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Dutch Dyslexia in Adulthood: Core Features and Variety

Judith Bekebrede, Aryan van der Leij, and Anna Plakas
University of Amsterdam

David Share
University of Haifa

Eleni Morfidi
University of Ioannina

This study tested the phonological core deficit hypothesis among Dutch dyslexic adults and also evaluated the pattern of individual differences among dyslexics predicted by the phonological-core variable-orthographic differences (PCVOD) model (van der Leij & Morfidi, 2006) in a sample of 57 control adults and 56 dyslexic adults. It was confirmed that Dutch adult dyslexics share a phonological core deficit. As predicted, there was significantly larger variability among dyslexics in orthographic coding relative to phonological coding. Orthographic coding also explained additional variance in word reading fluency after phonological coding was partialled out. Consistent with the PCVOD model, when two subgroups were selected, which differed in levels of orthographic coding, the high-scoring subgroup outperformed the low-scoring subgroup on almost all reading and reading-related tasks. As anticipated, the high-scoring subgroup had near-normal levels of orthographic abilities. These advantages were not attributable to differences in general cognitive competence, print exposure, or educational attainment.

In the present study the core features of a Dutch adult dyslexic sample are investigated, in particular the persistence of problems with phoneme awareness, rapid serial naming and phonological recoding. We also evaluate the phonolog-

Correspondence should be sent to Judith Bekebrede, Department of Education, University of Amsterdam, PO Box 94208, 1090 GE, Amsterdam, the Netherlands. E-mail: j.i.bekebrede@uva.nl

ical-core variable-orthographic differences model (PCVOD) proposed by van der Leij and Morfidi (2006) to explain the heterogeneity within the dyslexic group. According to the PCVOD approach, a common core phonological deficit is accompanied by greater variability in tasks that rely on orthographic coding.

PHONOLOGICAL CORE DEFICITS ACROSS ORTHOGRAPHIES AND AGE

It is well established that phonological coding, the ability to use speech codes to represent information in the form of words and parts of words including phonemes, is strongly implicated in reading acquisition. According to Vellutino, Fletcher, Snowling, and Scanlon (2004), phonological coding deficits qualify as the universal and stable core characteristic of dyslexia across languages with alphabetic writing systems. Subskills of reading that rely on phonological coding are phoneme awareness and rapid serial naming, and there is also a strong relationship with phonological recoding because grapheme–phoneme correspondences are required to retrieve the pronunciation of unknown words (e.g., Stanovich & Siegel, 1994).

Phoneme awareness has been found to be one of the strongest predictors of reading acquisition (e.g., Cardoso-Martins & Pennington, 2004; Share, Jorm, Maclean, & Matthews, 1984). This applies to all languages with alphabetic scripts studied to date (e.g., Caravolas, Volín, & Hulme, 2005; Holopainen, Ahonen, & Lyytinen, 2001; Ziegler & Goswami, 2005). Although the period during which phoneme awareness affects typical reading development may be relatively brief in more consistent orthographies (de Jong & van der Leij, 1999; Landerl & Wimmer, 2000), dyslexic readers show impairments in phoneme awareness when task demands are adapted to their developmental level, independent of orthographic depth and age (Bruck, 1992; Caravolas et al., 2005; de Jong & van der Leij, 2003; Elbro, Nielsen, & Petersen, 1994; Lyytinen, Leinonen, Nikula, Aro, & Leiwo, 1995; Miller-Guron & Lundberg, 2000; Miller-Shaul, 2005; Morfidi, van der Leij, de Jong, Scheltinga, & Bekebrede, 2007; Pennington, van Orden, Smith, Green, & Haith, 1990; Snowling, Nation, Moxham, Gallagher, & Frith, 1997; Wilson & Lesaux, 2001).

Rapid serial naming appears to be the most important predictor of fluency of word reading and dyslexia at a younger age in alphabetic scripts (e.g., Caravolas et al., 2005; de Jong & van der Leij, 2003; Denckla & Rudel, 1974; Vaessen, Gerretsen, & Blomert, 2009; van den Bos, Zijlstra, & lutje Spelberg, 2002; Wimmer, Mayringer, & Landerl, 2000). Moreover, it is clear that difficulties in rapid serial naming persist into adolescence (Morfidi et al., 2007) and adulthood (Miller et al., 2006; Reid, Szczerbinski, Iskierka-Kasperek, & Hansen 2007; Vukovic, Wilson, & Nash, 2004).

Poor phonological recoding skill has also been shown to be a universal characteristic of young dyslexics, for example, in English (Herrmann, Matyas, & Pratt, 2006; Rack, Snowling, & Olson, 1992; Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003), German (Landerl & Wimmer, 2000), and Dutch (van der Leij & van Daal, 1999; Yap & van der Leij, 1993). At a later age, severe difficulty with phonological recoding continues to be the most striking characteristic of dyslexics across languages and orthographies (Bruck, 1998; Elbro et al., 1994; Lyytinen et al., 1995; Miller-Guron & Lundberg, 2000; Miller-Shaul, 2005; Snowling et al., 1997). One of the aims of the present study was to investigate whether phonological core deficits extend to Dutch dyslexic adults who, as yet, have not been studied.

VARIABILITY IN ORTHOGRAPHIC CODING

Although the prevailing causal model of dyslexia focuses on the unitary phonological deficit model (Vellutino et al., 2004), it has been argued that these deficits may be accompanied by large individual differences in other domains of cognitive processing. In 1988, Stanovich developed the phonological-core variable-difference (PCVD) model, which postulates that all poor readers suffer from comparable core deficits in phonological processing but may differ in general cognitive skills. The PCVD model was proposed as a framework for conceptualizing the differences between IQ-discrepant dyslexics and IQ-nondiscrepant poor readers on tasks outside the phonological core. In a subsequent study, Stanovich and Siegel (1994) suggested that relative to nondiscrepant poor readers, dyslexic readers are relatively less disadvantaged in tasks that tap orthographic coding,[1] compared with their phonological deficits, and might even display a processing ("compensatory") superiority (see also, Siegel, Share, & Geva, 1995).

Extending the PCVD model to individual variation *within* the dyslexic population, van der Leij and Morfidi (2006) suggested that a phonological-core variable-*orthographic* differences model was a better description of their empirical evidence. The PCVOD model assumes that, although dyslexics may on average show less severely impaired orthographic skills (relative to their phonological deficits), there are large individual differences within the group. Some dyslexics' phonological deficits may be partly offset by relatively good performance on tasks that involve orthographic processing of larger orthographic units. In contrast, other dyslexics may have deficits in both phonological and orthographic coding and possess less compensatory potential in orthographic coding than is suggested by Stanovich and Siegel (1994).

[1]Orthographic coding, "the ability to represent a printed word in memory and then to access the whole word pattern, a single letter, or letter cluster in that representation" (Berninger et al., 1992; p. 260), relies less on phonological coding than phonological recoding does.

The PCVOD approach to the issue of heterogeneity within the dyslexic population differs markedly from the influential surface/phonological approach to dyslexia subtyping (e.g., Castles & Coltheart, 1993) in which, following the dual-route model of word reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the lexical and nonlexical (i.e., orthographic and phonological) dimensions of word recognition are considered two *equally* important sources of potential breakdown in word recognition among developmental dyslexics. The dual-route view implies that, in addition to dyslexics with both phonological and orthographic deficits, surface dyslexia (selective orthographic deficits) and phonological dyslexia (selective phonological deficits) will be equally prevalent. However, English-language findings (see, e.g., Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Stanovich, Siegel, & Gottardo, 1997) have shown that developmental surface dyslexia is both less severe and less common than phonological dyslexia. Furthermore, these disproportionate prevalence rates are consistent with many studies showing that *within* the dyslexic population as a whole, orthographic coding is less severely impaired than phonological processing (see, for a review, Share & Stanovich, 1995). More generally, it is well established that phonological processing correlates more strongly with reading ability than orthographic coding *in the general population* (Share, 1995). Finally, there is evidence that orthographic coding is partly but not entirely parasitic on phonological processing (Cunningham, Perry, & Stanovich, 2001). Collectively, these findings contradict what might be termed the "equivalence assumption" regarding orthographic and phonological causes of dyslexia. Instead, the data favor an approach to dyslexic heterogeneity characterized by greater heterogeneity in orthographic coding coupled with relative homogeneity as regards phonological deficits as exemplified in the PCVOD model.

Bekebrede, van der Leij, and Share (2009) tested the PCVOD model in a study of Dutch adolescents. Supporting the universality of the phonological core hypothesis, all dyslexics performed poorly on phonological coding and phonological recoding (pseudoword reading fluency). However, Bekebrede et al. found a dyslexic subgroup with better orthographic skills that excelled at silent speeded word processing and tasks relying on some kind of large-unit processing that extended across word type (words or pseudowords), language (Dutch or English) and response mode (lexical decision or typing). These differences could not be attributed to differences in print exposure, phonological coding, verbal competence or vocabulary, reading experience, or general intelligence.

THE PRESENT STUDY

The present study set out to examine the PCVOD predictions in a sample of Dutch dyslexic adults for several reasons. First, because the model is supported by data

from adolescents, it may be even more applicable in adults for whom reading is in its developmental end-state and individual differences have stabilized.

Second, because orthographic coding is partly but not entirely parasitic on phonological processing (Share & Stanovich, 1995), orthographic coding should account for unique variance in word recognition even after controlling for phonological variables such as phoneme awareness and phonological recoding (Cunningham et al., 2001). The variance explained by orthographic coding is only partly explained by experience (i.e., print exposure) among children and adults (Cunningham & Stanovich, 1990; see for a Dutch replication, Bekebrede et al., 2009), suggesting that orthographic coding is, at least in part, an individual or "within-child" ability.

Third, Dutch adults learn to read English as a second language. In comparison to their first language with its relatively shallow script, the study of L2 English reading is informative for the PCVOD model because of the greater demands in English on processing larger orthographic units (Seymour, Aro, & Erskine, 2003; Ziegler & Goswami, 2005). For example, Miller-Guron and Lundberg (2000) identified a subgroup of adult Swedish dyslexics who had, as they termed it, a "preference for English reading" but showed similar impairments in phonological coding in comparison to a subgroup without a preference for English. In a similar study with Dutch dyslexic adolescents, a subgroup of dyslexic students was found with superior orthographic knowledge in Dutch and English who also were better in English reading compared to other dyslexics. Phonological coding and Dutch reading, however, were comparable in the two groups (van der Leij & Morfidi, 2006).

Fourth, the model challenges the prevailing view expressed by Vellutino et al. (2004) that "there is abundant evidence that the child who has limited phonological awareness and limited alphabetic mapping skills also has limited orthographic awareness and limited orthographic knowledge. … These limitations have been observed in both dyslexic children and adults" (p. 7). In contrast, the PCVOD model predicts that the limitations in orthographic skills are less constrained among dyslexics than their limitations in phonological awareness.

RESEARCH QUESTIONS

The present study was designed to test the PCVOD model in a sample of Dutch dyslexic adults. The first prediction was that they would show a phonological core deficit. In particular we predicted poorer performance on standard tasks relying on phonological coding (i.e., phonemic awareness, rapid serial naming, and phonological recoding) relative to both control age *and* reading age controls. Other predictions addressed the issue of heterogeneity within the dyslexic group. The foundation assumptions of the PCVOD model were tested using the methodology of

Bekebrede et al. (2009). Given that orthographic coding is considered to be only partly parasitic on phonological skills, orthographic coding was expected to account for significant additional variance in fluency of word reading after phonological coding was partialled out. Next, the PCVOD model predicts that among dyslexics, the variability in orthographic coding will be significantly greater than the variability in phonological coding. Thus, some dyslexics (we term ORTH$^+$) will have relatively "normal" orthographic skills, whereas other dyslexics (termed ORTH$^-$) have very poor orthographic skills in spite of a common phonological deficit. We also sought evidence for external validity for the model by testing the hypothesis that differences between dyslexic subgroups in orthographic coding are accompanied by differences in performance on tasks that depend on the processing of larger orthographic units, either due to word characteristics (chiefly spelling-sound complexity) or stimulus presentation condition.

With regard to word characteristics, we exploited that fact that the most important second language in the Netherlands is English. English reading is known to be more dependent on larger orthographic units because a letter-by-letter reading strategy is often insufficient to identify many words owing to the extreme irregularity of English spelling (Share, 2008; Ziegler & Goswami, 2005).

Additional external validity was adduced using a stimulus presentation condition that necessitates the processing of larger orthographic units, namely, brief or "flashed" presentation of words (see, e.g., Bekebrede et al., 2009). Presenting words for 200 msec followed by masking deters the use of an exhaustive grapheme–phoneme decoding strategy, and increases reliance on larger (orthographic) units. Brain imaging studies have confirmed that in the first 250 msec of word recognition, the visual word form area is activated (e.g., Bolger, Perfetti, & Schneider, 2005; Maurer, Brem, Bucher, & Brandeis, 2005). Furthermore, event-related potential studies indicate that there is an orthographic/lexicality peak around N170, followed by a phonological peak around N300 (Dien, 2009; see also Simon, Bernard, Lalonde, & Rebaï, 2006). Together, these results support the assumption that recognition of larger orthographic units takes place within the first 200 msec (for a review, see Wolf, 2007). In particular, the processing of *pseudo*words flashed for only 200 msec may reveal whether multiletter units are processed because unfamiliarity at the word level makes "direct" word recognition impossible but, at the same time, also curtails processing at the single grapheme level (Yap & van der Leij, 1993).

Finally, a stringent test of the PCVOD model requires that several mediating factors be excluded. The subgroup with superior orthographic coding (ORTH$^+$) should not simply have had more exposure or experience with written Dutch or English reading, or differ in educational attainment or general ability. Furthermore, the PCVOD model predicts that, despite comparable print exposure, the subgroup with superior orthographic coding should be better readers than the subgroup with inferior orthographic coding because they are able to rely to a larger de-

gree on superior representations of spelling patterns of printed words and of sublexical letter clusters (Berninger et al., 1992).

