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The /O/ in OVER Is Different From the /O/ in OTTER: Phonological Effects in Children With and Without Dyslexia

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First-letter naming was used to investigate the role of phonology in printed word perception in children with and without dyslexia. In 2 experiments, all children showed faster first-letter-naming times in a congruent condition than in an incongruent condition, which suggests that phonology is a fundamental constraint in the printed word perception of readers of all levels and all skills. An explanation in terms of a recurrent network put forward by G. C. Van Orden and S. D. Goldinger (1996) is discussed to account for the apparent paradox in the reading behavior of readers with dyslexia, that is, that in first-letter naming, dyslexic readers appear to show phonological congruity effects, whereas in pseudoword reading, their phonological knowledge appears to be deficient or absent.

The reading behavior of Dutch children at the beginning of first grade is characterized by the sounding out of each grapheme of a word, as in, for example, /mmm/. . . , /a/. . . , /t/. . . /MAT/. Some time later, these same children will respond almost instantaneously with /MAT/ upon visual presentation of the word *Mat* without showing overt phonological recoding.

Some researchers have held the opinion that beginning readers initially rely on the recoding of graphemes into phonemes (i.e., phonological recoding). With increasing experience, readers develop a second option that enables them to read words without the use of phonology, that is, they make a direct match between the printed word and a representation in memory (e.g., Backman, Bruck, Hebert, & Seidenberg, 1984; Doctor & Coltheart, 1980; Ehri, 1980, 1992; Reitsma, 1983). In the course of acquiring literacy, the role of phonology is assumed to become subsidiary (for dissenting views, see Gough & Hillinger, 1980; Juel, Griffith, & Gough, 1986; and Perfetti, 1995).[1]

Recently, however, a large number of studies have indicated that phonology is fundamental to the visual word perception of even highly skilled readers (e.g., Berent & Perfetti, 1995; Bosman & de Groot, 1995; Carello, Turvey, & Lukatela, 1992; Coltheart, Patterson, & Leahy, 1994; Frost, 1995; Perfetti & Zhang, 1995; Perfetti, Zhang, & Berent, 1992; Tan, Hoosain, & Peng, 1995; Van Orden, 1987; Van Orden, Pennington, & Stone, 1990; Ziegler & Jacobs, 1995; Ziegler, Van Orden, & Jacobs, 1997). A seminal example is the result obtained by Van Orden (1987) using a semantic-categorization task. Participants in his experiment were presented with a category name such as *flower* and subsequently saw a visual word stimulus. The stimulus either was an exemplar of the category of flower (e.g., ROSE) or was not (e.g., DOG). The participants' task was to evaluate whether the presented stimulus was a member of the category. To test the phonological activation hypothesis, Van Orden also presented his participants with homophones. A homophone is a word (e.g., ROWS) with phonology identical to, but orthography different from, that of an existing word (e.g., ROSE). The most important and interesting result was that experienced readers of English more often incorrectly classified homophones, such as ROWS, as a member of the predesignated category of flower than spelling controls, such as ROBS (a

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[1] It has also been claimed that children initially rely on nonphonologic reading and only later also learn to apply a phonologic strategy (e.g., Coltheart & Laxon, 1990; Marsh, Friedman, Welch, & Desberg, 1980; Rayner & Pollatsek, 1989).

word with spelling characteristics similar to those of ROWS but with dissimilar phonology). Van Orden's findings (and those reported since then) seriously challenge the hypothesis of the diminishing role of phonology in word perception with increasing reading skill.

In the present study we had two goals. First, we hoped to gain insight into the role of phonology in visual word perception during the course of acquiring literacy. To this end, we compared the performance of beginning readers with that of more advanced readers without reading problems on a first-letter-naming task. Second, we investigated whether the first-letter-naming performance of children with dyslexia would be different from that of children without dyslexia.

In the first-letter-naming task, participants are presented with words or letter strings and are asked to name as quickly and as accurately as possible the first letter of each stimulus (Bosman & de Groot, 1995; Rossmeissl & Theios, 1982; van Leerdam, 1995). We used the first-letter-naming task, because it enabled us to conduct reaction-time experiments with relatively young children (Bosman & de Groot, 1995; Goutbeek, 1994, Experiment 1). Goutbeek showed that reliable results could be obtained on the first-letter-naming task with children as young as 6 years.

Goutbeek (1994, Experiments 2 and 3) used two types of stimuli: long-vowel words and short-vowel words. A long-vowel word is a word in which one single consonant follows the vowel (e.g., ETEN; meaning, in English, food), whereas in a short-vowel word a cluster of two or more consonants follows the vowel (e.g., APPEL, ARTS, or ANGST, meaning, in English, apple, doctor, and fear, respectively). In Dutch, the pronunciation of the first letter of a long-vowel word (e.g., OVER) coincides with the letter name /o:/; the pronunciation of the first letter of short-vowel words (e.g., OTTER) coincides with the letter sound /o/ (i.e., the phoneme). Thus, if letter names are used to identify the first letter of a word, long-vowel words have a congruent pronunciation, and short-vowel words an incongruent pronunciation. But if letter sounds are used, the short-vowel words have the congruent pronunciation, and the long-vowel words the incongruent pronunciation.

Goutbeek (1994) found that beginning readers (children from Grades 1 and 2) and highly skilled readers (university students) who used letter names to identify the first letter named the first letter of long-vowel words (congruent stimuli) faster than the first letter of short-vowel words (incongruent stimuli). However, when these groups used letter sounds to identify the first letter, they were faster on the short-vowel words (congruent stimuli) than on the long-vowel words (incongruent stimuli). Bosman and de Groot (1995) and van Leerdam (1995) found similar effects using nonwords. These congruity effects suggest that in the first-letter-naming task, readers activate the phonology or words and nonwords whether it is helpful or not.

At this point, we would like to emphasize that it is not our belief that first-letter naming is part of silent reading. Just like any other laboratory task (e.g., naming, lexical decision, and semantic categorization), first-letter naming serves as a means to reveal hidden processes. The results obtained with first-letter naming strongly suggest that highly experienced and beginning readers activate the phonology of printed words even if the circumstances do not require it, as is the case in first-letter naming.

An interesting question that emerges from the results outlined above is whether performance on the first-letter-naming task will differ for children with and without dyslexia. Results from a large number of studies indicate that the main reading problem of children with dyslexia resides in a phonological deficit (e.g., Bradley & Bryant, 1978; Wagner & Torgesen, 1987; for a review, see Rack, Snowling, & Olson, 1992). The most consistent finding suggesting a phonological deficit in people with dyslexia is their problem with pseudoword reading (e.g., Murphy & Pollatsek, 1994; Pennington, Van Orden, Smith, Green, & Haith, 1990; Snowling, Hulme, & Goulandris, 1994; van den Bos & Scheepstra, 1993; Vellutino, Scanlon, & Spearing, 1995). Thus, if reading performance in people with dyslexia is seriously impaired because of a phonological deficit, that is, an absence of structured knowledge of orthographic–phonologic relations, one would expect children with dyslexia not to show the same phonological congruity effects observed in children without dyslexia.

However, an absence of phonological knowledge in people with dyslexia seems too strong a hypothesis (see Bruck, 1988). For example, Van Orden et al. (1990) and Van Orden and Goldinger (1996) reported strong phonological effects in adults with dyslexia performing semantic categorization. These people had great difficulty rejecting an incorrect homophone, for example, rejecting ROWS as an exemplar of the category *flower*. Apparently, the phonology of ROWS activated the exemplar ROSE. Similar results have been found for beginning readers (Bosman & de Groot, 1996) and for highly skilled readers (Coltheart et al., 1994; Jared & Seidenberg, 1991; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988) on the same task. These findings (a) indicate that phonology is fundamental to the reading both of beginning and skilled readers and of readers with dyslexia and (b) suggest that children with dyslexia will show phonological congruity effects just like people without dyslexia.

These two sets of findings present us with a paradox in the reading behavior of people with dyslexia. On the one hand, they appear to lack adequate phonological knowledge in a pseudoword-reading task, but on the other hand, they seem to be very susceptible to phonology in a semantic-categorization task. We address this issue in detail in the General Discussion.

In the present study, we conducted two experiments in which we used the first-letter-naming task to investigate the role of phonology in visual word perception. In Experiment 1 we used words, and in Experiment 2 we used nonwords. In both experiments, three groups of readers participated: children with dyslexia, children with a reading level equal to that of children with dyslexia (i.e., the reading-match group), and children whose chronological age matched that of the children with dyslexia (i.e., the age-match group). The children in the reading-match group served as a control group for the children with dyslexia, and they also constituted the group of beginning readers. Similarly, the children in the age-match group served as a control group for the children with dyslexia, and they constituted the group of more advanced readers.

The experiments were conducted in the Netherlands. Dutch orthography is shallow with respect to spelling-to-sound relations, which are highly consistent. For a more detailed description of Dutch orthography, refer to van Heuven (1980) or Reitsma and Verhoeven (1990). All children participating in this study were instructed according to the same reading curriculum, that is, *Veilig*

Leren Lezen (Caesar, 1979 [*Learning to Read Safely*]). It is the most widely used curriculum in the Netherlands, and it stresses the importance of phonics instruction.

Experiment 1

Method

Participants. Sixty children participated in this study. Twenty children constituted the group of children with dyslexia. They were recruited from a school for children with specific learning difficulties. The 40 remaining children were without reading problems and attended a regular primary school. These children were matched to the children with dyslexia on either chronological age (age-match group, 20 children), or on word-reading level (reading-match group, 20 children; see Backman, Mamen, & Ferguson, 1984, and Rack et al., 1992).

One week before the experiments were conducted, children's reading skills were assessed. Word-reading level was measured with a standardized reading-decoding test (Brus & Voeten, 1972). The score on this test is the number of words read correctly in 1 min. Pseudoword reading was assessed by means of a standardized pseudoword-reading test (van den Bos, Spelberg, Scheepstra, & de Vries, 1994). The score on this test is the number of pseudowords read correctly in 2 min. Table 1 presents the scores on the reading tests and the mean ages of the three experimental groups.

The children in the age-match group were as old as the children with dyslexia (mean age = 10 years 7 months), but the word-reading and pseudoword-reading levels of the age-match group were significantly higher than those of the children with dyslexia: $F(1, 38) = 77.2, p < .001$ for word reading, and $F(1, 38) = 78.7, p < .001$ for pseudoword reading. The children in the reading-match group (mean age = 8 years 1 month) were on average 2.5 years younger than the children with dyslexia. Performance on the word-reading test was the same for children in the reading-match group and children with dyslexia. However, the reading-match group performed significantly better on the pseudoword-reading test than did the children with dyslexia, $F(1, 38) = 24.5, p < .001$.

Note that our selection criteria for children with dyslexia coincide with Rayner and Pollatsek's (1989) definition of dyslexia: Children who score 2 or more years below their expected reading level (granted a normal IQ) are designated as dyslexic. IQ scores were not assessed, because the relevance of this variable with respect to reading problems is highly debatable. Siegel (1988, 1993) maintained that IQ does not contribute independent variance to word reading (but see, Leong, 1993, and Torgesen, 1989). Moreover, children in the Netherlands entering a school for specific learning disabilities are required to take an IQ test, and those with an IQ below normal are not admitted. Both the reading-match and the age-match groups consisted of an equal number of boys and girls, whereas the number of boys (65%) exceeded the number of girls (35%) in the group with dyslexia, a phenomenon found consistently in other studies (e.g., Dumont, 1984; Pennington, Lefly, Van Orden, Bookman, & Smith, 1987; Thomson, 1984).

Materials. Forty words were used in the experiment, 20 long-vowel words and 20 short-vowel words. The initial letter of each word was always a vowel, that is, an A, E, or O, and the second letter was always a consonant (i.e., a VC pair; V = vowel, C = consonant). The pronunciation of the first vowel depends on the orthographic structure of the word. Generally, in Dutch orthography the first vowel of words with a VCV* structure (e.g., ADEL, EVEN, or OVER) is pronounced as a long vowel (A is pronounced as /a:/, E as /e:/, and O as /o:/). The first vowel in words with a VCC* structure (e.g., ALBUM, ERF, or OTTER) is usually pronounced as a short vowel (A is pronounced as /a/, E as /e/, and O as /o/). Letter names were used to identify the first letter of these words, and thus long-vowel words constituted the congruent condition, and short-vowel words constituted the incongruent condition. The mean length of the two types of words was the same (4.1 letters in both cases). Appendix A presents the stimuli used in Experiment 1.

The 40 experimental stimuli were selected from a larger set of 60 words. Ten graduate students from the Department of Psychology of the University of Amsterdam indicated whether they considered the initial vowel of each presented word to be long or short. Words on which judges agreed unanimously and that were semantically familiar to the children were considered suitable for selection as experimental stimuli.

Procedure. The children were told that letter strings would appear on the computer screen and that they had to name the first letter of each word and ignore the word the first letter was part of. All children used letter names to indicate the first letter.

We ran the experiment on a Macintosh Classic computer. The stimuli were presented in lowercase letters of the Helvetica font. Helvetica is highly familiar to the children, because it is used in their reading books. The first letter of the word was always located at a fixed point in the center of the screen. A software program controlled stimulus presentation, stimulus randomization, response latency registration, and data recording.

Each trial started with an auditory warning signal 500 ms prior to presentation of the stimulus, which remained visible until the child had responded. Naming times were registered with a voice key and a millisecond timer. The experimenter evaluated the correctness of the response by pressing a key on the computer keyboard, thereby initiating the next trial. The children received 10 practice trials before the experiment proper.

Results

Before naming latencies were subjected to analysis, the following types of responses were removed from the data set: naming errors (2.8%), errors due to voice-key failure (3.8%), and extremely long responses (more than 3 *SD* above the mean; 1.5%). A three (reading group: dyslexic vs. reading match vs. age match) by two (stimulus type: long vowel vs. short vowel) analysis of variance was performed on both subjects' and items' mean latencies. Table 2 presents the mean latencies of the participants.

Table 1
Mean Age in Months, Sex Ratio, Mean Word-Reading Level, and Mean Pseudoword-Reading Level of All Readers

	Age			Word reading		Pseudoword reading		
Reading group	*M*	*SD*	Girls/boys	*M*	*SD*	*M*	*SD*	*N*
Dyslexic	127	8.9	7/13	37.3	10.1	19.3	7.5	20
Reading match	97	8.8	10/10	37.3	10.7	32.6	9.3	20
Age match	127	7.9	10/10	70.4	13.5	56.7	17.3	20

Table 2
Mean First-Letter Naming Times (in Milliseconds) of Experiment 1

	Initial vowel					
	Long		Short		Total	
Reading group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Dyslexic	694	128	725	126	710	124
Reading match	715	98	741	115	728	102
Age match	564	86	582	99	573	91
Total	657	124	683	133		

The significant main effect of stimulus type revealed that all three groups of readers named the first letter of long-vowel words (phonologically congruent stimuli) faster than the first letter of short-vowel words (phonologically incongruent stimuli): $F(1, 57) = 15.26, p < .001$ by subjects, and $F(1, 38) = 11.71, p < .01$ by items. The main effect of reading group was also significant: $F(2, 57) = 12.61, p < .001$ by subjects, and $F(2, 76) = 362.42, p < .001$ by items. Children in the age-match group were faster than those in the reading-match group (Newman–Keuls test, $p < .01$) and in the dyslexic group (Newman–Keuls test, $p < .01$). The apparently shorter response times of the dyslexic group compared with the reading-match group reached significance only in the item analysis: $F(1, 38) = 7.19, p < .01$ by items, and $F < 1$ by subjects. The interaction effect between reading group and stimulus type did not reach significance (both Fs < 1).

In a post hoc analysis, we tested whether children from the dyslexic group with severely limited reading skills differed from children from the dyslexic group whose reading skills were less impaired. Children who had a standard score on the pseudoword reading test between 0 and 3 ($n = 11$) were considered to be severely impaired readers, whereas those with a standard score between 4 and 6 ($n = 9$) were considered to be less impaired readers. The presence of the main effect of stimulus type and the absence of an interaction between level of reading impairment and stimulus type ($F < 1$) indicated that both groups behaved identically on this task.

Discussion

The most important result of Experiment 1 is that all three groups of readers named the first letter of phonologically congruent words faster than they named the first letter of phonologically incongruent words. The congruity effect, which we interpret as a phonological effect, was present in readers with different levels of word-reading skills. Moreover, the results from the post hoc analysis revealed a phonological congruity effect in even the most impaired readers.

Our results are in accordance with those reported by Goutbeek (1994). Highly skilled readers (university students) who performed first-letter naming on a similar set of words were also faster on long-vowel (congruent stimuli) than on short-vowel words (incongruent stimuli). The only difference between readers with different skills on the first-letter-naming task is overall naming time. Highly skilled readers show faster naming times than less skilled readers. The mean naming latency for Goutbeek's skilled readers was 466 ms, whereas in the present study the mean naming latencies were 573 ms for the age-match group, 710 ms for the children with dyslexia, and 728 ms for the reading-match group.

In sum, the results from the first-letter-naming task indicate that readers of all levels (beginning and more advanced) and all skills (with and without dyslexia) are similarly affected by the phonological properties of words. Stated more generally, these findings are in accordance with the assumption that phonology remains a fundamental constraint in the visual word perception of all readers. Further discussion of these findings is postponed until the General Discussion section.

Experiment 2

In Experiment 2, we presented nonwords to the same children. We wanted to investigate whether the phonological congruity effects established with words would also be obtained with orthographically legal nonwords. Moreover, establishing that phonological congruity effects occur with nonwords would indicate more strongly that subword phonology plays a part in printed word perception. In Experiment 2, two types of incongruent stimuli were used. These stimuli differed in the level of their incongruity, which enabled us to test whether children with dyslexia would show the same differential sensitivity toward words with different levels of congruity as would children and adults without dyslexia.

Method

Participants. The children of Experiment 1 also participated in Experiment 2. They took part in Experiment 1 first.

Materials. The stimuli, 60 legal monosyllabic nonwords, were identical to those used by Bosman and de Groot (1995, Experiment 3). All stimuli consisted of three letters. The initial letter of a stimulus was always a vowel, and was either an A, E, O, or U. Twenty stimuli had a VCC structure (e.g., ARG /arg/; single-vowel stimuli), 20 had a V_1V_1C structure (e.g., AAB /ab/; double-vowel stimuli), and 20 had a V_1V_2C structure (e.g., AUF /auf/; mixed-vowel stimuli). All spelling patterns used in this experiment were highly familiar to the children. These spelling patterns constitute a large and core part of Dutch orthography, and the children had been presented with them from the beginning of their formal reading instruction.

When letter names are used to identify the first letter of these nonword stimuli, the double-vowel stimuli constitute the congruent condition. The pronunciation of the first letter in double-vowel stimuli (e.g., AAB) is similar to the letter name (i.e., A). The pronunciations of the single-vowel stimuli and the mixed-vowel stimuli differ from the pronunciation of the letter name. Therefore, the single-vowel and the mixed-vowel stimuli constitute incongruent conditions. Note that the task required that the children always respond with the letter name. Appendix B lists the stimuli used in Experiment 2.

Procedure. The procedure of this experiment was identical to that of Experiment 1.

Results

Before naming latencies were subjected to analysis, the following types of responses were removed from the data set: naming errors (4.5%), errors due to voice-key failure (3.7%), and extremely long responses (more than 3 *SD* above the mean; 1.7%). A three (reading group: dyslexic vs. reading match vs. age match) by three (stimulus type: double vowel vs. single vowel vs. mixed vowel) analysis of variance was performed on both subjects' and items' mean latencies.

The main effect of reading group was significant: $F(2, 57) = 9.84$, $p < .001$ by subjects, and $F(2, 114) = 204.00$, $p < .001$ by items. The children in the age-match group showed faster first-letter-naming times than did the children in the reading-match group (Newman–Keuls test, $p < .01$) and the children in the dyslexic group (Newman–Keuls test, $p < .01$). The seemingly shorter naming latencies of the dyslexic group compared with the reading-match group were confirmed by a significant item analysis only: $F(1, 57) = 26.37$, $p < .001$ by items, and $p > .15$ by subjects. The mean latencies of the participants are presented in Table 3.

The main effect of stimulus type was also significant: $F(2, 114) = 65.27$, $p < .001$ by subjects, and $F(2, 57) = 65.63$, $p < .001$ by items. The first letter of double-vowel nonwords was named faster than the first letter of single-vowel nonwords (Newman–Keuls test, $p < .01$), which, in turn, was named faster than the first letter of mixed-vowel nonwords (Newman–Keuls test, $p < .01$).

This finding, however, needs qualification, because the interaction effect between reading group and stimulus type was also significant: $F(4, 114) = 6.01$, $p < .001$ by subjects, and $F(4, 114) = 7.98$, $p < .001$ by items. In a post hoc analysis, it appeared that both the children of the dyslexic group and those of the reading-match group named the first letter of double-vowel nonwords faster than the first letter of single-vowel nonwords (both groups, Newman–Keuls tests, $p < .05$), which, in turn, they named faster than the first letter of mixed-vowel nonwords (both groups, Newman–Keuls tests, $p < .05$). The children in the age-match group, however, named the first letter of double-vowel nonwords faster than the first letter of single-vowel and mixed-vowel nonwords (Newman–Keuls test, $p < .01$ in both cases), but no significant difference emerged between the single-vowel and the double-vowel nonwords.

As in Experiment 1, we performed a post hoc analysis on the group of children with dyslexia. Again, no difference emerged between those with severely impaired reading skills and those with less impaired reading skills.

Discussion

As in Experiment 1, in general all readers named the first letter of phonologically congruent stimuli more quickly than the first letter of phonologically incongruent stimuli. The reduced (nonsignificant) naming-time difference between double-vowel nonwords and single-vowel nonwords in the age-match group replicates the finding of Bosman and de Groot (1995). This difference between the double-vowel and single-vowel conditions was also reduced in their skilled adult readers compared with their beginning readers.

The results of Experiment 2 indeed suggest that phonological congruity is a matter of degree. Both the single-vowel nonwords and the mixed-vowel nonwords are considered phonologically incongruent when letter naming is required. Nevertheless, naming the first letter of single-vowel nonwords was faster than naming the first letter of mixed-vowel nonwords, which suggests that mixed-vowel nonwords are more incongruent than single-vowel nonwords. Single vowels (e.g., /a/) and double vowels (e.g., /a:/) are phonetically more similar to each other than to mixed vowels (e.g., /au/). Double vowels are in fact a lengthened version of the single vowels, whereas mixed vowels are diphthongs, an articulatory transformation from one vowel to another (an English example is the *ai* in TAIL).

An alternative explanation for the congruity effect established in Experiment 2 is that the context of single-vowel nonwords (e.g., ARG) and mixed-vowel nonwords (e.g., AUF) may produce lateral masking effects caused by incongruent flankers (Eriksen & Schultz, 1979; Ridderinkhof & van der Molen, 1995). In the double-vowel nonwords (e.g., AAB) the detection of the first letter is enhanced because of a congruent flanker. We would like to point out that this explanation only holds if naming the first letter of double-vowel nonwords always constitutes the fastest condition.

However, the results of a large number of experiments with beginning and fluent readers show that in the case of letter-sound naming, the single-vowel stimuli constitute the fastest condition (Bosman & de Groot, 1995, Experiment 3; Goutbeek, 1994, Experiments 2 and 3; van Leerdam, 1995, Experiment 3D). Using letter sounds to identify the first letter of nonwords causes the single-vowel nonwords to have the phonologically congruent pronunciations and the double-vowel and mixed-vowel nonwords to have the phonologically incongruent pronunciations. Using letter sounds (i.e., phoneme naming), beginning readers and skilled adult readers named the first letter of single-vowel nonwords faster than they named the first letter of double-vowel nonwords, which, in turn, were named faster than the first letter of mixed-vowel stimuli. In terms of the Eriksen paradigm (Eriksen & Schultz, 1979), the single-vowel nonwords (and the mixed-vowel nonwords) have incongruent flankers, whereas the slower double-vowel nonwords have congruent flankers.

To confirm our claim that first-letter naming in children with dyslexia is also based on phonology, we reran Experiments 1 and 2 with a new group of children with severe reading problems.[2] These children, however, were asked to identify the first letter using letter sounds instead of letter names. The statistical details of the results are presented in Footnote 2. As in children without dyslexia who were also asked to use phonemes, they were faster naming congruent stimuli (e.g., OTTER) than incongruent stimuli (e.g.,

Table 3
Mean First-Letter Naming Times (in Milliseconds) of Experiment 2

	Initial vowel							
	Double		Single		Mixed		Total	
Reading group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Dyslexic	689	135	743	164	785	193	739	160
Reading match	713	81	774	113	902	172	797	113
Age match	584	94	606	113	661	145	617	113
Total	662	118	708	149	783	195		

[2] A group of 15 children with severe reading problems was selected to participate in two experiments. This group of dyslexic readers contained 5 girls and 10 boys. Their mean age was 115 months (SD = 7.0). Their

OVER). In the nonword experiment, the same effect emerged: Congruent stimuli (single-vowel nonwords, e.g., ARG) were named faster than incongruent stimuli (double-vowel nonwords, e.g., AAB; and mixed-vowel nonwords, e.g., AUF).

These results contradict a lateral masking explanation. The mixed-vowel condition (e.g., AUF) is a condition in which the flanker of the first letter is incongruent (as is the case in the single-vowel condition; e.g., ARG). Only in the double-vowel condition (e.g., AAB) is the flanker congruent with the first letter. However, response times to the two conditions with incongruent flankers were faster than response times to the condition with a congruent flanker. Thus, these findings are incompatible with the lateral masking hypothesis and are in accordance with a phonological activation hypothesis.

To summarize, both children with dyslexia and children without dyslexia are affected by the phonological properties of nonwords when naming the first letter of these stimuli. The phonological congruity effects in our readers confirmed earlier findings with young beginning readers in Grade 1 and with highly skilled adult readers. Moreover, the phonological effects found with nonwords are highly similar to the phonological effects found with the words used in Experiment 1.

General Discussion

Both in Experiment 1, in which we used words, and in Experiment 2, in which nonwords constituted the set of stimuli, reliable congruity effects emerged. These effects suggest that while performing a first-letter-naming task, readers are unable to suppress the phonology of a visually presented letter string.

The hypothesis, advocated by a number of researchers (see our introduction), that with increasing reading experience the role of phonology diminishes, was not corroborated by the results of our experiments. The more advanced readers, who had about 4 years of formal reading instruction, showed the same phonological effects as the beginning readers, who had 1.5 years of reading instruction. The reading-match and age-match groups and the reading-impaired children showed strikingly similar performance on both versions of the first-letter-naming task, which suggests that phonology is a powerful constraint in printed word perception irrespective of reading level or reading skill (see also, Bosman, 1994; Bosman & de Groot, 1996; Bryant & Impey, 1986; Murphy & Pollatsek, 1994; Szeszulski & Manis, 1987).

It would, however, be incorrect to conclude from the above findings that children with dyslexia do not differ at all in their reading behavior from children without dyslexia. The performance of the children with dyslexia on the experimental tasks was similar to that of the age-match and the reading-match children, but the dyslexic children's scores on the pseudoword-reading test were significantly worse (see also the results obtained in German by Landerl, Wimmer, & Frith, 1997). These findings appear contradictory. The children with dyslexia appeared to use phonology in the experimental tasks but had great difficulty using it in the pseudoword-reading test.

Van Orden and Goldinger (1996) were the first to point out this apparent paradox pertaining to the reading behavior of children with developmental dyslexia. Not only do children with developmental dyslexia appear to be phonologically deficient when asked to read pseudowords, they also have great difficulty with a pig-Latin task. In a pig-Latin task, for example, the first phoneme of a word must be moved to the end and pronounced with /AY/ (e.g., /dog/ becomes /OGDAY/). People with dyslexia perform very poorly on this task compared with control participants with similar word-reading skills, even when they only need to recognize whether someone else has produced correct pig Latin (Pennington et al., 1990).

As mentioned in the introduction, other studies have also indicated strong effects of phonology in people with dyslexia. