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The impact of orthographic consistency on dyslexia: A German-English comparison

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Abstract

We examined reading and phonological processing abilities in English and German dyslexic children, each compared with two control groups matched for reading level (8 years) and age (10–12 years). We hypothesised that the same underlying phonological processing deficit would exist in both language groups, but that there would be differences in the severity of written language impairments, due to differences in orthographic consistency. We also hypothesized that systematic differences due to orthographic consistency should be found equally for normal and dyslexic readers. All cross-language comparisons were based on a set of stimuli matched for meaning, pronunciation and spelling. The results supported both hypotheses: On a task challenging phonological processing skills (spoonerisms) both English and German dyslexics were significantly impaired compared to their age and reading age controls. However, there were extremely large differences in reading performance when English and German dyslexic children were compared. The evidence for systematic differences in reading performance due to differences in orthographic consistency was similar for normal and for dyslexic children, with English showing marked adverse effect on acquisition of reading skills.

1. Introduction

A massive body of evidence suggests that genetically and neurologically based deficits in phonological processing underlie the reading difficulties of a sizeable proportion of otherwise normally developing children (e.g., Pennington et al., 1990; Siegel, 1993; Stanovich, 1994) who are referred to as dyslexic. This evidence has largely come from children with difficulties learning to read English.

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However, it has been assumed that in principle the phonological deficit account would hold for all alphabetic orthographies. The argument would be that: (a) all alphabets follow the principle that graphemes represent abstract phonemic units of languages, which are difficult to access because they are embedded in the speech stream, and (b) phonologically impaired children have difficulties in accessing these abstract phoneme units and consequently in mapping alphabetic print onto spoken language (e.g., Gleitman and Rozin, 1977; Liberman, 1982). This universal account of dyslexia needs to be reconciled with the fact that different orthographies have different mapping rules: There is a wide range in the degree of consistency with which alphabets represent phonemes by graphemes. Some orthographies, such as Finnish or Turkish, correspond to the alphabetic ideal of one phoneme–one grapheme very closely. Others, such as English or Danish, have traded in the strict rule of one-to-one correspondence between phonemes and graphemes for consistencies at the morphemic level (e.g., *sign–signature*). It seems plausible that orthographic consistency affects both the nature and degree of reading difficulties. Thus, if grapheme–phoneme relations are consistent, then even a child with phonological difficulties may, with appropriate instruction, learn to map print onto speech and accordingly show little or no delay in reading acquisition. Conversely, if such a child learned an orthography with opaque and confusing grapheme–phoneme relations, then there would be severe problems in reading acquisition.

From the study of normal reading development it can be concluded that consistent orthographies pose much less of a hurdle for beginning readers than an inconsistent orthography such as English. In particular, young readers in Italian, Spanish, Turkish, Greek and German have been found to have little difficulty with independent word recognition via phonological recoding, while English children in the various comparisons had strikingly more problems (Cossu et al., 1995; Goswami et al., 1995; Oney and Goldman, 1984; Porpodas, 1989; Thorstad, 1991; Frith et al., in press; Wimmer and Goswami, 1994). These findings suggest that it would be wrong to think that phonological recoding is necessarily a demanding task: When grapheme–phoneme relations are consistent, children can easily acquire the grapheme–phoneme correspondence rules and use these to assemble pronunciations for novel letter strings. The critical test of this skill used in the studies mentioned above is reading nonwords.

In contrast to the increasing number of studies comparing reading development in various consistent orthographies with English, there is a dearth of comparative research on dyslexic children. For English dyslexic children, a large number of studies, recently reviewed by Rack et al. (1992), have shown that the phonological recoding of nonwords is excessively difficult. In contrast, for children with specific reading difficulties in more consistent orthographies evidence for a phonological recoding deficit is rather sparse. A series of studies by Wimmer (Wimmer, 1993, 1996a,b) with German dyslexic children found that only in first grade did they exhibit higher levels of errors for nonwords and difficulties with phonemic segmentation. In the subsequent grades both nonword reading errors and phonemic segmentation errors become very infrequent. However, a specific speed deficit for nonword reading persists. So, fourth graders with dyslexia read nonwords more slowly than normally reading second graders, even though both groups were carefully matched on reading speed for the words from which the nonwords were derived (Wimmer, 1996b). Similarly, Yap and van der Leij (1993) found low error rates for both words and nonwords in 10 year-old Dutch dyslexic readers when unlimited time for response was available. Lindgren et al. (1985) found that US children with dyslexia exhibited more reading errors for nonwords than Italian children. This difference, however, is equivocal since the nonword stimuli were different in the two orthographies.

The present research attempts a stringent comparison of the reading impairments of typical German and English dyslexic children. These children were between 11 and 13 years of age and had shown persistent reading difficulties during their whole school career. German and English comparisons are particularly well suited to this purpose. First, almost identical stimuli can be used. Due to common roots both German and English share many words which are spelled and pronounced in a highly similar way. Second, German and English have very different degrees of orthographic consistency. The difference is most striking for vowels. To illustrate, the grapheme *a* stands for the same vowel in the German words *Ball*, *Katze* and *Hand*, while the same grapheme represents different vowels in the corresponding English words *ball*, *cat* and *hand*. Different pronunciations of one and the same vowel grapheme such as in the English words *hear*, *bear*, *heard*, *beard*, are not possible in German. The German umlaut signs (e.g., *Ball–Bälle*) allow to mark vowel changes due to morphological processes such as pluralization and broaden the graphemic means for vowel representation. There are further complexities in the orthographic representation of vowel length. Vowel lengthening is achieved by doubling of the vowel letter (*Tee*), by the silent h after the vowel letter (*Bohne*) or simply by not doubling the consonant letter after the vowel, since this normally signals that the vowel is short (*Ofen* vs. *offen*). Even if such complexities of vowel length representation are neglected by the beginning reader, there is a good chance that phonological recoding will lead to the correct word pronunciation, because it is quite exceptional that two words differ solely in vowel length.