METHOD

Participants

The parents of the children who participated in the longitudinal study of the Dutch Dyslexia Program (van der Leij, Lyytinen, & Zwarts, 2001) were invited to participate in the present study. The van der Leij et al. study comprised a group of infants with a genetic risk for dyslexia and a matched control group without this genetic risk. The at-risk infants had at least one dyslexic parent *and* another first- or second-grade relative who reported lifelong reading and/or spelling difficulties and who performed poorly on a word and pseudoword reading fluency test administered to all parents at the start of the project. In addition, a questionnaire was administered to gain information about additional learning disabilities or neuropsychological deficits. Five fathers reported hyperactivity or attention problems—three were in the at-risk group and two in the control group. Because no formal diagnoses were available and there were no overall groupwise differences, these parents were kept in the sample. Five years later, 113 parents consented to participate in the present study. There were 57 parents in the control group (27 male, 30 female) and 56 in the dyslexic group (25 male, 31 female). There was no relationship between gender and reading status (dyslexic/control) $\chi^2(1, N = 113) = .08$, *ns*.

The typical educational attainment of these adults was middle to higher vocational education. As anticipated, there was a significant effect of educational attainment on the participants' reading status, $U = 1230$, $Z = -2.24$, $p < .05$, with the dyslexic group's educational attainment lower than the nondyslexic group. The average age among the adults was 37 years 3 months ($SD = 4$ months), with a range of 28 to 48. There were no differences between the groups in age.

The adult dyslexics were also compared to 23 normal readers from Grades 8 and 9 (M age = 14;10 years) selected from the dataset of Morfidi et al. (2007) and used as a reading age control group. These two groups were matched on Dutch word reading fluency (dyslexic adults $M = 78.5$ words per minute, $SD = 17.05$; reading age controls $M = 83.5$ words per minute, $SD = 12.45$), $F(1, 78) = 1.59$, *ns*. A variety of reading and phonological data were available from the reading-age control group.

Phonological Coding

Phoneme awareness. To measure phoneme awareness a computerized word reversal task was developed as part of the Interactive Dyslexia Test (IDT; Bekebrede, van der Leij, Plakas, & Schijf, 2006). This subtest was originally de-

veloped by Buis (n.d.). Participants hear two pseudowords (e.g., *ket – tek*) and are asked to press a True or False button to indicate whether the second word is the reverse of the first. The test consists of 10 examples and 60 test items—all monosyllabic words with either one or two consonants at the beginning or end of the word. The internal consistency (Cronbach's alpha) was found to be .84.

Rapid serial naming of digits (Denckla & Rudel, 1974). The participants are required to read aloud a series of 50 digits (8, 1, 3, 6, 5 in random order) as quickly and accurately as possible while time is recorded. Van der Leij and Morfidi (2006) reported test–retest reliability of .74.

Orthographic Coding

Orthographic choice L1. To measure orthographic knowledge in native Dutch, van der Leij and Morfidi (2006) developed an adaptation of Olson, Forsberg, Wise, and Rack's (1994) English orthographic choice task. Forty pairs of homophonic words (e.g., '*hoet – hoed*' [hat]) are presented on a printed page. The participants are asked to choose the correctly spelled word. Both accuracy and time are recorded. The internal consistency (Cronbach's alpha) was found to be .68.

Orthographic choice L2. This test (Olson et al., 1994) was used to evaluate orthographic knowledge in L2 English. Forty pairs of printed words (e.g., *wurd-word*) are presented, and the participants are required to choose the correctly spelled word. Both accuracy and time are recorded. Internal consistency (Cronbach's alpha) was found to be .81.

Reading Measures in Dutch

Word reading fluency L1. The Een Minuut Test (One Minute Test; Brus & Voeten, 1973) was used to identify poor readers in L1 Dutch. The test consists of 116 words of increasing difficulty. The participant is asked to read aloud as many words as possible in 1 min. Both accuracy and speed are emphasized. The test score is the number of words read correctly in 60 sec. Parallel test and test–retest reliabilities are over .80 (van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1994).

Pseudoword reading fluency. The Klepel (van den Bos et al., 1994) is a speeded reading test consisting of 116 pseudowords of increasing difficulty. The test was constructed by changing consonants or vowels in the words of the Dutch One Minute Test without violating the pronunciation rules of Dutch. The test score is the number of pseudowords correctly read in 2 min. Parallel test reliabilities are reported to be over .89 (van den Bos et al., 1994).

Flashed word identification. In this test (IDT; Bekebrede et al., 2006) a word appears on a computer screen for 200 msec and then masked. The participants are required to press a True or False button to indicate whether the word is correctly spelled. The test consists of three examples and 40 items containing one, two, and three syllables. In each block of 10 items there are 5 correctly spelled words. The internal consistency (Cronbach's alpha) was found to be .74.

Flashed word production. This task (IDT; Bekebrede et al., 2006) requires silent reading and production of real words and depends on both speed and accuracy. A word is flashed on a computer screen for 200 msec and then masked. The participant is asked to type the flashed word. Again, there are three examples followed by 40 items with one, two, and three syllables. The test is discontinued after eight incorrect responses in a set of 10 items. The internal consistency (Cronbach's alpha) was found to be .91.

Flashed pseudoword production. In this silent pseudoword reading and production task, a pseudoword is flashed on a computer screen for 200 msec and then masked (IDT; Bekebrede et al., 2006). The participant is required to type the flashed pseudoword. The pseudowords were constructed by changing the vowels of another flashed word production test not administered to these adults. The test consists of three examples followed by three blocks of 10 items containing one, two, and three syllables. When the participant commits more than eight errors in a single block, the test is discontinued. The internal consistency (Cronbach's alpha) was found to be .90.

Reading Measures in L2 English

Word reading fluency L2 (One Minute Test). The English One Minute Test (Fawcett & Nicolson, 1996) demands speed and accuracy in reading English words. The test consists of 120 words of increasing difficulty. The test score is the number of words read correctly in 1 min. Fawcett and Nicolson reported test-retest reliability of .99.

Flashed word production L2. In this silent reading and production task, an English word is presented on a computer screen for 200 msec and then masked (IDT; Bekebrede et al., 2006). The participants are asked to type the English word. Block 1 consists of 20 monosyllabic words, Block 2 consists of 10 two-syllable words, Block 3 consists of 10 three-syllable words, and Block 4 consists of 10 final "e" words with one to three syllables. The test is discontinued after more than eight errors in a single block. Internal consistency (Cronbach's alpha) was found to be .96.

Control Measures

Nonverbal (spatial) ability. To measure general nonverbal ability, a spatial subtest of the General Aptitude Test–Battery (van der Flier & Boomsma-Suerink, 1994), was administered. The participants are required to solve as many questions as possible in 6 min with a maximum of 40. The participants see an unfolded figure and must choose among four options which figure is correctly folded. The complete General Aptitude Test–Battery has good reliability and sufficient construct validity according to the national assessment of psychometric qualities of tests.

General verbal ability. When the parents were selected to participate in the longitudinal study, verbal ability was measured with the Similarities subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1955/1970). This task does not involve reading. The participants are asked in what way two words are similar. Responses to each of the 13 items are awarded 2, 1, or 0 points. After four consecutive 0-point answers, the test is discontinued. Split-half reliability of .81 is reported.

Literacy questionnaire. A questionnaire assessing background information regarding reading habits was developed. The questionnaire consisted of five "themes" with 22 multiple-choice questions: perceived easiness of the English language (consisted of 4 questions with a reliability of $\alpha = .86$), preference for Dutch (consisting of 6 questions with a reliability of $\alpha = .75$), exposure to English (4 questions with a reliability of $\alpha = .85$), exposure to Dutch (4 questions, reliability of $\alpha = .73$), and 5 additional questions about computer use. A translation of this questionnaire is given in the appendix.

