corresponding German words. As in Study 1, about half of the words in the English set were of regular spelling, half irregular. The additional set of 24 CVCVCV nonwords used in Study 2 consisted of simple open syllables without consonant clusters. This structure is unusual for both languages but allows for the relatively straightforward application of phonological recoding skills. Examples are *tarulo, heleki, tokala, surimo, refeku,* and *nateli.* For the purposes of scoring, stress placement was disregarded.

Task format. The stimuli were presented one at a time on a computer screen. Each stimulus was preceded by a short (1-sec) visual and acoustic marker. The visual marker marked the place in the middle of the screen where the first letter of the word or nonword would appear. Letter sizes were 0.5 cm (lowercase) and 1 cm (uppercase).

The stimuli were presented in six subsets of 32. Each subset consisted of all words or nonwords of a given length. Children were informed before each block whether normal words or "strange words without a meaning" would have to be read. Because the task was part of a larger battery of tests, the six subsets could be interspersed among other tasks. The first subset always consisted of the one-syllable words. The sequence of the other subsets was varied for each child.

The children were instructed to press the mouse button as soon as they felt able to read the word aloud. Pressing the mouse button made the word disappear from the screen. Reaction time was measured from onset of stimulus presentation to pressing of the mouse button. The experimenter (Karin Landerl), who has training in phonetic transcription, noted children's readings.

Five one-syllable words and nonwords were used as practice items to familiarize children with the task. The two- and three-syllable word and nonword subsets started with two practice examples each to allow children to adapt to these stimuli. Similarly, the identical nonword task was preceded by five practice items of a structure similar to that of the actual stimuli.

Results

One- and Two-Syllable Stimuli

Figure 2 presents the mean error percentages for the 8-year-olds only, as the 12-year-olds made hardly any errors with these stimuli. As in Study 1, scoring of nonwords was lenient. For example, for the English nonword *yead,* the responses /ji:d/, /jed/ and /jid/ were all scored as correct readings.

Figure 2 shows that the German-speaking 8-year-olds read one- and two-syllable items with high accuracy and showed little effect of lexicality and word frequency. In contrast, these effects were strong for the English-speaking children. An ANOVA showed significant effects of orthography, $F(1, 37) = 7.5$, $p < .001$, and an Orthography × Lexicality interaction, $F(1, 37) = 2.52$, $p > .1$. Further, there were

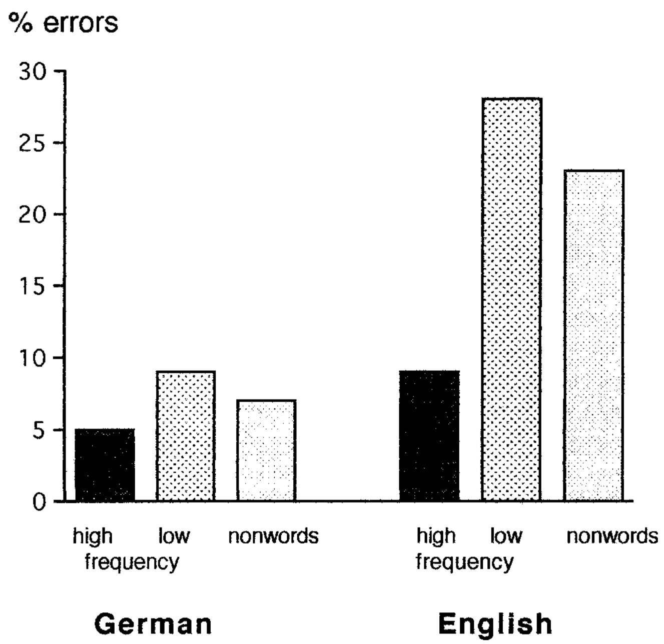

FIGURE 2 Mean error percentage for high- and low-frequency one- and two-syllable words and nonwords in Study 2. Comparison of German- and English-speaking 8-year-olds.

significant effects of frequency, $F(1, 37) = 93.89$, $p < .001$, and an Orthography × Frequency interaction, $F(1, 37) = 46.4$, $p < .001$. The third-order interaction, Orthography × Lexicality × Frequency, $F(1, 37) = 42.0$, $p < .001$, was also significant: There was hardly any group difference in the case of the high-frequency words (English 9%, German 5%). However, the disadvantage of the English-speaking children was considerable for low-frequency words (28% vs. 9% errors) and nonwords (23% vs 7% errors). The higher proportion of errors in low-frequency words compared to nonwords is readily explained by the fact that the nonwords were scored leniently, the words not.

