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Developmental dyslexia in different languages: Language-specific or universal?

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Abstract

Most of the research on developmental dyslexia comes from English-speaking countries. However, there is accumulating evidence that learning to read English is harder than learning to read other European orthographies (Seymour, Aro, & Erskine, 2003). These findings therefore suggest the need to determine whether the main English findings concerning dyslexia can be generalized to other European orthographies, all of which have less irregular spelling-to-sound correspondences than English. To do this, we conducted a study with German- and English-speaking children ($n = 149$) in which we investigated a number of theoretically important marker effects of the reading process. The results clearly show that the similarities between dyslexic readers using different orthographies are far bigger than their differences. That is, dyslexics in both countries exhibit a reading speed deficit, a nonword reading deficit that is greater than their word reading deficit, and an extremely slow and serial phonological decoding mechanism. These problems were of similar size across orthographies and persisted even with respect to younger readers that were at the same reading level. Both groups showed that they could process larger orthographic units. However, the use of this information to supplement grapheme–phoneme decoding was not fully efficient for the English dyslexics.

Keywords: Developmental dyslexia; Phonological deficit; Reading; Length effect; Cross-language research

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Introduction

Children affected with developmental dyslexia have difficulty learning to read and spell despite adequate intelligence and educational opportunity, and in the absence of any profound sensory or neurological impairment. Dyslexia is the most common of the childhood learning disorders.

Much of what we know about the nature and the origin of developmental dyslexia comes from studies that were conducted in English-speaking countries. A simple check in the Medline database (http://www.ncbi.nlm.nih.gov) shows that about two-thirds of all publications on developmental dyslexia since 1998 have came out of English-speaking countries (US, UK, Australia, Canada, and New Zealand). Given the dominance of research using the English language, it is of great importance to know whether dyslexia is the same in countries that use different languages. The ideal research design would be to give dyslexic children who are learning to read different languages the *same* reading tests with highly comparable linguistic material while also ensuring that participants had been matched for other potentially important variables such as age, vocabulary development, and general intellectual ability. Unfortunately, only very few studies have met these strict criteria (e.g., Landerl, Wimmer, & Frith, 1997a; Paulesu et al., 2001) and they produced slightly conflicting results. The neuroimaging studies suggest a universal basis for dyslexia (Paulesu et al., 2001), whereas the behavioral studies suggest that the nature and prevalence of dyslexia might differ between orthographies (Landerl et al., 1997a).

As concerns the origin of developmental dyslexia, the most unifying hypothesis suggests that dyslexic children have specific impairments in representing, storing, and retrieving phonological information (i.e., the *phonological deficit hypothesis*, see Ramus, 2003; Snowling, 2000; Wagner & Torgeson, 1987). Because reading acquisition requires the child to learn the mapping between orthography and phonology (Jorm, Share, MacLean, & Matthews, 1984; Share, 1995), problems in the representation and use of phonological information inevitably lead to problems in reading acquisition (e.g., Bradley & Bryant, 1983; Bryant & Bradley, 1985; Goswami & Bryant, 1990). The phonological deficit hypothesis is supported by a number of studies showing that dyslexics have difficulties in tasks requiring verbal short-term memory, phonological awareness, phonological recoding, and rapid automatized naming (e.g., Brady & Shankweiler, 1991; Denckla & Rudel, 1976; Rack, Snowling, & Olson, 1992). Although it is still a matter of debate whether the phonological deficit can be reduced to a more low-level sensory deficit (e.g., Goswami et al., 2002; Helenius, Uutela, & Hari, 1999; Manis et al., 1997; Marshall, Snowling, & Bailey, 2001; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998a, 1998b; Serniclaes, Sprenger-Charolles, Carré, & Demonet, 2001; Tallal, 1980), it seems quite clear that any theory of dyslexia needs to account for the robust phonological deficits that are present in most dyslexics (Ramus, 2001, 2003; Ramus et al., 2003). A universal theory of dyslexia predicts that phonological deficits are very similar for dyslexics in different countries, an argument that we discuss further subsequently.

Reading acquisition in different countries

An accumulating number of studies suggest that learning to read English is harder, and possibly qualitatively different, from learning to read other European orthographies (Goswami, Gombert, & Fraca de Barrera, 1998; Goswami, Porpodas, & Weelwright, 1997; Goswami, Ziegler, Dalton, & Schneider, 2001, 2003; Oney & Goldman, 1984; Porpodas, 1999; Thorstad, 1991). Most strikingly, in a collaborative effort, a group of European scientists[1] compared word and nonword reading performance after the first year of reading instruction across 13 European countries (for a description of the results, see Seymour et al., 2003). They showed that word and nonword reading accuracy was only about 40% for English children at the end of grade 1. In contrast, word reading accuracy in most other European orthographies was close to ceiling (about 95%, with the exception of France and Denmark, which were about 75%). Similarly, nonword reading accuracy was quite high in all European orthographies (about 90%, with the exception of Denmark, 53%, and Portugal, 76%). These results suggest that English children have specific reading difficulties, a finding that raises doubts about whether studies of dyslexia predominantly conducted in English can be easily generalized to other orthographies.

It is commonly accepted that the main reason for the delay of the English-speaking children lies in the irregularity (inconsistency) of the writing system (e.g., Frith, Wimmer, & Landerl, 1998). English, in comparison to all other European orthographies, such as Italian, Spanish, German, Greek, or Turkish, has a much more inconsistent mapping between spelling and sound. That is, in English the same spelling patterns can often be pronounced in multiple ways (e.g., compare the pronunciation of -*ough* in *cough*, *bough*, *tough*, *through*, and *dough*, see Ziegler, Stone, & Jacobs, 1997).

One of the strongest cross-language comparisons is between German and English. Because of their common Germanic origin, both languages have a very similar orthography and phonology but they differ with respect to how consistently units of spelling map onto units of sound (Ziegler, Perry, & Coltheart, 2000). The German–English comparison has been used in a number of studies to investigate reading development and skilled reading comparing regular with less regular writing systems (Frith et al., 1998; Goswami et al., 2001, 2003; Wimmer & Goswami, 1994; Ziegler, Perry, Jacobs, & Braun, 2001). One of the key findings of this cross-language research is that children learning to read a regular orthography rely to a greater extent on grapheme–phoneme decoding whereas children in English-speaking countries supplement grapheme–phoneme decoding by rhyme and whole word strategies

[1] National representatives of the COST Action were: H. Wimmer, T. Reinelt (Austria), J. Alegria, J. Morais (Belgium), C. Elbro, E. Arnbak (Denmark), H. Lyytinen, P. Niemi (Finland), J.-E. Gombert, M.-T. Le Normand, L. Sprenger-Charolles, S. Valdois (France), A. Warnke, W. Schneider (Germany), C. Porpodas (Greece), V. Csepe (Hungary), H. Ragnarsdottir (Iceland), C. Cornoldi, P. Giovanardi Rossi, C. Vio, A. Parmeggiani (Italy), C. Firman (Malta), R. Licht, A.M.B. De Groot (Netherlands), F.-E. Tonnessen (Norway), L. Castro, L. Cary (Portugal), S. Defior, F. Martos, J. Sainz, X. Angerri (Spain), S. Stromqvist, A. Olofsson (Sweden), P. Seymour, P. Bryant, U. Goswami (UK).