Procedure

All tasks were individually administered in two sessions of up to 45 min in a quiet room at home or in a laboratory setting. One session included all the paper-and-pencil tests in the same fixed order (orthographic choice L1, L2; rapid serial naming; word reading fluency L1 and L2; pseudoword reading fluency; General Aptitude Test–Battery spatial ability); the other session included the computerized tests in the same fixed order for practical reasons (word reversal; flashed word identification; flashed word, pseudoword, and English word production).

RESULTS

Comparisons Between Dyslexic Adults and Normal Adult Readers

In Table 1 the control adults are compared with the dyslexic adults in a multivariate analysis of variance. As predicted by the phonological core hypothesis,

TABLE 1
Mean Scores, Standard Deviations, and Main Group Effects for Control Adults and Dyslexic Adults on Phonological, Orthographic, Reading and Control Measures

	Controls (57)		*Dyslexics (56)*		*MANOVA*	*Effect Size*
Variables (Max)	*M*	*SD*	*M*	*SD*	*F(1, 110)*	η^2_p
Word reversal (60)	55.29	3.37	46.87	6.24	78.17**	.42
Rapid serial naming (sec)	17.23	4.04	22.44	6.01	28.69**	.21
Orthographic choice L1 (40)	38.61	1.25	36.43	2.41	36.66**	.25
Time orthographic choice L1 (sec)	62.51	18.19	100.93	39.16	44.69**	.29
Orthographic choice L2 (40)	39.51	0.78	36.63	3.45	37.69**	.26
Time orthographic choice L2 (sec)	53.65	17.02	96.80	61.48	25.98**	.19
Word reading fluency L1 (116)	106.14	9.65	78.45	17.05	112.86**	.51
Pseudoword reading fluency (116)	102.19	12.89	59.22	19.51	190.58**	.63
Word reading fluency L2 (120)	97.88	18.12	63.80	19.66	90.32**	.45
Flashed word identification (40)	35.04	2.61	28.70	3.10	138.47**	.56
Flashed word production (40)	38.81	1.64	33.89	6.30	32.41**	.23
Flashed pseudoword production (30)	21.02	2.89	12.55	4.10	161.04**	.59
Flashed English word production (50)	48.51	2.35	37.82	11.06	50.87**	.31
Spatial ability (GATB 3) (40)	25.70	6.09	25.55	5.34	0.02ns	.00
Verbal ability (26)	16.79	2.91	16.47	3.73	0.25ns	.002

Note. MANOVA = multivariate analyses of variance; GATB = General Aptitude Test–Battery.
** $p < .01$.

the dyslexics' performance was well below the control adults on both phonological coding measures, word reversal and rapid serial naming. In addition, the dyslexic adults were inferior on the four orthographic measures, despite a ceiling effect on English orthographic choice with the control adults, as well as on all the reading fluency measures (Dutch and English words and pseudowords) and flashed identification and production tasks. On spatial ability and verbal competence there were no significant differences between the two groups.

Comparisons Between Dyslexic Adults and Younger Reading Age Controls

The findings indicated that the dyslexic adults performed worse than the reading age controls on pseudoword reading fluency (dyslexic adults $M = 59.22$, $SD = 19.51$; reading age controls $M = 79.43$, $SD = 17.69$), $F(1, 78) = 18.37$, $p < .01$, $\eta^2_p = .20$) and were slower on rapid serial naming (dyslexic adults $M = 22.44$, $SD = 6.01$; reading age controls $M = 18.24$, $SD = 2.26$), $F(1, 78) = 8.90$, $p < .01$, $\eta^2_p = .10$. On a spoonerisms task (participants had to transpose the onsets of two words, see van der Leij and Morfidi, 2006), the dyslexic adults (*M(z-score)* = –.37, $SD = 1.18$) also performed worse than the reading age controls (*M*(*z-score*) = 3.04, $SD = .75$),

$F(1, 78) = 5.60$, $p < .05$, $\eta^2_p = .07$. However, on word fluency in English the adults performed better than the younger reading age controls (dyslexic adults $M = 63.80$, $SD = 19.66$; reading age controls $M = 51.04$, $SD = 16.20$), $F(1, 78) = 7.49$, $p < .01$, $\eta^2_p = .09$. On orthographic choice accuracy the groups did not differ (dyslexic adults $M = 36.43$, $SD = 2.41$; reading age controls $M = 35.61$, $SD = 2.17$), $F(1, 78) = 1.97$, *ns*. These data not only confirm the severity of the phonological deficit among adult dyslexics in Dutch but also support a central claim of the PCVOD model that phonological and orthographic deficits are not equally important sources of reading difficulty as assumed in the influential surface/phonological typology.

Hierarchical Regression Analysis

Following Cunningham et al. (2001), we combined all four orthographic measures (Dutch and English orthographic choice accuracy and time) into a single composite measure. (A principal components analysis revealed a one-factor solution with an eigenvalue of 3.1 that explained 77.7% of the variance emerged; all the factor loadings exceeded .83.) The four measures were combined by averaging standardized scores. The two phonological coding tasks, however (rapid serial naming and word reversal), were not treated as a composite because the correlation was only moderate (–.36).

Hierarchical regression analysis was employed to determine whether orthographic coding played a significant role in predicting Dutch word reading fluency after the influence of phonological variables was ruled out. In this analysis (see Table 2), verbal ability was entered at Step 1 to control for general cognitive abilities and accounted for 4.1% of the variance, followed by the phonological measures, word reversal and rapid serial naming at Steps 2 and 3, accounted for 31.7% and 27.5%, respectively. After these measures were partialled out, the orthographic composite explained a significant portion of additional variance (9.8%) in word reading fluency.

TABLE 2
Variance (ΔR^2) in Predicting Dutch (L1) Fluency of Word Reading Explained by Phonological and Orthographic Variables

Step	*Variable*	*R*	ΔR^2	ΔF	β	*t*
1	Verbal ability	.203	4.1%	4.55^{*}	–.02	$-.39^{ns}$
2	Word reversal	.598	31.7%	51.84^{**}	.23	3.41^{**}
3	Rapid serial naming	.796	27.5%	78.12^{**}	–.46	-8.09^{**}
4	Orthographic composite	.855	9.8%	37.40^{**}	.39	6.12^{**}
Total			73.1%			

Note. Orthographic composite = orthographic choice L1 accuracy and time, orthographic choice L2 accuracy and time.

$^{*}p < .05$. $^{**}p < .01$.

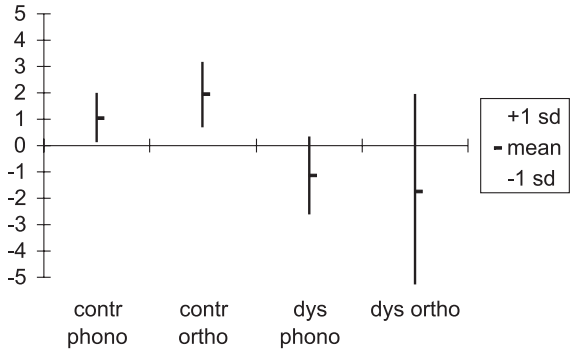

FIGURE 1 Variability among dyslexic and control adults on phonology and orthography. *Note.* contr = control adults; dys = dyslexic adults; phono = phonological composite word reversal and rapid naming; ortho = orthographic composite orthographic choice L1 accuracy and time, orthographic choice L2 accuracy and time.