Three-Syllable Stimuli

Because there were sufficient numbers of errors with these stimuli in all groups, it was possible to carry out an ANOVA with Lexicality (Words vs. Nonwords) as a within-subjects factor and Orthography and Age as between-subjects factors. Note that, with three-syllable words, low frequency and high frequency could not be contrasted, as the words were all of low frequency. The main effects of orthography and age and the Orthography × Age interaction were all significant, $Fs(1, 71) =$ 63.9, 71.7, and 41.7, $ps < .001$. As shown in Figure 3, the stimuli proved very

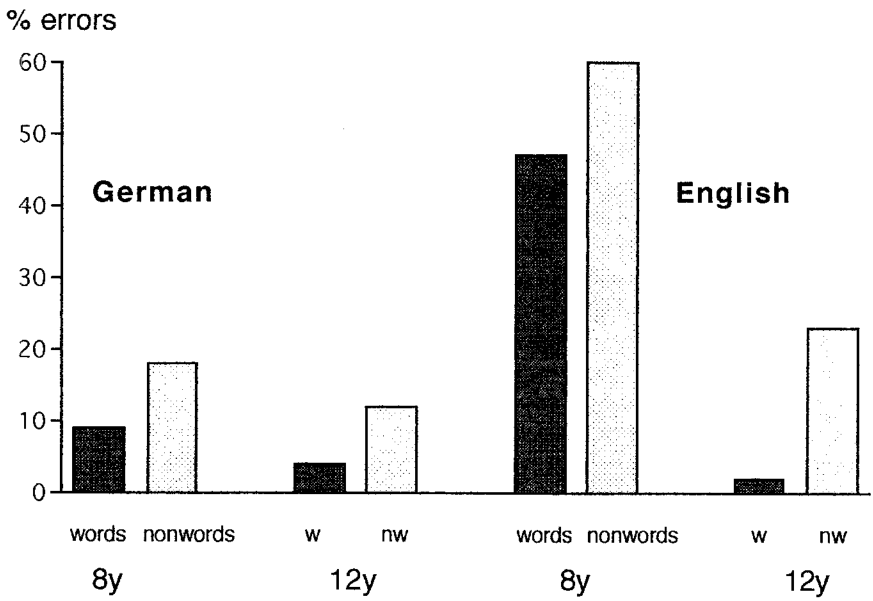

FIGURE 3 Mean error percentage for three-syllable words and nonwords in Study 2. Comparison of German- and English-speaking 8-to 12-year-olds.

difficult for the English-speaking 8-year-olds (combined error rate for words and nonwords = 53%) but much less so for the German-speaking 8-year-olds (error rate = 12%). It can be seen that the Orthography × Age interaction was due to age-related improvement being much greater for the English-speaking children. However, the English-speaking 12-year-olds who read the words nearly without errors (2%) still made a substantial number of errors (22%) with the nonwords. The corresponding percentages for the German-speaking 12-year-olds were 4% and 12%. The word advantage was significantly greater for the English-speaking children, $F(1, 34) = 58.7$, $p = .004$. The Orthography × Lexicality interaction was significant also for both age groups combined, $F(1, 71) = 6.9$, $p < .02$. The word advantage was larger for English-speaking children (words 25%, nonwords 41%) than for German-speaking children (words 7%, nonwords 15%).

Stimulus Naming Latency

Because only the latencies for correctly read items were used, the number of reaction times for the low-frequency words and nonwords is substantially smaller for the 8-year-old English-speaking children than for their German-speaking age peers. For statistical analysis, log-transformed time scores were used, as the variances of the reaction-time scores were very high, especially for the English-speaking subjects. Further, distributions were trimmed by discarding reaction times more than 3 *SD*s above the mean for a given condition.