The main strategy of the present research was to contrast reading words with reading nonwords using stimuli that are highly similar in the two orthographies in terms of meaning, spelling and pronunciation. The nonwords were derived from the words. The German and the English dyslexic children were, therefore, presented with the same or else highly similar grapheme patterns and had to produce similar pronunciations. Nevertheless we expected that the efficiency of phonological recoding during nonword reading should be affected by the differences in orthographic consistency.

English and German dyslexic children's word and nonword reading abilities were assessed in a single item reading task which enabled us to measure latency to correctly decoded stimuli separately. This meant we could assess the influence of item characteristics on both accuracy and processing speed. The second stimulus characteristic explored in this task was item length. Words of one, two and three syllables and nonwords derived from these words were used. A subset of the presented German and English words were divided into high- and low-frequency groups. Elevated error rates and/or reading times in high-frequency word reading would indicate a deficit in fast automatic word recognition. Low-frequency words, which presumably are not directly recognized, are likely to need phonological recoding.

Additionally, both the German and the English dyslexic children were confronted with a phonological processing task using spoken words which also consisted of very similar items for both orthography groups. We decided to choose a complex spoonerism task for which the onsets of two words had to be exchanged (e.g. *man* and *hat* become *han* and *mat*). This is a challenging test of phonological processing abilities as it requires not only segmentation of the words into consonantal onset and rime, but also reassembly of these segments into new pronunciations. Obviously, performing this task places high demands on phonological working memory because—depending on strategy—up to four segments have to be retained. Paulesu et al. (1996) found the spoonerism task to be sensitive in discriminating compensated adult English dyslexics and Gallagher et al. (1996) used this task with adolescents. It thus seemed appropriate to the age of the present dyslexic groups.

To summarize, the main methodological aspect of this cross-orthography dyslexia comparison is the use of word and nonword stimuli that are almost identical across the two languages. The similarity of the items with respect to meanings (for words), spellings and pronunciations largely rules out visual or phonological/articulatory differences as explanatory factors for reading differences between English and German dyslexic children. Therefore, any differences between the two groups should be interpretable as being caused by the difference in grapheme–phoneme consistency. To further strengthen this interpretation, two control groups were used for each dyslexia group. One group was matched on chronological age. This allowed us to compare how normally developing children of the same age as the dyslexic children in each orthography would perform on the tasks. The second control group was matched on reading level. In the present context, the reading level control group serves two purposes. One is to check whether any difficulties of German or English dyslexic children with nonword reading and phonological processing go beyond their word reading impairment. The main purpose in the present study was, however, to examine whether any reading or phonological processing differences between English and German dyslexic children are orthography/language related. If this were the case we would expect that differences of a similar nature should also be observed between the normally developing English and German readers.

2. Method

2.1. Participants

The definition of dyslexia is contentious in either of the two countries. Yet, the condition is recognised by teachers and researchers. For the purpose of the present study it was important to select children with roughly equal difficulties in reading acquisition and showing equivalent problems of the kind that are typically observed in dyslexic children in each orthography. We therefore selected children aged 11–12, whose reading difficulties had persisted over several years and who were delayed by about 3–4 years compared to their peers.

For selection of the English subjects we relied on official statementing procedures. Sixteen of the eighteen children were already statemented as having specific learning difficulties, for two children the statementing process was underway. Ten children attended special schools for dyslexic children, four received intensive remediation in dyslexia centres associated with their schools and two were enrolled in special remediation programs in their schools. Their current reading abilities were assessed by the British Ability Scales Word Recognition Test (Elliot et al., 1983), a graded word reading test. Sample characteristics, together with reading and spelling level and nonverbal intelligence are set out in Table 1.

As can be seen in Table 1, the word recognition abilities of all the English dyslexic children were below percentile 19 in comparison to normal readers of the same age. Their mean reading age was 8;3 years (range: 7;3–10;9). Thus, on average, their reading abilities were about 4 years below their chronological age. Table 1 also shows that dyslexic children's spelling abilities assessed by British

Table 1
Mean age, reading level, spelling level and nonverbal intelligence of English and German dyslexics, age level controls and reading level controls (ranges in parentheses)

	N (% boys)	Age	Reading level (percentile)[a]	Spelling level (percentile)[b]	Nonverbal IQ
German:					
Dyslexics	18 (78)	11;7 (10;7–12;7)	12 (1–41)	3 (0–13)	103 (85–145)
Age level controls	18 (56)	11;7 (10;4–13;2)	87 (50–99)[c]	46 (2–99)	100 (91–145)
Reading level controls	18 (56)	8;8 (7;4–9;5)	17 (1–75) [56 (23–90)][d]	–	107 (99–132)
English:					
Dyslexics	18 (83)	12;3 (10;9–13;11)	8 (2–19)	8 (2–22)	103 (91–121)
Age level controls	19 (58)	12;7 (11;6–14;0)	66 (33–97)	48 (16–96)	106 (91–124)
Reading level controls	21 (57)	8;3 (7;4–9;1)	8 (2–19) [50 (33–64)][d]	–	106 (97–130)