Individual Differences

The PCVOD model predicts that there will be greater variability among dyslexics in orthographic coding compared to phonological abilities. Figure 1 shows the mean and variance (±1 *SD* scores) for phonological and orthographic coding among the dyslexic and control adults. To facilitate comparison, phonological coding is indicated by a phonological composite (for this purpose only) consisting of word reversal and rapid serial naming, and orthographic coding is indicated by the same four-measure composite as above. Figure 1 confirms that there exists more variability among dyslexics in orthographic coding than in phonological coding. In addition, the variability amongst dyslexics in orthographic coding is larger than among controls. To formally test this, we used multilevel analysis by organizing our data with test scores nested in participants. Subsequently, we used a multivariate analysis enabling a comparison between groups as well as tests. Consistent with this key prediction of the PCVOD model, the dyslexics were found to have more variation on orthography than on phonology compared to control adults ($p < .01$).[2]

To further investigate the orthographic variability, the dyslexics were subdivided into subgroups with high and low orthographic coding. The dyslexic adults

[2]To use multivariate analyses we specified three different contrasts: (a) the variances of orthographic scores of the control adults are equal to the variances of the orthographic scores of the dyslexics (χ^2 = 815.201); (b) the variances of the phonological scores of the control adults are equal to the variances of the phonological scores of the dyslexics (χ^2 = 769.496), and (c) the variances of the orthographic scores of the dyslexics are equal to the phonological scores of the dyslexics (χ^2 = 783.750). These three models were contrasted with a model with no restrictions to the variances (χ^2 = 759.393). All the restricted models were significantly worse; therefore, the conclusion is that in comparison with the control adults, the dyslexics have more variance on orthographic coding than on phonological coding.

were divided into three almost equal groups based on the orthographic composite. The dyslexics who scored in the top third of the composite (n = 19) formed the ORTH$^+$ subgroup with high orthographic coding, whereas the dyslexic adults who scored in the lowest third of the orthographic composite (n = 19) formed the ORTH$^-$ subgroup with low orthographic coding. (The intermediate group [n = 18] was discarded).

To validate this subdivision, performance on the separate orthography measures was compared across the three groups. The means, standard deviations and main effects of group are presented in Table 3. The three planned contrasts to examine differences between the groups are reported in the text if the multivariate statistics indicated significant overall differences.

The contrast between the ORTH$^-$ subgroup and the controls showed a significant difference on the orthographic composite, $F(1, 92) = 132.83$, $p < .01$, $\eta^2_p = .59$, and on the four variables separately, accuracy of orthographic choice in Dutch, $F(1, 92) = 69.63$, $p < .01$, $\eta^2_p = .43$, and in English, $F(1, 92) = 140.44$, $p < .01$, $\eta^2_p = .61$; and speed of orthographic choice: Dutch, $F(1, 92) = 76.81$, $p < .01$, $\eta^2_p = .46$, and English, $F(1, 92) = 77.54$, $p < .01$, $\eta^2_p = .46$.

The contrast between the ORTH$^+$ subgroup and the control adults did not reveal a significant difference on the orthographic composite, $F(1, 92) = 3.36$, $p = .07$. The ORTH$^+$ subgroup scored below normal readers on the time of the Dutch orthographic choice task, $F(1, 92) = 4.29$, $p < .05$, $\eta^2_p = .05$, but performed as well as the control adults on accuracy on orthographic choice in Dutch and on accuracy and speed of the orthographic choice in English: accuracy L1, $F(1, 92) = 3.69$, $p = .058$; accuracy L2 ($F < 1$); and speed L2, $F(1, 92) = 1.41$, *ns*. These data indicate that the ORTH$^+$ subgroup of dyslexics perform within the normal to low-normal range in orthographic skills.

The two dyslexic subgroups differed in the defining measure of overall orthographic coding, $F(1, 92) = 63.94$, $p < .01$, $\eta^2_p = .41$, and ORTH$^+$ also outperformed ORTH$^-$ on the four constituent variables: orthographic choice in Dutch, $F(1, 92) = 84.00$, $p < .01$, $\eta^2_p = .24$, and in English, $F(1, 92) = 82.35$, $p < .01$, $\eta^2_p = .48$, and the time to complete these orthographic choice tasks, Dutch, $F(1, 92) = 30.64$, $p < .01$, $\eta^2_p = .25$, and English, $F(1, 92) = 39.45$, $p < .01$, $\eta^2_p = .30$.

Phonological Coding

To test the assumption of a common phonological core among dyslexics, performance of the three groups on the phonological tasks is presented in Table 3.

The planned contrast between the ORTH$^-$ subgroup and the control adults revealed that ORTH$^-$ performed worse on word reversal, $F(1, 89) = 90.94$, $p < .01$, $\eta^2_p = .51$, and rapid serial naming, $F(1, 89) = 35.21$, $p < .01$, $\eta^2_p = .28$. ORTH$^+$ were also significantly below control adults on both word reversal, $F(1, 89) = 18.17$, $p < .01$, $\eta^2_p = .17$, and rapid serial naming, $F(1, 89) = 14.80$, $p < .01$, $\eta^2_p = .14$.

TABLE 3
Mean Scores, Standard Deviations, and Main Group Effects for the Control Adults and Two Dyslexic Subgroups on orthographic and phonological coding

	Control (57)		*ORTH⁺ (19)*		*ORTH⁻ (19)*		*MANOVA F*	*Effect Size*
Task (Max)	*M*	*SD*	*M*	*SD*	*M*	*SD*	*(2, 92)*	η^2_p
Orthographic choice L1 (40)	38.61	1.25	37.74	1.15	34.72	3.06	$34.82^{**}_{a,c}$	.43
Time orthographic choice L1 (seconds)	62.51	18.19	77.53	13.57	127.33	52.17	$38.41^{**}_{a,b,c}$	.46
Orthographic choice L2 (40)	39.51	.78	39.11	1.10	33.61	3.85	$72.51^{**}_{a,c}$	.61
655 Time orthographic choice L2 (seconds)	53.65	17.02	66.00	12.96	147.06	84.31	$39.27^{**}_{a,c}$	.46
Orthographic composite	1.94	1.23	.83	0.72	–5.16	4.71	$66.93^{**}_{a,c}$	.60
	(56)		(19)		(17)		*F*(2, 89)	
Word reversal (60)	55.29	3.37	50.29	4.59	44.58	5.91	$47.48^{**}_{a,b,c}$	.52
Rapid serial naming (seconds)	17.23	4.04	22.24	5.36	24.63	5.82	$20.68^{**}_{a,b}$	.32

Note. Orthographic composite = Orthographic choice L1 accuracy and time, orthographic choice L2 accuracy and time. Significant between-group differences are indicated by subscripts: $_a$Controls – ORTH⁻; $_b$Controls – ORTH⁺; $_c$ORTH⁺ – ORTH⁻. ORTH⁺ = superior orthographic coding, ORTH⁻ = inferior orthographic coding.

$^{**}p < .01$.

There was no significant difference between the two subgroups on rapid serial naming, $F(1, 89) = 2.34$, *ns*. However, ORTH$^+$ outperformed ORTH$^-$ on word reversal, $F(1, 89) = 16.39$, $p < .01$, $\eta^2_p = .16$. We return to this finding next.

Reading in Dutch and English

Reading ability in Dutch and English were compared across the three groups (see Table 4).

The ORTH$^-$ subgroup performed more poorly than the controls on all the Dutch reading tasks: word reading fluency, $F(1, 91) = 116.90$, $p < .01$, $\eta^2_p = .56$; pseudoword reading fluency, $F(1, 91) = 157.77$, $p < .01$, $\eta^2_p = .63$; flashed word identification, $F(1, 91) = 145.41$, $p < .01$, $\eta^2_p = .62$; flashed word production, $F(1, 91) = 103.86$, $p < .01$, $\eta^2_p = .53$; and flashed pseudoword production, $F(1, 91) = 147.55$, $p < .01$, $\eta^2_p = .62$. In addition, on the two English reading tasks ORTH$^-$ performed more poorly—English word reading fluency, $F(1, 90) = 103.26$, $p < .01$, $\eta^2_p = .53$, and flashed English word production, $F(1, 90) = 181.30$, $p < .01$, $\eta^2_p = .67$.

The ORTH$^+$ subgroup was also inferior to the control adults on all the Dutch reading tasks except flashed word production, $F(1, 91) = 1.77$, *ns*. Word reading fluency, $F(1, 91) = 38.77$, $p < .01$, $\eta^2_p = .30$; pseudoword reading fluency, $F(1, 91) = 66.04$, $p < .01$, $\eta^2_p = .42$; flashed word identification, $F(1, 91) = 44.26$, $p < .01$, $\eta^2_p = .33$; and flashed pseudoword production, $F(1, 91) = 51.16$, $p < .01$, $\eta^2_p = .36$. There was also a significant difference on the English word reading tasks—English word fluency, $F(1, 90) = 27.06$, $p < .01$, $\eta^2_p = .23$, and flashed English word production, $F(1, 90) = 7.16$, $p < .01$, $\eta^2_p = .07$.

As predicted, when the two dyslexic subgroups were compared, ORTH$^+$ outperformed ORTH$^-$ on Dutch word reading: fluency, $F(1, 91) = 15.00$, $p < .01$, $\eta^2_p = .14$; flashed word production, $F(1, 91) = 53.38$, $p < .01$, $\eta^2_p = .37$; and flashed word identification, $F(1, 91) = 20.74$, $p < .01$, $\eta^2_p = .19$; and also on English word reading: fluency, $F(1, 90) = 18.35$, $p < .01$, $\eta^2_p = .17$, and flashed English word production, $F(1, 90) = 81.39$, $p < .01$, $\eta^2_p = .48$. In addition, ORTH$^+$ was better on pseudoword reading fluency, $F(1, 91) = 14.29$, $p < .01$, $\eta^2_p = .14$, as well as flashed pseudoword production, $F(1, 91) = 17.85$, $p < .01$, $\eta^2_p = .16$.

To control for differences in phoneme awareness as an explanation of the differences in the reading measures as opposed to orthographic coding differences, the word reversal task was used as a covariate in the analysis of reading outcomes: Five of the seven differences remained significant. The differences between the ORTH$^+$ and ORTH$^-$ subgroup remained significant for flashed word identification, $F(1, 33) = 11.56$, $p < .01$, $\eta^2_p = .26$; flashed word production, $F(1, 33) = 9.09$, $p < .01$, $\eta^2_p = .22$; flashed pseudoword production, $F(1, 33) = 4.11$, $p = .05$, $\eta^2_p = .11$; English flashed word production, $F(1, 33) = 14.88$, $p < .01$, $\eta^2_p = .31$; and English word fluency, $F(1, 33) = 11.12$, $p < .01$, $\eta^2_p = .26$. However, the difference in

TABLE 4
Mean Scores, Standard Deviations, and Main Group Effects for the Control Adults and Two Dyslexic Subgroups on the Dutch and English Reading Measurements

	Control (57)		*ORTH⁺ (19)*		*ORTH⁻ (18)*		*MANOVA*	*Effect Size*
Task (Max)	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F(2, 91)*	η^2_p
Dutch								
Word reading fluency L1 (116)	106.14	9.65	85.68	14.61	69.89	17.04	$65.26^{**}_{a,b\ c}$	.59
Pseudoword reading fluency L1 (116)	102.19	12.89	68.68	21.60	49.33	15.99	$92.45^{**}_{a,b,c}$	.67
Flashed word identification (40)	35.04	2.61	30.63	2.11	26.89	2.49	$79.98^{**}_{a,c}$	.64
Flashed word production (40)	38.81	1.64	37.63	1.83	29.61	6.87	$52.66^{**}_{a,b,c}$	.54
Flashed pseudoword production (30)	21.02	2.89	14.79	3.75	10.22	3.92	$83.06^{**}_{a,b,c}$	.65
English	57		19		17		*F*(2, 90)	
Word reading fluency L2 (120)	97.88	18.12	74.21	16.16	49.65	14.71	$55.69^{**}_{a,b,c}$	.55
Flashed word production (50)	48.51	2.35	45.11	3.57	30.65	9.79	$90.81^{**}_{a,b,c}$	.67

Note. Significant between-group differences are indicated by subscripts: $_a$Controls – ORTH⁻; $_b$Controls – ORTH⁺; $_c$ORTH⁺ – ORTH⁻. ORTH⁺ = superior orthographic coding; ORTH⁻ = inferior orthographic coding.

$^{**}p < .01$.

Dutch word fluency and in (Dutch) pseudoword reading fluency disappeared after partialling out word reversal: word fluency, $F(1, 33) = 2.73$, *ns*; pseudoword fluency, $F(1, 33) = 1.91$, *ns*.

Cross-Script Comparisons

To test the prediction that ORTH+ will have an advantage reading English words that are more dependent on larger-unit orthographic processing, we examined the interaction between ORTH+ and ORTH– and flashed word production in Dutch and English. Consistent with PCVOD predictions, there is a greater difference between the groups in English: the ORTH+'s advantage is even greater in English than in Dutch: Greenhouse-Geisser, $F(1, 36) = 19.53$, $p < .01$, $\eta^2_p = .35$. It turns out that ORTH+ benefit from English in the flashed condition, where there are greater demands on orthographic coding. Even in (nonflashed) reading fluency an interaction was found: Greenhouse-Geisser, $F(1, 34) = 5.27$, $p = .028$, $\eta^2_p = .13$. The ORTH+ are better overall (summing across languages), and Dutch is easier overall (summing across groups), but, as predicted, the ORTH+ had a greater advantage in English.

Ruling Out Alternative Accounts for ORTH+'s Advantages

The PCVOD model predicts that the differences between the subgroups on orthographic coding are not due to differences in general intelligence, age, gender, or educational attainment (Table 5).