As shown in Figure 4, there were substantial differences at age 8, with German-speaking children responding faster than English-speaking children. Latencies for the shorter stimuli were analyzed separately. The ANOVA showed a significant main effect of orthography, $F(1, 37) = 13.2, p < .01$, and significant Orthography × Lexicality, $F(1, 37) = 22.4, p < .001$, and Orthography × Frequency, $F(1, 37) = 7.0, p < .05$, interactions. The increase in reaction time from words to nonwords and from high- to low-frequency words was relatively small for the German-speaking children and significantly larger for the English-speaking children. The ANOVA for three-syllable stimuli gave a significant orthography effect, $F(1, 34) = 5.0, p < .05$, indicating that the English-speaking 8-year-olds performed more slowly. However, there was no longer an Orthography × Lexicality interaction; both language groups needed more time to decode long nonwords compared to words.

From Figure 5, it is evident that, at age 12, recognition latencies of German- and English-speaking children were remarkably similar. Both groups required somewhat longer processing for nonwords than words, and this difference was significant for short and long stimuli. Thus, there was no longer a difference in naming latency between the German- and English-speaking 12-year-olds. This result is somewhat different from the reading-accuracy result showing that the English-speaking 12-year-olds still produced more nonword errors than the German-speaking children and a larger word advantage.

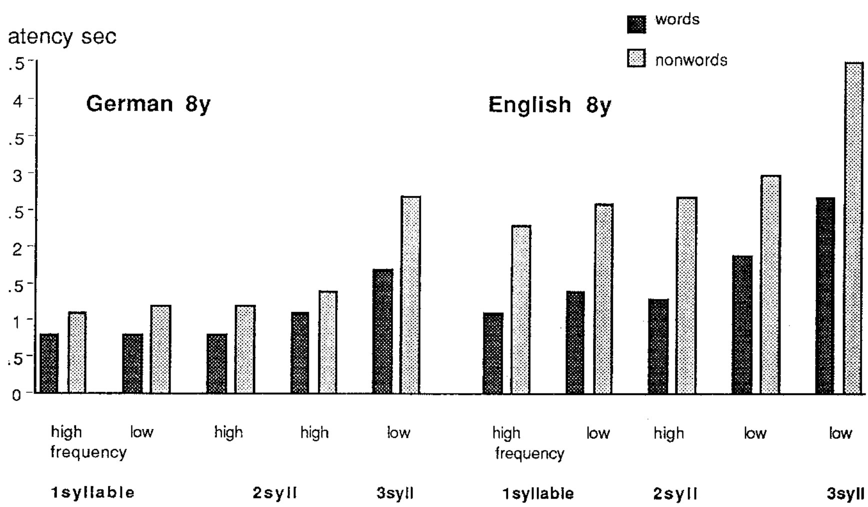

FIGURE 4 Mean latencies for correct responses in all stimulus categories used in Study 2. Comparison of German- and English-speaking 8-year-olds.

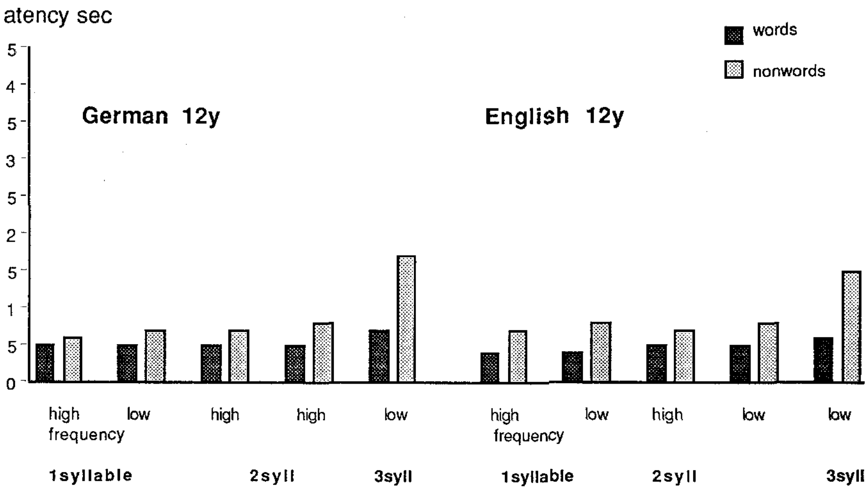

FIGURE 5 Mean latencies for correct responses in all stimulus categories used in Study 2. Comparison of German- and English-speaking 12-year-olds.