(e.g., Goswami et al., 2001, 2003). Thus, there are not only quantitative but also qualitative differences in the way English children and children using other languages learn to read.

Developmental dyslexia in different countries

A number of studies have investigated dyslexia in different countries. However, most of them used a monolingual research design; that is, they did not compare performance of dyslexics from different countries on identical tasks and stimulus material. Taking the English orthography first, virtually all the monolingual research studies have found a nonword reading deficit in dyslexic children compared to *both* reading level and control age (CA) matched children (for a review, see Rack et al., 1992). This nonword reading deficit is particularly marked when the nonwords were constructed to be dissimilar to real words (e.g., 'tegwop,' 'twamket,' Snowling, 1980). Rack et al. (1992) noted that English studies that did not find a nonword reading deficit in dyslexia in comparison to a reading level match typically used young readers (7 years) as controls, and used nonwords with relatively familiar orthographic patterns. However, a quantitative meta-analysis using the same database showed that differences in age, intelligence, and word recognition ability were more important than the type of nonwords used (Van Ijzendoorn & Bus, 1994).

A number of monolingual studies from different countries seem to support the existence of a phonological decoding deficit in consistent orthographies. For example, Porpodas (1999) found that Greek dyslexic children read 93% of the nonwords correctly, compared to 97% for the CA controls (a significant difference). Dyslexic children in France read about 75% of nonwords correctly compared to 90% for the CA controls (Sprenger-Charolles, Cole, Lacert, & Serniclaes, 2000). Finally, Dutch dyslexic fourth-graders showed marked nonword reading deficits both in comparison to CA and reading level controls (Van der Leij, Van Daal, & De Jong, 2002).

The problem with monolingual studies is that they can tell us only very little about the degree of comparability between the different orthographies. For this purpose, cross-language studies on developmental dyslexia are particularly important. One of the rare cross-language studies was carried out by Landerl et al. (1997a). They employed the German–English comparison to investigate whether the nature and prevalence of developmental dyslexia differed between consistent and less consistent orthographies. In their study, Landerl et al. (1997a) asked German and English dyslexics and controls to read aloud words and nonwords. Both words and nonwords were very similar in terms of orthography, phonology, and meaning across the two orthographies (e.g., words: *bear-Bär*, *yacht-Jacht*, *fish-Fisch*, etc.; nonwords: *blear-Blär*, *cacht-Kacht*, and *bish-Bisch*). Their main finding was that English dyslexics suffered from much more severe reading impairments in both word and nonword reading than the German dyslexics, with their nonword reading deficit being much greater than their word reading deficit. For example, despite a lenient error scoring method, the English dyslexics had an error rate of around 70% on three-syllable nonwords. In contrast, the error rate of the German dyslexics was only 20% on the same stimulus group. The enormous difficulties the English dyslexics had with word and nonword reading were also reflected in a very slow reading speed. This was true even for short monosyllabic nonwords, which the English dyslexics read twice as slowly as the German dyslexics.

Although the conclusion that dyslexia is more severe in English-speaking countries fits the developmental data suggesting that reading acquisition is harder in English-speaking countries, there are three serious limitations of the Landerl et al. (1997a) study. First, the poor reading performance of the English children might have been amplified in their study by the inclusion of an exceptionally large number of words that were irregular in English but not in German (e.g., *bear*, *wolf*, *yacht*, *sword*, *comb*). Given that these irregular words produce regularization errors and strong latency costs even for skilled adult readers (e.g., Baron & Strawson, 1976; Seidenberg, Waters, Barnes, & Tanenhaus, 1984; Ziegler, Perry, & Coltheart, in press), it could be problematic to include too many of these items in a cross-language comparison. Similarly, given that the nonwords were derived from the real words, some of the nonwords contained particularly inconsistent correspondences, which again might contribute to the more severe impairment of the English children.

Second, many authors have suggested that reading speed is more critical than accuracy when regular and irregular orthographies are compared (e.g. De Jong, 2003; De Jong & van der Leij, 2003; Sprenger-Charolles et al., 2000; Wimmer, 1993). It should be noted that Landerl et al. (1997a) did in fact measure reading speed of the children. However, they did so by having the children press a mouse button as soon as they *knew* the pronunciation. This is only a coarse estimation of reading speed. For example, such a procedure would not be sensitive enough to detect a speed deficit in rapid automatized naming. Furthermore, this mode of responding might be contaminated by decision and response criterion effects.

Third, and most importantly, although absolute differences in accuracy and speed between languages are certainly intriguing, they give little insight into the processes underlying reading deficits. To gain further insight into the processes underlying reading, the strategy of the present study was to go beyond absolute levels of accuracy or speed by considering *marker effects* of the underlying reading process.

Goal of the present study

The goal of the present study was to investigate reading characteristics of dyslexic children in regular and less regular orthographies. In particular, we wanted to test whether the English orthography amplifies phonological decoding difficulties, as suggested by Landerl et al. (1997a). More generally, because two-thirds of all studies on dyslexia have been done in English, it is important to know whether these results can be generalized to more regular orthographies. To study whether reading-related deficits are comparable across orthographies, it is necessary to consider theoretically critical marker effects of the reading process, such as effects of lexicality, length, and large orthographic units.

The *lexicality effect* (difference in word and nonword reading) allowed us to investigate whether the phonological decoding deficit was similar across languages. A phonological decoding deficit is indicated when the difference between nonword and word reading is relatively bigger in dyslexics than in controls. The *length effect* allowed us to investigate to what extent phonological decoding processes operate in a serial manner. That is, the greater the length effect, the more people rely on serial decoding strategies (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Weekes, 1997). Finally, *large-unit effects* were used to investigate whether dyslexics were able to efficiently process larger orthographic units. This is an important test because it could be that dyslexics must rely on low-level phonological decoding because they cannot process larger orthographic units. As a marker effect for large-unit processing, we used *body neighborhood effects* (Ziegler & Perry, 1998). Body neighbors are words that share the same *orthographic rime* (i.e., *body*), such as *street*, *meet*, *feet*. It has been found that large body neighborhoods facilitate word and nonword reading, especially for English-speaking readers (Ziegler et al., 2001).