There were no differences between any of the groups on spatial ability or age. There was also no relationship between gender and group (control/ORTH+/ORTH–), $\chi^2(2, N = 95) = 1.52$, *ns*. Neither did the ORTH– subgroup differ significantly from the control adults on verbal competence, $F(1, 92) = 2.86$, $p = .09$, $\eta^2_p = .03$. The ORTH– subgroup, however, did have lower educational attainment than the control adults, U = 216, $Z = -4.17$, $p < .01$. The ORTH+ subgroup outperformed the control adults on verbal competence, $F(1, 92) = 4.83$, $p < .05$, $\eta^2_p = .05$. There were no differences on educational attainment, U = 538, $Z = -.05$, *ns*. The ORTH+ subgroup performed better on verbal competence, $F(1, 92) = 9.89$, $p < .01$, $\eta^2_p = .10$, than ORTH– subgroup, and there was a significant difference between the two subgroups on educational attainment, U = 71, $Z = -3.35$, $p < .01$.

To control for the differences in verbal ability as an explanation of the differences in the reading measures instead of orthographic abilities, the similarities task was used as a covariate in the analysis of reading measures. All significant differences between ORTH+ and ORTH– remained significant for all the reading measures. When educational attainment was used as a covariate, only the difference between ORTH+ and ORTH– on word reading fluency disappeared, $F(1, 38) =$

TABLE 5
Mean Scores, Standard Deviations, and Main Group Effects for the Control Adults and Two Dyslexic Subgroup on Control Measures

	Control (57)		*ORTH⁺ (19)*		*ORTH⁻ (19)*		*MANOVA*	*Effect Size*
Task (Max)	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F(2, 92)*	η^2_p
Spatial ability (GATB 3) (40)	25.70	6.09	27.16	3.92	23.65	6.54	1.65^{ns}	.04
Verbal ability (Screening) (26)	16.79	2.91	18.58	2.85	15.35	3.77	$5.03^{*}_{b,c}$	.10
Age (48)	37.72	4.49	38.11	3.30	36.35	4.12	$.90^{ns}$	.02
Educational attainment (7)[a]	5.88	1.14	5.89	1.15	4.29	1.61	$_{a,c}$	

Note. Significant between-group differences are indicated by subscripts: $_a$Controls – ORTH⁻; $_b$Controls – ORTH⁺; $_c$ORTH⁺ – ORTH⁻. Educational attainment = highest completed educational level—1 (primary school), 2 (lower secondary vocational education), 3 (lower general secondary education), 4 (upper general secondary education), 5 (preuniversity education), 6 (higher professional/vocational education), 7 (university).

ORTH⁺ = superior orthographic coding; ORTH⁻ = inferior orthographic coding; GATB = General Aptitude Test–Battery.

[a]Mann-Whitney statistics are reported in the text.

$^{*}p < .05$.

3.06, $p = .09$, $\eta^2_p = .08$. Once again, it appears that orthographic coding per se, rather than other alternative factors are responsible for the advantages of ORTH+.

Questionnaire Findings

With regard to English, ORTH− reported that they found it more difficult to read, $F(1, 87) = 51.61$, $p < .01$, $\eta^2_p = .37$; to speak, $F(1, 87) = 14.43$, $p < .01$, $\eta^2_p = .14$; to understand, $F(1, 87) = 13.29$, $p < .01$, $\eta^2_p = .13$; and that they needed more opportunities to recognize an unfamiliar word, $F(1, 87) = 25.50$, $p < .01$, $\eta^2_p = .23$, than the controls. ORTH+ also reported more difficulties with reading, $F(1, 87) = 4.18$, $p < .05$, $\eta^2_p = .05$, than the control adults and more time required to recognize an unfamiliar word, $F(1, 87) = 10.49$, $p < .01$, $\eta^2_p = .11$. There were no differences in understanding, $F(1, 87) = 1.12$, and in speaking ($F < 1$). ORTH− did differ from ORTH+ on two questions about perceived easiness of English: ORTH− reported more difficulties with reading, $F(1, 87) = 14.88$, $p < .01$, $\eta^2_p = .15$, and speaking, $F(1, 87) = 4.99$, $p < .05$, $\eta^2_p = .05$.

With regard to Dutch, ORTH− reported that they had more problems with reading, $F(1, 86) = 113.45$, $p < .01$, $\eta^2_p = .58$; spelling, $F(1, 86) = 120.62$, $p < .01$, $\eta^2_p = .59$; and reading subtitles, $F(1, 86) = 14.01$, $p < .01$, $\eta^2_p = .14$, than the controls. They also needed more encounters in order to recognize an unfamiliar word, $F(1, 86) = 40.91$, $p < .01$, $\eta^2_p = .33$. ORTH+ reported more difficulties with reading, $F(1, 86) = 29.96$, $p < .01$, $\eta^2_p = .26$, and spelling, $F(1, 86) = 41.26$, $p < .01$, $\eta^2_p = .33$, than the control adults. They also needed more time to recognize an unfamiliar word, $F(1, 86) = 21.33$, $p < .01$, $\eta^2_p = .20$. There were no reported differences in reading subtitles, $F(1, 86) = 1.30$. ORTH+ reported fewer difficulties than ORTH− with reading, $F(1, 86) = 10.88$, $p < .01$, $\eta^2_p = .12$, and spelling, $F(1, 86) = 7.52$, $p < .01$, $\eta^2_p = .08$. The subgroups reported equal difficulties with the subtitles, $F(1, 86) = 3.32$, *ns*, and they did not differ in the time they needed to recognize an unfamiliar word ($F < 1$). There were no significant differences between the groups in preferring Dutch or English in reading or spelling ($F < 1$).

On all questions regarding exposure to English and Dutch (reading and writing for work and for leisure L1 and L2), there were no group differences. There were also no differences on the questions involving computer use.

DISCUSSION

The first prediction of this study was that Dutch dyslexic adults suffer from a phonological core deficit in their relatively transparent native orthography. The findings confirmed that adult dyslexics have deficient performance on tasks of phoneme awareness, rapid serial naming and phonological recoding (pseudoword reading fluency). The dyslexics also had severe difficulties in word reading fluency and on all the (computerized) reading tasks. Supporting the universality of

their difficulties, the dyslexic adults also had severe reading problems in English. These differences did not appear to be due to a problem in general learning ability, because there were no differences on tasks tapping spatial ability and verbal competence. Therefore these findings support the view of dyslexia as a specific learning disorder (e.g., Stanovich, 1988). The fact that these dyslexics also performed below the much younger reading age control group on tasks tapping phoneme awareness, rapid serial naming and phonological recoding, provides strong evidence of a phonological core deficit. The finding that the adult dyslexics outperformed the reading age controls on English word fluency reflects the fact that they had much more experience with the English language. The reading age control group had not as yet received much formal teaching in English.

Our study also aimed to determine whether the PCVOD model of dyslexic heterogeneity can be extended to adult dyslexics. The prediction that orthographic coding contributes to the prediction of word reading fluency was confirmed because it explained additional variance after phoneme awareness and rapid serial naming were partialled out. This is consistent with the view (see Share, 1995) that orthographic coding is partly but not entirely parasitic on phonological processing. Our data also confirmed the prediction that dyslexics have significantly greater variability in orthographic coding than in phonological coding compared to control adults (Figure 1). These findings collectively confirm that orthographic abilities are an important source of heterogeneity within the dyslexic subpopulation.

Two findings jointly confirmed the central assumption of the PCVOD model that phonological and orthographic deficits are not equally important sources of reading difficulty. First, the combined dyslexic group's phonological skills fell below both chronological age *and* reading age controls, whereas their orthographic skills surpassed reading age controls. Second, the subgroup with superior orthographic abilities ($ORTH^+$) were comparable to normal (age-matched) readers in orthographic coding but performed poorly on phonological coding tasks, whereas the subgroup with inferior orthographic abilities was poor in both. These outcomes contrast sharply with the assumption of equivalence inherent in the surface/phonological typology founded on the dual route model (Castles & Coltheart, 1993; Coltheart et al., 2001).

Another prediction concerned differences in tasks that are commonly assumed to rely on the processing of larger orthographic units. As anticipated, the $ORTH^+$ subgroup had fewer problems reading English words, which tend not to adhere to the (relatively regular) Dutch grapheme–phoneme correspondence rules. In addition, the $ORTH^+$ subgroup was better on tasks tapping speeded word processing (flashed (pseudo)word identification and production in Dutch and English), which are also assumed to rely heavily on rapid processing of larger orthographic units. The $ORTH^+$ subgroup showed a larger effect of language and were better in the English (relative to Dutch) flashed word production task.

It might be argued that the ORTH+ subgroup were better readers, not because of their orthographic superiority, but owing to more exposure and reading experience than the ORTH− subgroup (as suggested by Stanovich et al., 1997). However, self-report data indicated that there were no differences in exposure to either Dutch or English between the two subgroups. In particular, data about English exposure may be considered a good test case for the development of individual differences in reading acquisition because not only is English a compulsory second language in the Netherlands at the secondary and tertiary level of schooling, but it also plays an important role in everyday life. The findings suggest that similar exposure had different effects on L2 learning in the two subgroups, in accordance with the predictions of the PCVOD model. There were, however, some minor experience-related differences. The ORTH+ subgroup indicated that they encountered fewer difficulties with Dutch reading and spelling than the ORTH− subgroup and that they considered English reading and spelling easier. These results, however, were in accordance with the finding that the ORTH+ subgroup members were better readers. When these variables were covaried, all the group differences remained, with the sole exception of pseudoword reading fluency which just lost its significance. It may be argued that pseudoword reading fluency (phonological recoding of unknown words) is relatively close to the phonological core in comparison to the other reading tasks. The other tasks either permit the use of lexical knowledge (e.g., word reading fluency in Dutch and English) or oblige the reader to use larger orthographic units owing to the brief presentation time. However, owing to the fallibility of self-report data, our data cannot conclusively dismiss the possibility of more experience and exposure as an alternative explanation, but it seems fair to say that there is little support for this alternative.

A potentially more damaging alternative explanation is that ORTH+ had less severe phonological deficits. The ORTH+ subgroup did indeed perform better on phoneme awareness and the reading task that depends heavily on phonological coding (pseudoword reading fluency). To investigate whether the reading differences between ORTH+ and ORTH− might simply be the product of the phoneme awareness advantage of the ORTH+ subgroup, we partialled out this factor. Five of the seven differences between the two subgroups on the reading tasks remained significant (the exceptions being Dutch word and pseudoword reading fluency). Moreover, the reliable differences that remained were, as anticipated, on those measures that appear to have a strong orthographic processing component (the English-language tasks and the flashed tasks in both languages). The fact that there were no differences between the subgroups in rapid serial naming is consistent with a number of studies finding that RAN is not reliably linked to orthographic processing (Bowey & Miller, 2007; Cunningham, 2006; Moll, Fussenegger, Willburger, & Landerl, 2009).

A third alternative explanation is that the ORTH+ subgroup had superior cognitive abilities. However, these adults did not differ on spatial ability, and although

the ORTH+ subgroup outperformed both the control adults and ORTH− subgroup in verbal ability, when verbal ability was used as a covariate, all the reading differences remained. These findings, therefore, do not support a general cognitive abilities explanation for the differences in reading performance between the two dyslexic subgroups.

One appealing interpretation of the findings is offered by the three components of the connectionist model: phonology, orthography, and semantics (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996). Within this framework, ORTH+ is mainly hampered when processing depends heavily on phonology. When orthography is predominant they perform at comparable levels to control adults. In semantics they may even have an advantage. These two strengths may enable them to compensate for their reading deficit to a certain extent particularly in circumstances that place a premium on orthographic processes (Snowling, 2000). It might be speculated that this explains the difference in educational attainment with ORTH−. ORTH− are far worse than ORTH+ in semantics and orthography but less so in phonology. Similar profiles were obtained in our earlier study of young Dutch adolescents (Bekebrede et al., 2009). A subgroup of dyslexics with better orthographic coding was less impaired in tasks tapping orthographic and semantic competence than in tasks tapping phonology, whereas ORTH− was hampered in all three.

In sum, although Dutch-speaking adult dyslexics share a core phonological deficit, there exists substantial variability in their orthographic coding as specified by the PCVOD model. Moreover, the dyslexic subgroup with greater orthographic coding was superior on all tasks that are conventionally assumed to involve the processing of larger orthographic units. These differences were not found to be attributable to nonorthographic factors such as phoneme awareness, general cognitive abilities or print exposure, or educational attainment. Above all, both subgroups can be classified as dyslexics by virtue of the fact that they fall far below typical readers on the majority (ORTH+) or all (ORTH−) of the reading and reading-related tasks.

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APPENDIX

Additional questions relating to computer use:

1. With how many fingers can you type?
2. Can you touch type? Yes/No

3. How often do you work at a computer?
   Every day/ Several times per week/ Once a week / Less than once a week
4. Do you work at the computer only at work or also for your leisure?
   Only at work/ Only for leisure/ Both at work and for leisure

***Questions relating to perceived easiness of the English language*:**

5. How easy do you find reading English?
   Very easy /Easy/ Not easy or difficult/ Not easy/ Not easy at all
6. After how many times do you recognize an unknown English word immediately?
   After one time/ After several times/ After many times/ Never
7. How easy do you find speaking English?
   Very easy /Easy/ Not easy or difficult/ Not easy/ Not easy at all
8. How easy do you find understanding English?
   Very easy /Easy/ Not easy or difficult/ Not easy/ Not easy at all

Questions relating to exposure of English:

9. On average how many hours a week do you spend on reading in English (books, magazines, newspapers, Internet)?
   a) For work/study: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
   b) For leisure: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
10. On average how many hours a week do you spend on writing in English (email, letters, diary)?
    a) For work/study: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
    b) For leisure: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week

Questions relating to preference for Dutch:

11. Do you have problems reading the subtitles on television?
    Yes/ No
12. Do you have problems with reading in Dutch?
    No problems/ A little/ Frequently/ Many/ Very much
13. After how many times do you recognize an unknown Dutch word immediately?
    After one time/ After several times/ After many times/ Never
14. Do you have problems with spelling?

No problems/ A little/ Frequent/ Many/ Very much

15. Are you better in reading English or Dutch?
    English/ Dutch/ Equally well
16. Are you better in writing English or Dutch?
    English/ Dutch/ Equally well

Questions relating to exposure of Dutch:

17. On average how many hours a week do you spend on reading in Dutch (books, magazines, newspapers, Internet)?
    a) For work/study: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
    b) For leisure: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
18. On average how many hours a week do you spend on writing in Dutch (email, letters, diary)?
    a) For work/study: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week
    b) For leisure: Less than 1 hour a week/ 1 to 3 hours a week/ 3 to 6 hours a week/ 7 to 10 hours a week/ More than 10 hours a week