Error Analysis

Inspection of the reading errors of the German-speaking children showed that very few errors were due to incorrect grapheme–phoneme recoding. In a few cases, word-reading errors were due to incorrect stress assignment. This occurred for *Dentist, Atom, Monarch,* and *exotisch,* for which stress on the first syllable (most common among German two-syllable words) is incorrect. There were also some cases of *b–d* confusion (e.g., *plausibel–plausidel*). Other errors seemed to be due to difficulties during phonological assembly of long stimuli. For example, *Parlament* led to *parlement, paralament,* and *paralment.* Apparently, in the case of longer nonwords, children sometimes lost track of which graphemes they had already recoded, or they might have lost some phonemes before assembly.

In contrast, the English-speaking children made a large number of grapheme–phoneme recoding errors, particularly in the case of vowels. Examples from the younger children's misreadings of vowel letters are *sweat–sweet* (18 cases), *beer–bear* (4), *beast–best* (5), *bush–bash* (5), *contour–counter* (9), *foul–fool* (2), *echo–itcho* (2), *yacht–yatcht* (3), and *division–die-vishn* (2). Altogether, the English-speaking children produced 338 instances of incorrect sounding of the first vowel grapheme in a word, whereas the German-speaking children produced only 8 instances of such vowel errors. Other errors were due to inconsistent consonant graphemes (e.g., *monarch–mona-tch* [7]) or pronunciation of the silent letters in *sword, comb, muscle, plough,* and *ballet.* In other errors, misreading of an inconsistent grapheme might have led to further errors. For example, misreading the vowel letter in *bush* as /^/ might have led to the errors *brush* (2) and *blush* (1). Similar examples are *beast–breast, prince–price,* and *ballet–battle.* As before, a large proportion (30%) of all misreadings of one- and two-syllable nonwords was words. However, this was the case for only 10% of errors on three-syllable nonwords.

Identical Nonword Task

The simple syllable structure of the CVCVCV nonwords was helpful for all of the groups, as their mean error rate was dramatically reduced compared to that for the three-syllable nonwords based on real words. Figure 6 shows that, with the exception of the English-speaking 8-year-olds, the groups produced very few errors (German-speaking 8-year-olds = 0.5%, 12-year-olds = 3%; English-speaking 12-year-olds = 7%). These error rates were not statistically different from one another. In contrast, the mean error rate of the English-speaking 8-year-olds was 30% (*SD* = 22%); this group's errors were all deviations from the grapheme sequence and might have been due to errors in both decoding and assembly (typical examples were *twiwana* and *teluda* for *tewanu* and *antina* for *utina*).

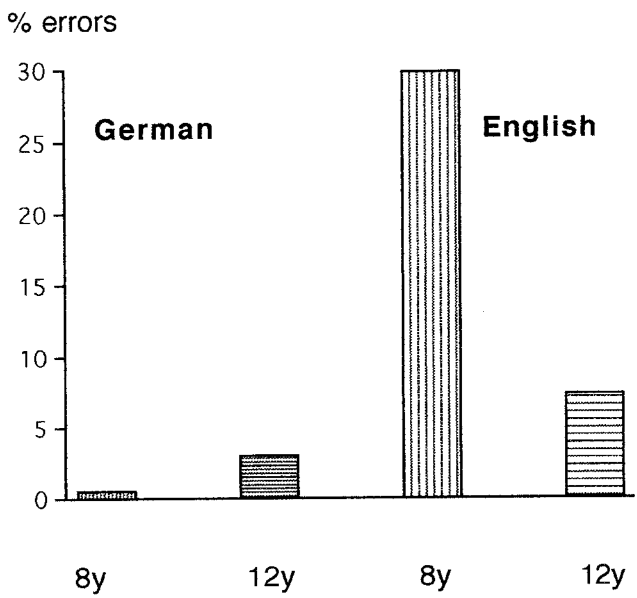

FIGURE 6 Mean error percentage for simple CVCVCV nonwords (*tarulo, heleki, tokala*). Comparison of German- and English-speaking 8- to 12-year-olds.

The naming latencies—again, for correct responses only—were very similar to those obtained for the previous three-syllable nonwords, with no orthography difference between 12-year-olds but a substantial difference for 8-year-olds. The English-speaking 8-year-olds showed a mean recognition latency of 4.3 sec per stimulus (SD = 2.1 sec), whereas the German-speaking 8-year-olds had a mean latency of 1.9 sec (SD = 0.9 sec). For the 12-year-olds, the means were 1.03 sec (SD = 0.61 sec) and 1.02 sec (SD = 0.49 sec) for the German- and English-speaking children, respectively. The Orthography × Age interaction was significant, $F(1, 71) = 10.2$, $p < .001$, due to the longer latencies of the English-speaking 8-year-olds.