[a] German: Salzburger Lese- und Rechtschreibtest; English: BAS Word Recognition Test.
[b] German: DRT 4–5; English: BAS Spelling Scale.
[c] The reading level of the German age level control group seems to be quite high. However, this is an artefact because as mentioned already, the test we used is only standardized up to Grade 4 while the subjects of the present study attended Grade 5 or 6. The average spelling level of this group in fact suggests that their literacy development was normal.
[d] For the reading level controls two mean percentile scores are presented. The first score is based on the Grade 4 norm sample the dyslexic sample was compared with. This score shows that their reading level is similar to that of the corresponding dyslexic sample. The second score, in brackets, presents the mean percentile in comparison to the norm group of the same age. This score shows that the reading level control children are normally developing readers.

Ability Scales Spelling Scale (Elliot, 1992) were even poorer than reading, corresponding to a mean percentile rank of 8.

For the German sample, subject selection was less straightforward, because there is no official diagnosis of specific learning disabilities. Furthermore, the typical reading problems of older German dyslexic children are different from those reported for English children; their problem at older ages is impaired reading speed rather than reading accuracy. It is important to note that the speed impairment of typical German dyslexic children is a serious handicap and puts them at a grave disadvantage compared to their peers. Dyslexic children's reading is so slow and laborious that book reading is aversive and learning from text difficult, so that all school activities involving reading are highly problematic for these children.

The German dyslexic children were recruited from two longitudinal studies of reading difficulties conducted in our laboratory in Salzburg[1]. Children were included in the present study: (a) if they had shown early reading difficulties, and (b) still did so at the age of 11–12 years. The early reading difficulties had been first diagnosed at the end of Grades 1 or 2. At that point the children had been identified by their teachers as having specific difficulties in the acquisition of reading and spelling. Their performance on a standardized word recognition test [DLT 1-2 (Weyermüller, 1978) or Salzburger Lese- und Rechtschreibtest (Landerl et al., 1997)] in every case was more than one standard deviation below the mean. The second step of the diagnosis was the assessment of children's current reading abilities at age 11–12 years. For this purpose we used a word recognition test, i.e. the Salzburger Lese- und Rechtschreibtest (Landerl et al., 1997). Although this test is only standardized up to Grade 4 (the children of the present study were in Grades 5 and 6) it was more appropriate for the present purpose, as all available German reading tests for children older than 10 years are tests of reading comprehension throughout. As older German dyslexic children do not produce many reading errors, the main diagnostic criterion was reading speed. As Table 1 shows, the present group of dyslexics showed a mean reading speed which corresponded to a percentile of 12 in comparison to the slightly younger Grade 4 norm sample. Reading speed was measured both for a short text and for a list of complex compound words (e.g., *Obststand, Krankenschwester*). As a group, the German dyslexic children's reading speed was low average in comparison to 8–9 year-old children. Thus, their reading development was delayed by about 3–4 years[2]. Table 1 shows that the German dyslexic children generally had very poor spelling abilities, corresponding to a mean percentile rank of 3 on the standardized spelling test [DRT 4-5 (Seyfried et al., 1987)].

From this two-step diagnosis it is clear that the reading problems of the German

[1] As the Austrian children from Salzburg were learning to read in German, they are referred to as 'German' children throughout the paper for ease of exposition.

[2] Two of the grade six dyslexic children showed less serious reading speed impairments and were on the 41st percentile in relation to the grade four norm sample of our test. However, one of these two children had traded speed for accuracy and made five reading errors on the short text which places him at percentile rank 1. Furthermore, both children showed extremely poor spelling abilities resulting in a percentile score of 2 in the spelling test.

dyslexic children participating in this study just like the English dyslexics' were persistent, and had been evident during their whole school career. Another indication of the similar severity of their reading deficit is that all the dyslexic children in this study, both German and English, had received reading remediation. All German dyslexic children were enrolled in dyslexia courses in their primary schools (one group lesson weekly for a maximum time of 1.5 years). Four children had received an additional remediation program of between 20 and 60 lessons in our lab when they were in Grade 2; two further children were in the middle of such a program when they were tested for this study. In all these respects–persistence of difficulties, extent of reading delay, participation in remedial programs–the German and English groups were the same. Children's nonverbal intelligence assessed by Raven's Standard Progressive Matrices (Raven, 1987) was average for both English and German children. Their socioeconomic background was predominantly middle class. Two control groups were assigned to each of the two groups of dyslexic children. One group was matched on chronological age and the other group on reading level; see Table 1.

2.2. Procedure

2.2.1. Single word/nonword reading

192 items were used, comprising one-, two- and three-syllable words and nonwords derived from these words. The words were very similar in English and German in terms of spelling and pronunciation, and they were also identical in meaning (e.g., *boat–Boot*, *motor–Motor*, *quality–Qualität*). The one- and two-syllable nonwords were derived from the words by exchanging the consonantal onsets. For example, the English nonword *hoat* was derived from *hand* and *boat*, and, equivalently, the German nonword *Hoot* was derived from *Hand* and *Boot*. For the three-syllable nonwords the syllables of the words were rearranged. 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 is *Ralektiv*. The word and nonword items are given in Appendix A.

The items were presented one by one on a computer screen. Immediately after a short (1 s) visual and acoustic marker the item appeared in the middle of the screen (letter size: 0.5 cm for lower-case and 1 cm for upper-case letters). The children were instructed to look at the item and to press the mouse button as soon as they knew the pronunciation. As soon as the child pressed the mouse button, the item disappeared from the screen. The child then had to say the name of the item aloud. The reaction time for each item was measured from the onset of presentation until the mouse button was pressed[3].

The items were presented in six subsets of 32: one-, two- and three-syllable

[3] We did not use a voice key since it was found that the dyslexic readers quite often made several false starts when reading an item, and the German children would sometimes start to sound out an item well before having completed the reading process. Therefore, we developed a task which measured reaction time only after the reading process was completed.

words and one-, two- and three-syllable nonwords. Because the word/nonword reading task was part of a larger battery of phonological, reading and spelling tasks, the six subsets of items could be interspersed among other tasks. The first subset were always the one-syllable words. The sequence of the other subsets was varied for each child. Five practice one-syllable words were presented to familiarize children with the task. Before the first subtest with nonword items, children were introduced to nonwords as 'strange words without meaning' and five practice items were presented. The two- and three-syllable word and nonword subsets started with two practice examples each to allow the children to adapt to these items.

2.2.2. Phonological processing

For each item of the spoonerism task children were presented with two words and had to exchange the consonantal onsets of these words (e.g., *boat–fish* becomes *foat–bish*). This task requires phonological analysis (isolate onsets) and synthesis (recombine onsets and rimes). It also places high demands on phonological working memory. To reduce the memory load the child was shown a booklet with two pictures on each page depicting the words whose onsets had to be exchanged. The experimenter named the two pictures and asked the child to 'exchange the word beginnings of these two words'. Five practice examples were administered to clarify the meaning of 'word beginning', then ten experimental items followed. In half of the items both words had only one consonant in the onset (e.g., *ship–cat* becomes *kip–shat*) while in the other half one of the two words started with a consonant cluster (e.g., *blue–red* becomes *rue–bled*). Only words that were similar in the two languages were used (e.g., Engl.: *gold–silver*, Germ.: *Gold–Silber*). Since one of the English dyslexic children was not available for testing, only 17 English dyslexics participated.

3. Results

3.1. Single word/nonword reading

3.1.1. Analysis

Because of the single item measurement of reading time used in this task, both subject and item analyses for errors and time could be conducted. The subject analysis allows generalization beyond children participating in this study while the item analysis allows generalization beyond the items used in the present experiment. The *minF'* analysis is the most conservative as it allows generalization beyond subjects and items (Clark, 1973). Significant results of the item or subject analysis will only be reported if the *minF'* did not reach significance. The effects of lexicality (words, nonwords) and item length (one-, two-, three-syllable items) on the two dyslexic groups were explored first. In a second step, each dyslexic group was compared to the control groups of the respective orthography. For ease of exposition, only significant group effects or interactions with the group will be reported.

3.1.2. Reading errors

English nonword readings were scored leniently. In particular, in order to be correct, it was not necessary to read a nonword in analogy to the corresponding numberword. Moreover, any grapheme-to-phoneme translation which exists in a real English word—irrespective of position and graphemic context—was accepted. For example, the nonword *thoul* could be read as /θoul/, /θaul/ or /θu:l/. The upper section of Fig. 1 presents the mean error percentages for words and nonwords of all three item lengths for dyslexic and reading level control children.

German vs. English dyslexic children: Fig. 1 shows that overall the English dyslexic children made many more errors than the German dyslexic children. There was no overlap in mean error percentages: The German dyslexic children read the three syllable nonwords (the most difficult item category) more accurately than the English dyslexics read the one-syllable words (the easiest item category). Fig. 1 also shows that the increase in errors with increasing syllable length was

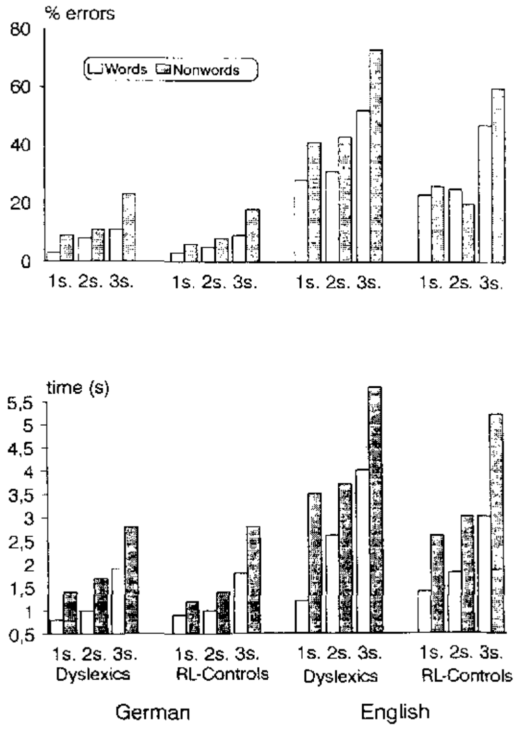

Fig. 1. Mean error percentages (upper section) and mean reading times for correctly read items (lower section) for one-, two- and three-syllable items of the single word/nonword reading task for German and English dyslexic and reading level control children.

larger for the English than for the German children, as was the increase in errors from words to nonwords (orthography: $minF'(1,41) = 49.07$, $p < 0.01$; lexicality × orthography: item analysis: ($F(1,186) = 7.56$, $p < 0.01$, orthography × item length: $minF'(2,218) = 8.35$, $p < 0.01$).

German dyslexic vs. reading level control children: Because of the generally low error scores, the errors for all three syllable lengths were combined. On this combined score, the German dyslexic children showed slightly more nonword reading errors (14%) than the reading level control children (10%). In a nonparametric Mann-Whitney test, the relatively small difference between dyslexic and reading level control children was found to be reliable, $U = 109$, p(corrected for ties) < 0.05 (one-tailed).

English dyslexic vs. reading level control children: Only the group effect and the group by lexicality interaction were reliable, ($minF'(1,42) = 4.7$, and $minF'(1,39) = 4.56$, $p < 0.05$). From Fig. 1 it is evident that for nonwords the dyslexic children showed many more errors than the reading level control group (52% vs. 35% combined over the three lengths), while for words the difference was negligible (37% errors vs. 32% errors).

3.1.3. Error analysis

A direct consequence of orthographic consistency is the difference in the number of errors where the vowel grapheme(s) of word items was misread, in the sense that a possible but inappropriate grapheme–phoneme relation was used. In the erroneous readings /li:θə/ and /liəθə/ for *leather* the inappropriate vowel is the only error, while in 'find' for *friend* it is not the only error. Other examples for the use of possible, but inappropriate grapheme–phoneme relations are 'sweet' for *sweat*, which occurred twelve times, /tigə/ for *tiger*, or /bal/ for *ball*. Overall, there were 324 instances of incorrect pronunciation of the first vowel grapheme in the word items among the word reading errors of the English dyslexic children, while only 20 such vowel misreadings were observed among the German dyslexic children. A typical example of wrong vowel reading among the German dyslexic children was 'offen' (short vowel) for *Ofen* (long vowel), which occurred six times. Here, the rule was violated that only vowels which are followed by two consonants take the short pronunciation. This reading error was obviously promoted by the fact that 'offen' (open) as well as 'Ofen' (oven) are German words. Another typical error of the English children were consonant intrusions. English examples for such intrusions are 'brind' or 'blend' for *biend*, German examples are 'braind' for *Beund* or 'Fleisch' for *Fisch*. Such consonant intrusions occurred 310 times for the English and 67 times for the German children.

A frequently occurring error among the English dyslexic children was that a similar word was read for a word item (e.g. 'find' for *friend*) or a nonword item (e.g., 'blind' for *briend*). For the three-syllable word *character*, five different erroneous word responses occurred ('chancelor', 'calendar', 'calculator', 'charger' and 'tractor'). A common characteristic of the majority of these erroneous word responses is that they share the initial and the final grapheme(s) with the target. Overall, the English dyslexic children produced erroneous word responses to 14%

of all word items and to 6% of all nonword items. The low percentage of word responses to nonwords reflects the fact that the nonwords were always presented as a block and the children were told that they were nonwords. Due to the comparatively few errors of the German dyslexic children, only 2% of the word items and 1% of the nonword items led to a wrong word response. Further evidence for a lexical strategy on the part of the English dyslexic children is provided by the number of refusals for word items which was considerably higher than for nonword items (81 vs. 15).

Another observation was that many different readings were produced by the English dyslexic children for the same item. For the three syllable nonwords, English dyslexic children produced on average 14 different pronunciations. This means that most of the 18 children created a novel pronunciation.

3.1.4. Reading time

The analysis of reading speed is based on reaction times for correctly read items only. Four English dyslexic children were excluded from analysis since they failed to give a single correct response for the three-syllable nonwords. Due to English children's lower reading accuracy, the number of reaction times was smaller for the English than for the German dyslexic children particularly for nonwords. Since the variance of the reaction time scores was very high, they were subjected to a log transformation. The reaction time distributions were further trimmed by discarding reaction times more than 3 SDs. above the mean for a given condition. The mean reading time scores for correctly read items are presented in the lower section of Fig. 1.

German vs. English dyslexic children: Fig. 1 shows that the reading speed advantage of the German over the English dyslexic children was similar for all three item lengths. For German dyslexic children the difference between words and nonwords (1.2 s vs. 1.9 s) was smaller than for English dyslexic children (2.3 s vs. 4.0 s). Fig. 1 shows that this orthography dependent word–nonword effect differed with item length. For the English dyslexic children the word–nonword difference was particularly pronounced for the one syllable items, with relatively fast reading times for words and very slow reading times for nonwords. In contrast, the German dyslexic children showed a word–nonword difference that was fairly constant across all three item lengths (orthography: $minF'$s$(1,55) = 10.93$, $p < 0.01$; orthography × lexicality: $minF'(1,55) = 8.36$, $p < 0.01$; orthography × lexicality × item length: subject analysis: $F(2,58) = 5.81$, $p < 0.01$, item analysis: $F(2,185) = 4.54$, $p < 0.05$).

German dyslexic vs. reading level control children: Fig. 1 shows that for words of all three item lengths the dyslexic children showed very similar reading times compared to reading level controls. However, when reading nonwords the dyslexic children performed worse than controls except for the three syllable nonwords which were read equally slowly by the control children (reading group: item analysis: $F(1,186) = 23.12$, $p < 0.001$; reading group × lexicality × item length: $minF'(2,93) = 3.69$, $p < 0.05$).

English dyslexic vs. reading level control children: The means in Fig. 1 show, that for one-syllable words the dyslexic children tended to read faster than the reading level controls while for the corresponding nonwords they were slower. For the other item length levels the dyslexic children showed slower reading times for both words and nonwords than the control group (reading group: item analysis: $F(1,120) = 29.46$, $p < 0.001$; group × lexicality: item analysis $F(1,120) = 8.2$, $p < 0.001$; group × lexicality × item length: item analysis: $F(1,120) = 3.1$, $p < 0.05$, subject analysis: $F(2,58) = 6.0$, $p < 0.01$).

3.1.5. Reading of high- and low-frequency words

To examine the influence of word frequency on reading performance, we selected as high-frequency items 12 words (six one- and six two-syllable words) which were included in Dale's list of 769 best-known words by 8 year olds (Harrison, 1980) and also in a similar German list of the 2000 most used words by 9 and 10 year olds (Bamberger and Vanecek, 1984). None of the three-syllable words could be categorized as being of high frequency according to this criterion, and thus they were excluded from this analysis. Similarly, 12 low-frequency items were selected, which were neither in Dale's list nor in the corresponding German list and additionally had low counts in the Thorndike and Lorge (1944) frequency count. The high- and low-frequency words are marked in Appendix A. Table 2 presents the mean error percentages and reading times for German and English dyslexic and reading level control children.

Inspection of error scores showed that the German dyslexic children read both the high- and the low-frequency words with few errors. In contrast, the English dyslexic children showed an enormous difference with 10% errors for the high-frequency and 50% errors for the low-frequency words. Similar error percentages for high- vs. low-frequency words were shown by the English reading level control children. An ANOVA of the error scores with word frequency and reading group (English dyslexic vs. English reading level control) found neither the group nor the group by frequency interaction reliable, *minF'*s < 1. The English age level control children made no errors at all on the high-frequency words and less than 10% errors on the low-frequency words.

The effect of word frequency on reading time was examined only for the

Table 2
Effects of word frequency

	Errors		Time	
	High frequency	Low frequency	High frequency	Low frequency
German:				
Dyslexic	2%	7%	0.7 s	1.1 s
Reading age controls	0.5%	3%	0.8 s	1.0 s
Age level controls	0.5%	0.5%	0.5 s	0.5 s
English:				
Dyslexic	10%	50%	1.1 s	–
Reading age controls	6%	45%	1.1 s	–
Age level controls	0.4%	8%	0.4 s	0.4 s

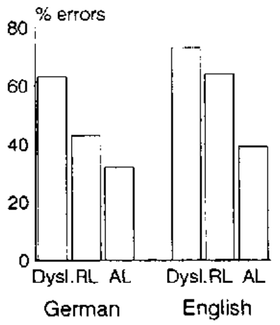

Fig. 2. Mean error percentages for the spoonerism task for German and English dyslexic, reading level and age level control children.

German children, since there were not enough reading time scores for the English dyslexic children to justify statistical analysis. For the German children there was a sizeable effect of frequency on reading time, $t(17) = 5.2$, $p < 0.001$. Quite similar means were found for the reading level control children. However, the age level control children responded equally fast to high- and low-frequency words. The difference between the dyslexic and the age level control children was reliable even for the high-frequency words, $t(34) = 3.1$, $p < 0.001$. This pattern mirrors the pattern observed for the English children using error data.

For an analysis of the high-frequency words there were enough time scores from the English dyslexic children to allow meaningful comparisons. Their mean reading time was found to be slower than the mean of the German dyslexic children ($t(34) = 2.8$, $p = 0.01$) and of the English age level control children ($t(35) = 7.1$, $p < 0.001$). However, as in the case of the German dyslexic children, the English dyslexics did not differ from reading level controls.

3.2. Phonological processing

The results of the spoonerism task are illustrated in Fig. 2. The surprising finding here was that German dyslexic children found this task nearly as difficult as English dyslexic children (63 vs. 73% errors, $t(33) = 1.25$, $p > 0.1$). Both dyslexic groups performed poorer than the corresponding age level control group (German: 32% errors, $t(34) = 4.15$, $p < 0.001$; English: 40% errors, $t(34) = 4.67$, $p < 0.001$). German dyslexic children's performance was even poorer than that of the corresponding reading level control group (43% errors, $t(33) = 2.59$, $p < 0.05$). English reading level control children's performance (65% errors) was almost as poor as that of the English dyslexic children ($t(35) = 1.17$, $p > 0.1$).

4. Discussion

The main finding of the present cross-orthography comparison of developmental dyslexia was that the English dyslexic children suffered from much more severe impairments in reading than the German dyslexic children. The extent of the impairment varied according to the stimuli. For words of high frequency there was relatively little difference. However, for words of low frequency, the percentage of correct readings by English dyslexic children dropped to about 50% and remained as low for the long, three-syllable words, which tended to be also of low frequency. Nonwords posed even more severe problems for the English dyslexic children, despite lenient scoring. Here, the error rate for the three-syllable nonwords climbed to about 70%. In contrast, the German dyslexic children showed very few reading errors. Even for the long, three-syllable words their error rate was only about 10%, and for the three-syllable nonwords their error rate was only about 20%.

The enormous difficulties of the English dyslexic children with word and nonword reading were also reflected in very slow reading speed, for items which were correctly identified. The exceptions were highly familiar words which they presumably were able to recognize without having to rely on piecemeal phonological recoding. Thus, the differences between the English and the German dyslexic children were comparatively small for the short, high-frequency words (1.1 s vs. 0.7 s). For all other conditions, however, the differences were enormous. Even recoding of short one-syllable nonwords was twice as slow for the English dyslexic children (3.5 s vs. 1.4 s). For the few correctly read three-syllable nonwords the English dyslexic children needed as much as 6 s per item, compared to about 3 s for the German dyslexic children. This is not to say that German dyslexic children showed little if any deficits. Both the German and the English dyslexic children were significantly slower than age level control children not only for nonwords, but also for words that could be considered as over-learned, such as short high-frequency words.

The most striking difference between the German and the English dyslexic children—and also between the young German and English reading level control children—emerged in the error rates for rare words and for nonwords, which require phonological recoding. The high error rates in English and also the kind of errors made suggest that the process of phonological recoding itself may be organized differently for German and English children. This different organization of phonological recoding may be triggered by the key orthographic feature distinguishing German and English orthography, namely the difference in the consistency of grapheme–phoneme relations for vowels. Treiman et al. (1995) have demonstrated that in English monosyllabic CVC-words which share the same vowel grapheme, the vowel pronunciation will be consistent in only about 60% of the cases. We hypothesize that the high consistency of the German grapheme–phoneme relations for single vowels allows for the immediate on-line assembly of syllables. Therefore, problems of working memory for unconnected phonemes as well as misleading intrusion from the phonological word lexicon are less likely. For example, for the low-frequency word *Biber*, the reader might produce /bi/-/bib/-/bi-be/-/bi-ber/. Notice that this on-line phonological recoding process involves a re-syllabification from incorrect /bib/ to the correct syllable /bi/.

However, the transcoded phonemes are always included in syllables, and no sequence of isolated phonemes has to be retained in working memory. Furthermore, the number of syllables is usually small, again reducing working memory load. Because of the dependency of vowel pronunciation from graphemic context, no such immediate on-line assembly of syllables can be assumed for English.

The differences in the severity of reading deficits of typical German and English dyslexic children cannot be attributed to visual or phonological/articulatory differences between the English and German word and nonword items, because the same task formats and very similar word and nonword stimuli were used for both groups. Obviously, a quite plausible interpretation of the differences between English and German dyslexic children's reading difficulties is that the English dyslexic children suffered from a more severe form of dyslexia than the German dyslexic children. From the given characteristics of the dyslexic samples alone it is difficult to rule out this possibility. We note, however, that both the German dyslexic children and the English dyslexic children are 4 years delayed in reading development. The other important finding is that on the spoonerism task which measures phonological processing deficits both the German and the English dyslexic children were impaired even in relation to children 4 years younger. For the German dyslexic children the difficulty with the spoonerism task is more surprising than for the English dyslexic children, because the German children had little difficulty with phonological recoding in reading and with phoneme segmentation in nonword spelling[4]. Finally, we can only refer to our long-term experience with German dyslexic children both in research and remediation to justify the claim that the present dyslexic participants are representative of severe cases of dyslexia in the German context. It was already mentioned that besides the consistency of the orthography the reliance on synthetic phonics as the teaching and remediation approach may also be of importance for the observed differences in the manifestation of dyslexia in German and English children.

Our interpretation that the differences in reading difficulties between English and German dyslexic children is due to differences in orthographic consistency is further strengthened by the finding that very much the same differences were also found for the young normal readers. The 8 year-old normal English readers showed much higher error rates than the young German readers. Furthermore, they were more affected by the word–nonword variation and by the increase in item length. Similar differences between young German and young English readers were found previously by Wimmer and Goswami (1994) and Frith et al. (in press). Clearly, these early differences do not persist as the German and the English age level control children aged 11–12 performed at very similar levels. In the case of dyslexia the adverse effect of English orthography remains evident at age 12 and may well persist.

[4] In a spelling task not reported in this study, English and German dyslexic children were asked to spell a subset of the nonwords of the reading task. The German dyslexic children were able to spell 89% of the one-, two- and three-syllable nonwords correctly, while their English counterparts produced correct spellings for only 65% of the nonword items.

One remaining issue is to explain why dyslexic children, if they suffer from an underlying phonological impairment, also show poor reading of high-frequency words and poor orthographic spelling. One explanation is that a good orthographic lexicon is contingent on multiple connections between orthographic and phonological word representation (Ehri, 1992; Perfetti, 1992) and that such multiple connections are less easily established by dyslexic children. The remarkable aspect of this explanation is that a phonological deficit cannot be fully compensated for even by a consistent orthography. Thus, German dyslexic children may successfully recode a frequently occurring word on many occasions, but may still not store the letter sequence of the word, because the letters and the letter clusters do not become connected with the phonemes and the larger segments of the phonological word representation.

At the start of our study we asked whether the phonological deficit account of dyslexia holds for all alphabetic orthographies and to what extent orthographies with opaque grapheme–phoneme relations have an additional adverse effect. The present direct comparison of the reading performance of German and English dyslexic children supports the phonological deficit account. It also demonstrates that the English dyslexic children were at an enormous disadvantage in their struggle to learn to read and write. This is evident in reading accuracy as well as speed. However, the deeper analysis of the reading difficulties of the German children showed that for them too severe impairments arise from a phonological dysfunction. This speed impairment implies a definite handicap relative to their peers and constitutes a barrier to learning from text. We conclude, that despite the superficially less severe manifestation of reading difficulties in German dyslexic children, the underlying neurocognitive deficit is the same.

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Appendix A

Items of the single word/nonword reading task

	Words		Nonwords	
	English	German	English	German
One syllable	ball[a]	Ball	grall	grall
	blind	blind	brind	Brind

	zoo[b]	Zoo	foo	foo
	wolf	Wolf	bolf	Bolf
	hand[a]	Hand	fand	Fand
	post	Post	blost	Blost
	beast[b]	Biest	fleast	Fliest
	yacht	Jacht	cacht	Kacht
	boat	Boot	hoat	Hoot
	bear	Bär	blear	blär
	foul	faul	thoul	Daul
	bush	Busch	swush	Schwusch
	fish	Fisch	bish	Bisch
	young[a]	jung	poung	Pung
	beer[b]	Bier	zeer	zier
	ghost	Geist	swost	Schweist
	dream	Traum	ream	raun
	blood[a]	Blut	bood	But
	wine	Wein	prine	Prein
	plough	Pflug	wough	Wug
	green	grün	dreen	Trün
	book	Buch	frook	Fruch
	flesh	Fleisch	besh	Beisch
	sword[b]	Schwert	ghord	gert
	round	rund	mound	munt
	friend	Freund	biend	Beund
	thief	Dieb	wief	Wieb
	comb[b]	Kamm	plomb	Pflamm
	milk[a]	Milch	bilk	Bilch
	bread[a]	Brot	yead	jot
	prince[b]	Prinz	bince	Binz
	sweat	Schweiß	yeat	Jeiss
Two syllables	butter	Butter	sutter	Sutter
	modern[b]	modern	odern	odern
	dentist	Dentist	hentist	Hentist
	atom	Atom	matom	Matom
	motor	Motor	potor	Potor
	weather	Wetter	meather	metter
	hammer	Hammer	nammer	Nammer
	muscle[b]	Muskel	uscle	Uskel
	doctor[a]	Doktor	soctor	soktor
	brother[a]	Bruder	sother	Schuder
	needle	Nadel	teedle	tatel
	monarch	Monarch	onarch	Onarch
	paper[a]	Papier	maper	Mapier
	nervous	nervös	servous	servös
	hunger	Hunger	gunger	Gunger

	beaver	Biber	meaver	Miber
	summer[a]	Sommer	dummer	Dommer
	sugar	Zucker	brugar	Brucker
	tiger	Tiger	higer	Higer
	echo	Echo	becho	Becho
	silver	Silber	milver	Milber
	mother[a]	Mutter	wother	Wutter
	bishop[b]	Bischof	rishop	Rischof
	ballet[b]	Ballett	lallet	Lallett
	coffee	Kaffee	boffee	Baffee
	salad	Salat	nalad	nalat
	gallop	Galopp	ballop	Balopp
	contour[b]	Kontur	bontour	Bontur
	music[a]	Musik	cusic	Kusik
	oven	Ofen	moven	Mofen
	reptile[b]	Reptil	deptile	Deptil
	leather	Leder	ceather	Keder
Three syllables	radio	Radio	ralective	Ralektiv
	serious	seriös	semater	semater
	paradise	Paradies	pacoble	Pakobel
	guarantee	Garantie	guaroment	Garoment
	electric	elektrisch	edusment	edusment
	theatre	Theater	therigious	therigiös
	positive	positiv	pepratic	Pfefratisch
	stereo	Stereo	sterotee	sterotie
	industry	Industrie	inlio	Inlio
	character	Charakter	chacustre	Chakuster
	elephant	Elefant	elotive	Elotiv
	banana	Banane	barano	Barano
	element	Element	etracty	Etraktät
	tomato	Tomate	tolition	Tolition
	coconut	Kokosnuß	cosimint	Kosiminz
	catalogue	Katlog	caviscope	Kaviskop
	attractive	attraktiv	atledent	atledent
	religious	religiös	renito	renite
	melody	Melodie	mexonut	Mexonuß
	irony	Ironie	inalogue	Inalog
	quality	Qualität	quaductric	quaduktrisch
	position	Position	poracous	Porakös
	peppermint	Pfefferminz	posidise	posidies
	microscope	Mikroskop	mictany	Miktanie
	president	Präsident	predition	Prädition
	uniform	Uniform	usision	Usision
	plausible	plausibel	plauperphant	plauferfant
	parliament	Parlament	parresion	Parresion

production	Produktion	prositry	Prositrie
discussion	Diskussion	disaform	Disaform
exotic	exotisch	eledy	eledie
division	Division	diliana	Dilane

[a] High-frequency word (for both English and German).
[b] Low-frequency word (for both English and German).

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