In the present study, the relative size of these marker effects was investigated in a German and an English population of dyslexic children. Performance of dyslexic children was compared to that of two control groups, one matched on chronological age and one matched on reading age. The reading-age match is important to exclude the possibility that a given deficit is simply a consequence of the poorer reading experience of dyslexic children (developmental delay). Alternatively, a deficit that persists in comparison to a group of younger children of the same reading age as the dyslexic children is likely to reflect a fundamental deviation from normal reading processes. As in the Landerl et al. study (1997a), we used the German/English comparison because identical stimulus material can be used across different orthographies. In addition, we measured reaction times (RTs) for each item and each participant using a voice key system that allowed us to digitally record all responses.

Method

Participants

Forty-nine dyslexic children participated in this study, 30 from an English-speaking population and 19 from a German speaking population. The English dyslexic children were recruited from a dyslexia center in Sydney, Australia. About half of them came to the dyslexia center for a one-day assessment. The other half was tested at the beginning of a short-term remediation program. The German dyslexic children were recruited from the Department of Child and Adolescent Psychiatry of the University Hospital, Marburg, Germany. Testing of these children was part of a one-day assessment. The English and German children were native speakers of their respective languages.

To qualify for the study, the children in both countries had to fall within the age range 9–13 years, attain an IQ score of 85 or above on the Wechsler Intelligence Scale for Children (WISC-III), and a reading score at or below the 25th percentile on standardized reading tests. For the assessment of the reading level in Australia, we used the *Woodcock Word Identification Subtest* (Woodcock, 1989). Reading level in Germany was assessed with the word reading subtest of the *Salzburger Reading and Spelling Test* (SLRT, Landerl, Wimmer, & Moser, 1997b). The Woodcock

Table 1
Characteristics of dyslexics, chronological-age controls and reading-level controls

	N	Age	Range	*SD*	RA	Range	*SD*
Australia							
Dyslexics	30 (22 male)	10;9	9;0–12;1	0.85	7;6	6;7–8;7	0.49
CA-controls	35 (17 male)	10;9	9;0–12;3	0.92	11;9	9;0–14;5	1.82
RL-controls	16 (6 male)	8;4	7;3–9;3	0.45	8;2	7;1–8;9	0.61
Germany							
Dyslexics	19 (13 male)	10;4	9;5–11;6	0.43	7;6	6;6–8;6	0.53
CA-controls	29 (15 male)	10;4	9:2–11;1	0.43	10;6	9;6–11;0	0.55
RL-controls	20 (11 male)	7;9	6;4–8;6	0.61	7;6	6;6–8;6	0.71

Note. *N*, Number of participants; *SD*, standard deviation; RA, reading age; RL, reading level.

reading test is based on accuracy data. The SLRT takes accuracy and reading speed into account. Reading performance of dyslexic children in both countries was on average three years behind that of their peers. Reading age rather than standard scores was used to match the dyslexic children in the two countries because the SLRT does not provide standard scores.

In both countries, two control groups were tested, one that was matched on chronological age (CA) and one that was matched on reading level. The reading age of the German CA group was slightly lower than that of the English CA group. However, it is likely that we underestimated the reading age of the CA controls because the SLRT provides reading ages only up to fourth grade. Thus, the reading age scores for some of the German high achievers were truncated to a reading age that would correspond to fifth grade. Because of time constraints imposed by the school, no IQ data could be obtained for these controls. All these children were native speakers of their respective languages and had no history of reading problems. Characteristics of the participants are shown in Table 1.

Design and material

The experimental conditions were created from a factorial combination of Language (English vs. German), Stimulus Length (three, four, five, and six letters), Body-N (large vs. small), and Lexicality (words vs. nonwords). Stimulus selection was based on the CELEX database, which exists for both German and English (Baayen, Piepenbrock, & van Rijn, 1993). In a first run, all German/English *cognates* were selected from the CELEX database. Cognates are words with identical meaning and similar orthography and phonology in two languages (e.g., *zoo* in English vs. *Zoo* in German). Pairs were then considered for further selection if: (1) both words were monosyllabic; (2) both words had regular grapheme–phoneme correspondences; (3) both words had the same number of letters; and (4) both words belonged to the same body-N class (either large or small).

These constraints resulted in the selection of 80 monosyllabic German/English word pairs. All items are listed in Appendix. Half ($n = 40$) had a small body neighborhood

(3.3 and 4.3 body-Ns for German and English, respectively), and half had a large body neighborhood (9.8 and 13.2 body-Ns for German and English, respectively). Each word pair belonged to one of four orthographic length groups (3, 4, 5, and 6 letters) with an equal number of items per group ($n = 20$). The stimuli in the two language groups were matched in terms of number of phonemes, and hence number of grapheme–phoneme correspondences (3.7 vs. 3.6 phonemes). For the six letter words, it was not possible to find monosyllabic German/English cognates. We therefore used words with comparable word frequencies that were orthographically and phonologically similar in the two languages (e.g., *flight*/*Frucht*). Mean word frequency was 192 per million for the German items and 191 per million for the English items. Word frequencies were taken from the CELEX database. Note that word frequencies greater than 1000 per million were truncated to this cut-off value. Word frequencies were matched in each cell of the experimental design.

The nonword manipulation paralleled the word manipulation. That is, 80 nonwords were used in each language. Nonwords were mainly identical across the two languages (*fot*/*Fot*, *lank*/*Lank*, *plock*/*Plock*, etc.). When this was not possible because of body-N constraints, we made sure that they were orthographically and phonologically as similar as possible (e.g., *ler*/*Lir*, *sibe*/*Seib*, *meast*/*Miest*, etc). Half of the nonwords ($n = 40$) had a small body neighborhood (2.5 and 2.9 body-Ns for German and English, respectively); and half had a large body neighborhood (8.5 and 10.9 body-Ns for German and English, respectively). Each cell in the design contained an identical number of items.

Procedure

In both countries, dyslexic children and control children were tested individually in a quiet room. Each session started with the reading aloud task and finished with the administration of the standardized reading tests. For the dyslexic children, the administration of reading and IQ tests was not part of the experimental session but had been completed shortly before the experiment by staff of the dyslexia centers.

For the reading aloud task, items were presented visually in the center of a computer monitor. Words and nonwords were mixed within a single block. The order of presentation was randomized for each participant. Inter-stimulus interval was six seconds for the dyslexics and reading level controls, and three seconds for the CA controls. The same typography and font size was used in the two countries. Participants were asked to read aloud the stimuli as quickly as possible. In both countries, the same software was used to control the experiment and to collect naming responses. This software recorded each response as a digital sound file.

Results

For each response of each participant, RTs were calculated from the onset of the stimulus until the onset of the response. This was initially done via a computer algorithm, but each response was also checked off-line using digital sound files that were recorded for each response of each child. Only RTs of correct responses were used to calculate the RT means. Errors were scored off-line. For error coding of nonwords, all phonologically plausible responses were considered correct, even if they did not respect the most frequent grapheme–phoneme correspondences (e.g., *voop* would be considered correct if the "oo"-correspondence was pronounced either long, /u/, or short, /ʊ/). Thus, as in previous cross-language studies (e.g., Frith et al., 1998; Landerl et al., 1997a), a lenient error coding criterion was adopted.

The presentation of the results is organized into five sections, which correspond to the main questions of the study: (1) Are there global differences in reading speed and accuracy between dyslexics and controls across languages? (2) Is the phonological deficit specific to English children? (3) Do dyslexics show stronger length effects than controls, and if so, does the size of this effect differ across languages? (4) Do dyslexics have problems in the processing of larger orthographic units? (5) Can large-unit processing compensate for small-unit decoding deficits?

The results were analyzed using analyses of variance (ANOVAs) with Group (Dyslexics vs. CA controls vs. reading level controls), Language (German vs. English), Length (three, four, five, and six), Body-N (high vs. low), and Lexicality (words vs. nonwords) as factors. Two additional sets of ANOVAs were performed, one for the comparison between dyslexics and CA controls, and one for the comparison between dyslexics and reading level controls. Instead of presenting a long list of main effects and interactions, we organize the presentation of the statistical results according to the five sections described above.

Global reading speed and accuracy

Means and effect sizes for reading speed and accuracy of dyslexics and controls in Germany and Australia are given in Table 2. The global ANOVA showed a significant main effect of Language both for RTs, $F(1, 141) = 13.0$, $p < .001$, and errors,

Table 2
Reading speed and accuracy for dyslexics, chronological age, and reading level controls in Australia and Germany

		RTs (ms)		Accuracy (% errors)	
		Australia	Germany	Australia	Germany
Groups	Dyslexic	2209	1829	38.3	14.3
	RL	1823	1431	36.9	16.7
	CA	911	821	10.5	6.4
Effect sizes	Dyslexic-RL	386*	398*	1.4	−2.4
	Dyslexic-CA	1299*	1008*	27.7*	7.9*
Effect sizes (*z* scores[a])	Dyslexic-RL	0.4	0.6	0.0	−0.1
	Dyslexic-CA	2.1	2.3	1.2	0.6

Note. Asterisks indicate significant group differences ($p < .05$).
[a] *z* scores were derived from the group differences expressed in standard deviation units using pooled SDs.

$F(1, 141) = 51.0$, $p < .0001$, indicating that the German children were generally faster and more accurate than the English children.

Dyslexics vs. CA controls

In terms of reading speed, there was a significant difference between dyslexics and CA controls, $F(1, 105) = 198.3$, $p < .0001$. The interaction between Language and Group, however, failed to reach significance. In terms of accuracy, dyslexics made significantly more errors than CA controls, $F(1, 107) = 53.1$, $p < .0001$. The interaction between Language and Group was significant, $F(1, 107) = 16.5$, $p < .0001$, indicating that English dyslexics made relatively more errors than German dyslexics in comparison with their respective controls.

Dyslexics vs. reading level controls

In terms of reading speed, there was a significant difference between dyslexics and reading level controls, $F(1, 77) = 8.7$, $p < .005$. The interaction between Language and Group was not significant, $F < 1$. In terms of accuracy, dyslexics were not significantly different from reading level controls, $F < 1$. The interaction between Language and Group was not significant, $F < 1$.

Summary

The results showed significant speed differences between dyslexics and controls. The speed impairment was not significantly different across languages as indicated by the absence of a significant Language by Group interaction. If effect sizes are expressed in *z* scores (see Table 2), the speed impairment was numerically even stronger in German than in English. In terms of error rates, English dyslexics made more errors than German dyslexics, as indicated by the significant Language by Group interaction. Because dyslexics were matched to reading level controls, we did not expect major differences between these two groups with regard to overall performance. Indeed, dyslexics in both countries were not different from reading level controls in terms of error rates. However, significant differences were obtained for reading speed. Note, however, that dyslexics and reading level controls were matched on the basis of *word* reading. To the extent that overall performance comprises both word and nonword reading, it is likely that the significant speed differences reflect difficulties in nonword reading rather than inadequate selection procedures of the reading level controls.

Nonword reading deficit

Average reading speed and accuracy for word and nonword reading is presented in Table 3. The size of the phonological decoding deficit can be estimated by comparing the difference between word and nonword reading (i.e., the lexicality effect) across different groups of readers. The global ANOVA showed significant main effects of Lexicality on both RTs, $F(1, 141) = 384.3$, $p < .0001$, and errors, $F(1, 141) = 288.6$, $p < .0001$. This main effect indicates that words were read faster and more accurately than nonwords.

Dyslexics vs. CA controls

The latency data exhibited a strong effect of Lexicality, $F(1,107) = 269.7$, $p < .0001$, an interaction between Lexicality and Group, $F(1,107) = 110.1$, $p < .0001$, and an interaction between Lexicality and Language, $F(1,107) = 6.8$, $p < .01$. Most importantly, the triple interaction between the effects of Lexicality, Group, and Language was not significant, $p > .20$. The main effect of Lexicality reflects the fact that words were read faster than nonwords by both groups of readers. The interaction between Lexicality and Group confirms that dyslexics were generally slower in nonword reading than CA controls. The interaction of Lexicality and Language suggests that the word-nonword difference for both groups of readers was stronger in English than in German. However, the absence of the triple interaction suggests that the nonword reading deficit of the dyslexic children was not different across languages. In fact, if the corresponding z scores are considered (see Table 3), the nonword reading deficit of the German dyslexics was very similar to that of the English dyslexics (1.35 vs. 1.27, respectively).

The error data mirrored the RT data with significant effects of Lexicality, $F(1,107) = 196.2$, $p < .0001$, significant interactions between Lexicality and Language, $F(1,107) = 27.1$, $p < .0001$, and significant interactions between Lexicality and Group, $F(1,107) = 41.1$, $p < .0001$. Most importantly, there was no hint of a triple interaction between the effects of Group, Lexicality, and Language, $F < 1$, suggesting again that the nonword reading deficit of the English dyslexics was not quantitatively different from that of the German dyslexics (13.9% vs. 11.8%).

Table 3
Latencies and accuracy for word and nonword reading

Length	Australia			Germany		
	Dys	RL	CA	Dys	RL	CAs
Latencies						
Words	1746	1513	806	1490	1277	749
Nonwords	2673	2133	1015	2168	1585	894
Effect size[a]	927*	621*	209*	678*	308*	145*
Dyslexic-RL	307* (0.35)	—	—	370* (0.59)	—	—
Dyslexic-CA	719* (1.27)	—	—	533* (1.35)	—	—
Error rates						
Words	25.2	23.7	4.4	6.9	11.7	4.9
Nonwords	51.4	50.1	16.7	21.6	21.7	7.8
Effect size[a]	26.2*	26.5*	12.3*	14.7*	10.0*	2.9
Dyslexic-RL	−0.3 (−0.01)	—	—	4.7 (0.28)	—	—
Dyslexic-CA	13.9* (0.65)	—	—	11.8* (0.93)	—	—

Note. Asterisks indicate significant differences ($p < .05$).

z scores (in parentheses) were derived from the group differences in effect sizes expressed in *SD* units using pooled *SD*s.

[a] Effect size = nonword/word difference.

Dyslexics vs. reading level controls

The latency data exhibited a main effect of Lexicality, $F(1,79) = 212.0$, $p < .0001$, an interaction between Lexicality and Group, $F(1,79) = 15.1$, $p < .001$, and an interaction between Lexicality and Language, $F(1,79) = 10.4$, $p < .01$. As with analyses involving CA controls, there was no significant interaction between the effects of Lexicality, Group, and Language, $F < 1$. That is, the nonword reading deficit was present for dyslexics in both countries (as indicated by the Lexicality by Group interaction), but the deficit was of similar size across orthographies.

In terms of error rates, we obtained a different pattern, with the critical Lexicality by Group interaction not being significant, $F < 1$. This suggests that, in terms of reading accuracy, the nonword decoding deficit was not greater for dyslexics than for reading level controls. This is also reflected in the effect sizes. The nonword reading deficit of the English dyslexics was even smaller than that of the controls (−0.3%). The triple interaction between Lexicality, Group, and Language also failed to reach significance, $F < 1.2$, confirming the absence of a nonword decoding deficit on error rates in both orthographies (z scores: 0.28 vs. −0.01, for German and English, respectively).

Summary

With regard to reading speed, the data showed that dyslexic children in both countries exhibited a robust nonword reading deficit. The deficit persisted in both countries even in the comparison with the reading level children. The size of the nonword reading deficit did not differ across orthographies. The error data showed the same pattern but only in the CA comparison. In the reading level comparison, the nonword reading deficit was not apparent. The absence of a nonword reading deficit for accuracy seems to stand in contrast to most English studies showing reliable nonword reading deficits even in comparison with a reading level group. However, this does not mean that that our dyslexics were not seriously reading disabled. It is more likely due to the fact that we employed very simple monosyllabic words and nonwords. In contrast, many of the English studies that found a nonword reading deficit in the reading level comparison used nonwords that were constructed to be dissimilar to real words (e.g., 'tegwop,' 'twamket,' Snowling, 1980). Also, a number of English studies that failed to find a nonword reading deficit in the reading level comparison used young readers (7 years) as controls (see Rack et al., 1992), and this applies to the present study as well.

Length effects

The global ANOVA showed a strong length effect both on RTs, $F(3,423) = 204.3$, $p < .0001$, and errors, $F(3,423) = 159.3$, $p < .0001$. More importantly, there was a Length by Group interaction on RTs, $F(6,423) = 48.9$, $p < .0001$, and errors, $F(6,423) = 15.3$, $p < .0001$, suggesting that there were significant differences in the size of the length effect between different groups of readers. Length effects as a function of language and group are presented in Table 4. Word and nonword data were collapsed in Table 4, because the ANOVA showed no significant interaction between Lexicality and Length, $F < 1$, or between Lexicality, Length,

Table 4
Length effects in reading (words and nonwords) for different groups of readers in Australia and Germany

	Australia			Germany		
	Dys	RL	CA	Dys	RL	CA
Latencies (ms)						
3	1679	1503	834	1341	1208	770
4	2050	1747	899	1728	1373	822
5	2358	1878	908	1988	1463	835
6	2751	2164	1002	2261	1680	857
Effect size[a]	352*	212*	51*	302*	151*	27*
Dyslexic-RL	141*	—	—	151*	—	—
Dyslexic-CA	301*	—	—	275*	—	—
Error rates (%)						
3	24.0	20.1	6.6	7.7	5.2	1.1
4	37.2	33.9	10.9	13.5	14.1	3.8
5	37.8	40.8	10.9	13.5	21.1	8.6
6	54.1	52.7	13.7	22.5	26.4	12.0
Effect size[a]	9.1*	10.5*	2.1*	4.4*	7.0*	3.7*
Dyslexic-RL	−1.4	—	—	−2.6*	—	—
Dyslexic-CA	7.0*	—	—	0.7	—	—

Note. Asterisks indicate significant differences ($p < .05$).
[a] Effect size = slope of the linear regression. i.e., costs per additional letter.

and Group, $F < 1$. In other words, the length effect itself was not modulated by word/nonword status. Although the length effect differed in size across groups, it is worth noting that separate ANOVAs for each group showed that the length effect was nevertheless significant in each group, all p's $< .001$.

Dyslexics vs. CA controls

The ANOVAs exhibited the critical Group by Length interaction both on RTs, $F(3, 321) = 110.0$, $p < .0001$, and errors, $F(3, 321) = 16.9$, $p < .0001$, confirming that dyslexic children showed greater length effects in reading than normal readers. On average, the costs per additional letter (as estimated by the slopes of a linear regression) were between 300 and 350 ms for dyslexics compared to 30–50 ms for CA controls. As mentioned above, this pattern was similar for words and nonwords, as indicated by the absence of an interaction with Lexicality ($F < 1$). With regard to reading speed, the length impairment of the English dyslexics was not significantly different from that of the German dyslexics, as indicated by the absence of an interaction between the effects of Length, Group, and Language, $F < 1$. However, English dyslexics showed a greater impairment than German dyslexics with regard to errors, $F(3, 321) = 8.87$, $p < .0001$.

Dyslexics vs. reading level controls

With regard to reading speed, the critical Group by Length interaction was significant, $F(3, 237) = 11.9$, $p < .0001$, which indicates that dyslexic children showed greater length effects even in comparison to younger readers of the same reading level. The costs per additional letter were still twice as large for dyslexics compared to reading level controls (see Table 4 for exact values). However, in terms of accuracy, dyslexics did not show greater length effects than controls. In fact, the opposite was the case. Dyslexics in both countries showed slightly smaller length effects than reading level controls, which is the opposite of what one would expect. With regard to the cross-language comparison, the presence of a length impairment for speed but also the absence of such an effect for accuracy was similar across orthographies, as indicated by the absence of a triple interaction between Group, Length and Language, both F's < 1.

Summary

In terms of reading speed, dyslexic children in both countries showed a strong length effect. The length effect was up to 11 times greater for the dyslexics than for CA controls, and the length effect was still twice as large for dyslexics than for reading level controls. Although longer words generally produced more errors than shorter words, there was no length-specific deficit for dyslexics with regard to error rates when performance was compared to reading level controls. The English dyslexics but not the German dyslexics showed a length-specific deficit on errors but only when compared to CA controls.

A pattern of particular interest in the results was the absence of an interaction between Length and Lexicality, which reflects the fact that length effects were of a similar size for both words and nonwords. This is different from what is found with adults, where length effects are typically stronger for nonwords than for words (Weekes, 1997). The adult data pattern is consistent with the idea that words as opposed to nonwords benefit from direct parallel orthographic access, whereas nonwords need to be phonologically decoded in a serial fashion (Coltheart et al., 2001). The absence of such an interaction in our study suggests that, in children's reading, words cannot yet benefit from direct parallel orthographic access. Instead, both words and nonwords are probably submitted to a similar serial decoding mechanism.

Before accepting this interpretation, however, we need to make sure that the length effects were not simply due to the fact that the longer words were more likely to contain complex onsets (e.g., *prince*, *strict*) than the shorter words. Indeed, because we only employed monosyllabic words, it was not possible to avoid having the longer words start with more complex onsets than the shorter words. To address the possibility that length effects could have been due to onset complexity, we ran a post-hoc analysis excluding all items with complex onsets. The results showed that the length effect for dyslexics was still highly significant once items with complex onsets were excluded ($p < .0001$). However, the resulting length effect was smaller in size. The slope for the English dyslexics was reduced from 352 ms per letter to 207 ms; the slope for the German dyslexics was reduced from 302 ms per letter to 202 ms. Thus, although onset complexity cannot fully account for the greater length effects found with dyslexics, it is certainly a factor that amplifies difficulties with longer words.

Body N effects

Reading latencies and errors are presented in Table 5 as a function of body N. The global ANOVA showed significant main effects of Body N on both RTs, $F(1,141) = 36.1,\ p < .0001$, and errors, $F(1,141) = 106.3,\ p < .0001$. This main effect indicates that items with many body neighbors were named faster and more accurately than items with few body neighbors. In general, body N effects were stronger for nonwords than for words, $F(1,141) = 4.25,\ p < .05$, and $F(1,141) = 15.0,\ p < .001$, for RTs and errors, respectively. However, because this word/nonword effect did not interact with Group, Language, or Language and Group (all F's < 1), we collapsed word/nonword data in order to simplify data presentation. The Body N by Language interaction was significant on RTs, $F(1,141) = 8.7$, $p < .01$, and errors, $F(1,141) = 10.9,\ p < .001$, reflecting the fact that body N effects were stronger in English than in German. Contrast analyses showed that body N effects were still significant in each of the German groups (see Table 5). Finally, there was no significant interaction between Body N and Group and between Body N, Group, and Language ($p > .10$), suggesting that different groups of readers showed similar body N effects.

Dyslexics vs. CA controls

The main effect of body N was significant on both RTs and errors, all p's $< .0001$. The interaction between Body N and Group was marginally significant in the RT analysis, $F(1,107) = 3.0$, $p < .10$, and significant in the error analysis, $F(1,107) = 19.8,\ p < .001$. This interaction reflects the fact that the dyslexics showed stronger facilitatory body N effects than the CA controls. The triple interaction between Body N, Group, and Language failed to reach significance, which suggests that the pattern of body N facilitation for dyslexics vs. CA controls was fairly similar across languages.

Table 5
Latencies and accuracy for items with many body neighbors vs. items with few body neighbors

	Australia			Germany		
	Dys	RL	CA	Dys	RL	CA
Latencies (ms)						
Few body N	2266	1925	939	1858	1454	834
Many body N	2153	1721	882	1800	1409	809
Effect size[a]	114*	205*	57*	58*	45*	25*
z scores	0.11	0.22	0.16	0.07	0.08	0.13
Error rates (%)						
Few body N	44.2	40.7	12.3	16.8	19.3	7.3
Many body N	32.3	33.0	8.7	11.8	14.1	5.5
Effect size[a]	11.9*	7.7*	3.6*	4.9*	5.2*	1.8*
z scores	0.39	0.24	0.20	0.28	0.30	0.16

Note. Asterisks indicate significant differences ($p < .05$).
[a] Effect size = "Few body N" minus "many body N".

Dyslexics vs. reading level controls

This comparison again showed that there were significant body N effects on both RTs and errors, all p's $< .0001$. More importantly, the Body N by Group interaction was not significant, all F's < 1.3, suggesting that facilitatory body N effects were similar for dyslexics and controls. Furthermore, this pattern was similar across languages as indicated by the absence of the triple interaction between the effects of Body N, Group, and Language, all F's < 1.7.

Summary

The data showed that the facilitatory body N effects were as large for dyslexics as they were for reading level controls. Dyslexics showed even greater levels of facilitation than CA controls. Body N effects were numerically larger in English than in German, and they were larger in nonwords than in words. However, none of these effects interacted with Group, suggesting that the facilitatory pattern in each language was stable across different groups of readers.

Body N by length interaction

The previous section showed normal body N effects in dyslexics compared to their controls. A crucial question is whether dyslexics can engage in large-unit processing to supplement grapheme–phoneme decoding, as would be expected for normal readers. If they were able to do so, an interaction between Body N and Length indicating that the length effects are reduced for words with many body N's should be found. The slopes of the length effect are presented in Table 6 as a function of body N.

The overall ANOVA showed that length effects were significantly reduced for items with many body N's, $F(3,423) = 12.96$, $p < .0001$. The biggest reduction was obtained for the English CA controls who showed length effect reductions in the order of 50%. German children showed no significant length effect reductions, $F < 1$, which is consistent with the fact that body N effects were much weaker in German than in English children (see Discussion). Most importantly, however, the English dyslexic children showed a smaller reduction than both reading level and CA controls, $F(6,255) = 3.41$, $p < .005$. For the Germans, this interaction was not significant, $p > .20$.

Table 6
Length effect slopes (in ms per letter) for words with many body neighbors as compared to words with few body neighbors

	Australia			Germany		
	Dys	RL	CA	Dys	RL	CA
Many body N	152	283	33	313	148	21
Few body N	271	420	69	290	153	33
% Reduction	33*	44*	52*	0	0	36

Note. Asterisks indicate whether the reduction of the length effect was significant (i.e., Length By Body N Interaction).

Summary

The data clearly showed that normally-progressing readers of English efficiently use large-grain size information to supplement grapheme phoneme decoding (i.e., all of them showed reductions of the length effect for items with many body N's). Dyslexic children were able to do so but their benefits were smaller than those of controls. For the German children, large-grain size processing did not seem to play a major role. Length effect reductions were minimal for older children and absent for both younger children and dyslexics.

Discussion

Among European orthographies, English seems to be the hardest to learn (Seymour et al., 2003). Yet, most of the research on reading development and dyslexia comes out of English-speaking countries. In the present research, an attempt was made to investigate whether the English dyslexia results can be generalized to a more regular orthography, like German. Of particular interest was a comparison of basic reading processes across orthographies. This comparison was designed to include three theoretically important psycholinguistic marker effects that are relevant for understanding the basic processes underlying reading. The lexicality effect was chosen to investigate whether the phonological decoding deficit was similar across languages. The length effect allowed us to quantify serial processes in word and nonword reading. Finally, the body N effect allowed us to investigate to what extent dyslexics were sensitive to larger orthographic units. Before considering each of these marker effects, we will briefly discuss similarities and differences in terms of the absolute speed and accuracy level of performance.

Reading speed and accuracy

The global speed analysis showed that the English dyslexics did not differ from the German dyslexics. That is, in both countries, dyslexics exhibited a marked speed deficit in comparison to both CA and reading level controls. The speed deficit was of similar size across orthographies. English dyslexics made more errors than German dyslexics. Note, however, that the English orthography also provides more opportunities for reading errors to be made because of its relatively high degree of inconsistency. As described earlier, even normally developing children make far more decoding errors in English-speaking countries than in German-speaking countries (e.g., Frith et al., 1998; Goswami et al., 2001).

Another problem with the interpretation of reading errors in our study is the fact that dyslexics in both countries did not make significantly more errors than reading level controls. Had we considered only reading errors, as is often done in dyslexia studies, we would have come to the conclusion that dyslexics in both countries exhibit a simple developmental delay (i.e., they are at the same level as the reading level controls). Such a developmental delay could have been the result of insufficient or inappropriate exposure to print. In contrast, the latency data clearly showed that the speed deficit of the dyslexics persists even in comparison with the reading level controls. This suggests that the speed deficit is not simply a consequence of poor exposure to text but rather a fundamental problem underlying dyslexia. Again, the speed deficit affects dyslexic children in both countries in a very similar way, as suggested by almost identical effect sizes. Altogether, the present data support previous claims that reading latencies rather than errors are the more sensitive variable when comparing reading performance across languages (De Jong, 2003; Sprenger-Charolles et al., 2000; Wimmer, 1993).

Does the English orthography amplify the phonological decoding deficit?

There is now overwhelming evidence in favor of a specific phonological deficit in dyslexia (e.g., Ramus, 2003; Snowling, 2000). One of the hallmarks of the phonological deficit is a nonword reading deficit. Given the nonword reading difficulties of normally developing English-speaking children (e.g., Frith et al., 1998; Goswami et al., 2001; Seymour et al., 2003), it was of particular interest to examine the possibility that the English orthography exaggerates the nonword reading deficit of dyslexic children. That is, it could be that the relatively irregular English orthography amplifies the decoding difficulties of dyslexic children, especially with respect to nonwords.

The results presented here are extremely clear. The nonword reading deficit was present in both languages. With regard to reading speed, the deficit persisted even in comparison with reading level controls, which points to a fundamental deficit. The size of the nonword reading deficit was similar across orthographies with almost identical effect sizes and z scores. The error data were less revealing because they failed to distinguish between dyslexics and reading level controls in either country.

Together then, the present study replicates the importance of a nonword decoding speed deficit that affects dyslexics in both regular and irregular orthographies in similar ways (see also De Jong, 2003; Wimmer, 1993). That is, dyslexics in both countries show remarkably slower decoding of nonwords than of words. Their decoding was even slower than that of children in primary school who were on average three years younger than they (i.e., reading level controls). The present result allows us to reject the possibility that research coming out of predominantly English-speaking countries has amplified the phonological decoding deficit. Given the fundamental role of phonological decoding for the process of learning-to-read (Jorm et al., 1984; Share, 1995), it is not surprising that problems in phonological decoding lead to similar reading delays in both countries.

Serial reading processes in dyslexics

The systematic investigation of stimulus length in words and nonwords allowed us to estimate processing costs that were caused by each additional letter. The results revealed a striking length effect for dyslexics in both countries. That is, with each additional letter, processing times dramatically increased in a linear fashion. For the German dyslexics, the processing costs per letter were up to 11 times greater than those of CA controls; for the English dyslexics, the costs were seven times greater. Such length effects suggest that the reading process of dyslexic children is extremely serial and letter-by-letter based. In contrast, the reading process of the CA controls is much more parallel. The length effect of dyslexics was also significantly greater than that of reading level controls, which points again to a fundamental deficit, at least with regard to speed.

Two points are worth noting. First, serial effects were not only present in nonword reading, as might have been predicted by models in which nonlexical processing operates in a serial fashion (e.g., Coltheart et al., 2001), but they were also present in word reading. In fact, we did not find interactions with lexicality (word/nonword status), which suggests that words and nonwords were processed by dyslexics in a serial letter-by-letter fashion. In dual route terminology (Coltheart et al., 2001), it is not only the nonlexical route that is deficient but also the direct lexical route. Second, we employed fairly "easy" (i.e., regular) monosyllabic words, for which the length manipulation was not as extreme as it could have been (i.e., stimuli varied between three and six letters). Still, for such "easy" material, dyslexics in both countries exhibited length effects that were up to 11 times greater than those of normal readers. Given that in normal text reading it is not unusual to encounter words with more than six letters, it becomes quite clear why the reading process of dyslexics is extremely effortful and time consuming. In addition, a serial decoding strategy would increase short-term memory demands because the serially assembled phonemes need to be blended into whole word representations. If short-term memory resources are used up during low-level decoding and blending, they might be lacking for higher-level syntactic processing and text comprehension.

Is the processing of larger orthographic units deficient?

One possible reason for a serial decoding strategy could be that dyslexics are not as efficient in the integration of large-unit information as normally developing readers are. Previous research with skilled readers and children has shown that words and nonwords with many body neighbors produce faster and more accurate reading responses than words with few body neighbors (e.g., Treiman, Goswami, & Bruck, 1990; Ziegler & Perry, 1998). In the developmental literature, this facilitatory effect is often taken to suggest that readers are able to use lexical analogies at the rime level to supplement phonological decoding (Goswami & Bryant, 1990). Alternatively, the effect could be explained by postulating that lexical feedback is particularly sensitive to body-size information because bodies allow the system to disambiguate inconsistencies at smaller grain sizes (Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995).

In our study, dyslexics showed normal facilitatory body N effects compared to their respective controls. That is, having a large number of body neighbors was as beneficial to dyslexics as it was to normally developing readers. German readers showed smaller body N effects than English readers, which is consistent with previous findings showing that German readers rely to a much smaller extent on large-unit processing than do English readers (Goswami et al., 2001, 2003; Ziegler et al., 2001).

If the integration of large-unit information were fully functional in dyslexics, one would, however, expect to find reductions of the length effect whenever dyslexics have the opportunity to extract larger orthographic units (i.e., when words have many body neighbors). Indeed, the English dyslexics exhibited a reduction of the length effect by about 33%. However, the reduction was smaller than that obtained by the controls (52 and 44%, for CA and reading level controls, respectively). German dyslexics showed no reduction of the length effect for large body-N items. However, their respective controls did not show significant reductions either. The German pattern is fully consistent with previous data showing that German readers rely to a great extent on small-unit processing even if large-unit information is available to them (see Goswami et al., 2001, 2003).

Conclusions

The goal of the present study was to obtain a more precise description of dyslexia in different orthographies. The results clearly showed that the similarities between orthographies were far bigger than their differences. That is, dyslexics in both countries exhibited a reading speed deficit, a specific nonword reading deficit, and a phonological decoding mechanism that operates extremely slowly and serially. These problems were of similar size across orthographies and persisted even with respect to younger readers (i.e., reading level controls). The dyslexics in both countries did not show a major deficit in using body-size information, that is, both groups showed normal facilitatory body N effect compared to their controls. The English dyslexics, however, showed that the integration of body-size information during the phonological decoding process was not fully efficient. German dyslexics showed no integration of body-size information during phonological decoding either. However, this process seems of little use for German readers because the controls did not show this effect either. Thus, the extremely slow and serial grapheme–phoneme decoding process remains the main problem for dyslexic readers in both countries.

English and German dyslexics clearly differed in terms of overall accuracy. However, accuracy differences should be treated with caution because overall accuracy failed to distinguish dyslexics from reading level controls and might therefore be simply related to the fact that the English orthography provides more opportunities for making reading errors than the German orthography. Moreover, when effect sizes rather than absolute levels of accuracy were compared, the dyslexics in the two countries exhibited very similar patterns.

There is one aspect about the present conclusion that seems puzzling at first. Why is the normal reading development of the English-speaking children delayed compared to children from other European countries (i.e., Seymour et al., 2003), and yet dyslexia looks quite similar in different orthographies? One possible answer to this puzzle is that the problems of the dyslexic children in both countries occur before regularity comes into play. That is, the bottleneck of the dyslexic children in both countries seems to lie in the establishment of *basic* phonological recoding procedures. In theory, regularity might only make a noticeable difference once the basic recoding skills are acquired. It is possible that dyslexic children never acquire the kind of efficient phonological decoding procedures that would be sensitive to the statistical regularities of the writing system.

In sum, the present study provides behavioral evidence that is perfectly in line with recent brain imaging work that compared dyslexia in England, France, and Italy (Paulesu et al., 2001). These authors found strong evidence for a common biological origin of dyslexia in different orthographies. If the results of the present study are taken together with those of Paulesu et al. (2001), it seems quite clear that the causes and consequences of dyslexia are extremely similar across regular and less regular orthographies. On the practical side, the present study allows us to confirm that dyslexia results from studies using the English language can be generalized to more regular orthographies, provided one uses "culturally fair" marker effects of the reading process in different orthographies.

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Appendix

Words				Nonwords			
Low Body N		High Body N		Low Body N		High Body N	
German	English	German	English	German	English	German	English
Tee	tea	Hut	hat	Lir	ler	Fot	fot
Zeh	toe	Heu	hay	Rie	rea	Lat	lat
Bus	bus	Eis	ice	Foo	foo	Dee	dee
per	per	Fan	fan	sil	sil	lan	lan
Zoo	zoo	rot	red	Tis	tis	pei	bry
See	sea	pro	pro	Nuf	nup	meu	moy
Arm	arm	Tag	day	Tof	tof	Sar	sar
Gas	gas	Bar	bar	Nal	nal	Sut	sut

Appendix (*continued*)

Words				Nonwords			
Low Body N		High Body N		Low Body N		High Body N	
German	English	German	English	German	English	German	English
Box	box	Kuh	cow	Heg	heg	Gat	gat
Akt	act	roh	raw	Fas	fas	nan	nop
Laut	loud	Post	post	Naul	naul	Gack	gack
plus	plus	Sand	sand	saun	saun	nist	nist
Form	form	Reis	rice	Trub	trup	Tord	tord
Text	text	Bank	bank	Seib	sibe	Torn	tain
Haar	hair	blau	blue	Bohm	boam	pund	pamp
Boot	boat	Nest	nest	Goft	goft	Lank	lunk
Film	film	vier	four	Noof	noof	nuck	nuck
Verb	verb	Mahl	meal	Furg	furk	Plar	plar
Floh	flea	Wein	wine	Parn	parn	Bick	bick
Golf	golf	Bier	beer	Perd	perd	Tind	tump
Sturm	storm	Nacht	night	Glirt	glird	Steck	steck
Punkt	point	Stein	stone	Brohl	broal	Plock	plock
Kleid	cloth	Start	start	Plohr	ploar	Grost	grost
Kreuz	cross	Stahl	steel	Spaut	spond	Dratz	drace
Sport	sport	Sicht	sight	Miest	meast	Bruck	bruck
Stuhl	chair	Traum	dream	Silch	spilk	Praum	proom
steif	stiff	Stock	stick	pisch	prish	dreil	drail
Biest	beast	Block	block	Glief	glief	Gruck	gruck
Schal	scarf	steil	steep	Drohn	droan	brist	brist
Front	front	Pfund	pound	Stork	sterk	Krost	crost
leicht	length	Frucht	flight	strond	strond	Sprand	sprand
Tausch	taught	Strand	strong	Friest	freast	Straum	stroom
Wunsch	weight	Schein	school	Blorst	blorce	Drecht	dright
prompt	prince	Brauch	bright	klackt	gladge	Spreil	sprail
Schlaf	change	gleich	ground	Breist	Baint	Flisch	flitch
Storch	course	Strich	stream	Parsch	plarch	Grecht	gratch
frisch	phrase	schwer	spring	flurst	flurst	pleich	plench
feucht	fierce	Pracht	please	strinz	stince	schast	scrast
Frosch	freeze	bleich	bought	Straul	straul	sprank	sprank
strikt	strict	Tracht	thrill	balsch	bralse	Fatsch	fratch

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