Study 2 Discussion

Study 2 extended and confirmed the Study 1 results. We found that, under strictly comparable conditions, English-speaking 8-year-olds showed less complete mastery of phonological recoding than their German-speaking counterparts. Higher error rates and longer latencies for correctly read stimuli indicated that their recoding skills were slower and hence less automatic. By age 12, however, both language groups showed equally fast and automatic phonological recoding. However, the English-speaking readers still made errors (about 1 in 5) when reading long and complex nonwords.

The delay in English-speaking children's acquisition of phonological recoding was particularly poignant in the case of highly regular CVCVCV nonwords: One in 3 were pronounced incorrectly by 8-year-olds whose word-reading ability, as assessed by a standard test, was age appropriate. This result suggests a serious limitation in basic recoding skills at a point when most of the present children will have had 3 years of reading instruction. The error pattern confirmed the Study 1 finding indicating serious difficulties in the pronunciation of vowels. Again, there was a tendency to substitute words when attempting to read nonwords. The word advantage was largely confined to high-frequency words in this group and, as before, was significantly larger than the word advantage shown by the German-speaking readers.

As discussed earlier, we believe that these findings provide evidence that learning to read in English implies a delay in the acquisition of phonological recoding, and, in comparison with learning to read in German, involves the use of rather complex and error-prone strategies.

GENERAL DISCUSSION

The results of Studies 1 and 2 fit in well with the results of previous comparative studies carried out with children learning a more consistent orthography than that of English. It is clear that phonological recoding is much more difficult for English- than for German-speaking children. The evidence suggests that mastery of phonological recoding—that is, the ability to translate printed words independently into their spoken equivalents—is not equal in the two language groups. There were considerable differences in speed and accuracy of decoding as well as in error patterns at younger ages. However, after a prolonged period of acquisition of a complex orthographic system, reading speed was highly comparable in both language groups at age 12. By that age, the English-speaking children had achieved automatic but still error-prone recoding skills.

Why was there such a big difference between English- and German-speaking children's acquisition of phonological recoding? This might have been due to differences in orthographic inconsistency but might also have been due to differences in instructional approaches. Systematic phonics teaching was used in the German-speaking schools but not in the English-speaking schools. In this study, nonword-reading responses were scored so as to give credit to any admissible pronunciation of phonemes. Thus, a bottom-up strategy based on phoneme assembly would have guaranteed success for nonwords. This is not a very helpful approach to reading irregular English words and consequently is not usually favored by teachers. An analogy strategy, using rimes as units of decoding, would also have led to success. It can be argued that such a strategy, compared to a phoneme-assembly strategy, is more helpful in English, as the pronunciation of vowels is more consistent at the onset and rime levels than at the phoneme level (Treiman et al., 1990). However, the young English-speaking children did not show great proficiency in using onsets and rimes as basic decoding units either. For example, only 4 of the 34 English-speaking children who read *heart* correctly read *theart* in analogy to *heart.*

Studies 1 and 2 together provide some evidence that phonological recoding might be qualitatively different in the two language groups. We suggest that Berent and Perfetti's (1995) two-cycle model of phonological recoding provides an explanation for the difficulties experienced by the English-speaking children. This model suggests that, in English, two cycles are necessary in recoding: First, the consonant skeleton is derived; second, the vowel pronunciation is elaborated. This model is supported by the error pattern obtained in Studies 1 and 2. One key orthographic feature might be responsible for this difference—the consistency of grapheme–phoneme relations for vowels. We hypothesize that the high consistency of vowels in German permits immediate on-line assembly of syllables. We suggest that another reason for the ease of acquisition of recoding skills in German is the repeated experience of success that arises from the normally close match between on-line assembled phonemes and whole-syllable or whole-word sound. It is plausible that teachers capitalize on this close match between subsyllabic and syllabic codes and find frequent occasion to reward a young child's attempts at phonological recoding in the early stages of learning.

In contrast, in English, the correct vowel sound is usually not available until the second decoding cycle. The consonant context has to be decoded before the vowel can be pronounced unambiguously, and hence on-line syllable formation is rarely possible. As a result, phonemic information acquired in the first decoding cycle might be lost, resulting in omissions and substitutions. The tendency to substitute other words suggests a stronger reliance on top-down processes in phonological recoding than is evident in German. The great facilitation of words compared to nonwords and of frequent words compared to infrequent words confirms that orthographic representations are of major importance in the recoding process and will be used to supplement processes of phonological assembly. For example, an English-speaking child might assemble the consonant skeleton /h/-/ʔ/-/r/-/t/ in the first cycle of phonological recoding. If the word is familiar, then lexical search might lead to the correct identification of the word *heart*. Clearly, with irregular words, the match between assembled phonemic or syllabic codes and whole-word sound is often very poor. For instance, the stimulus word *WORD* might be pronounced /w/-o/-/r/-/d/, which does not sound very much like /wərd/. The high likelihood of a mismatch would be particularly discouraging at the early stages of learning. In contrast, in German, the four segments of the stimulus *WORT* can be pronounced unambiguously /w/-/o/-/r/-/t/, which, sounded out in this order, closely resembles the sound /wort/.

If the task of phonological recoding is difficult and error prone for the normally developing English-speaking reader, in the case of dyslexia the problem is vastly aggravated. The problems that English-speaking dyslexics have with nonword reading were reviewed by Rack, Snowling, and Olson (1992). The error rates from the 16 studies with dyslexic children reviewed by Rack et al. were between 40% and 60%. In contrast, German dyslexic children show remarkably high accuracy when reading nonwords, but they suffer from a severe reading-speed deficit (Wimmer, 1993, 1995). A direct comparison of dyslexic English- and German-speaking children was recently carried out by Landerl (in press) using the stimulus material and procedure described in Study 2 here. Landerl found that the dyslexic German-speaking children read the one- and two-syllable nonwords with about 10% errors. Even the three-syllable nonwords led to only about 20% errors, whereas English-speaking dyslexic children made about 40% errors for the short nonwords and 70% for the long nonwords. However, in both groups, word-recognition latencies were slower than those of 7- to 8-year-olds matched on word-recognition accuracy.

Finally, we must reemphasize that cross-cultural comparisons are fraught with problems, and we cannot rule out the possibility that differences in teaching method rather than orthography caused the differences we found between English- and German-speaking children. We suggest, however, that orthographic consistency and instructional methods are linked. A consistent orthography lends itself to systematic teaching by a phonics method, whereas an inconsistent orthography demands more complex methods of teaching. Interestingly, it has been shown that English-speaking children benefit when taught by a systematic phonics approach (for a recent review, see Snowling, 1996). If, as we propose, the consistency of the orthography interacts with instructional practice, it would be important to study the effect of different teaching methods in different orthographic contexts.

Despite all the cultural and cognitive reasons for obtaining differences in phonological recoding skills and the processes underlying these skills, it is clear that, by age 12, such differences are largely invisible. This is encouraging, as it proves yet again the amazing resilience and adaptability of developing children. Most children can cope with the vicissitudes of writing systems and fashions in teaching methods and can overcome the many hurdles that often slow down the course of learning.

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APPENDIX

		Examples of Stimuli Used in Study 1
English	Words	*Summer, boat, garden, rose, heart, guest, bear, word*
	Nonwords	*Rummer, hoat, barden, bose, theart, wuest, lear, gord*
German	Words	*Sommer, Boot, Garten, Rose, Herz, Gast, Bär, Wort*
	Nonwords	*Rommer, Hoot, Barten, Bose, Derz, Wast, Lär, Gort*
		Examples of Stimuli Used in Study 2
One and two syllables, high frequency		
English	Words	*Ball, hand, butter, music*
	Nonwords	*Grall, mand, sutter, cusic*
German	Words	*Ball, Hand, Butter, Musik*
	Nonwords	*Grall, Mand, Sutter, Kusik*
One and two syllables, low frequency		
English	Words	*Zoo, wolf, tiger, bishop*
	Nonwords	*Foo, bolf, higer, rishop*
German	Words	*Zoo, Wolf, Tiger, Bischof*
	Nonwords	*Foo, Bolf, higer, Rischof*
Three syllables, low frequency		
English	Words	*Radio, serious, paradise*
	Nonwords	*Ralective, semater, pacoble*
German	Words	*Radio, seriös, Paradies*
	Nonwords	*Ralektiv, semater, Pakobel*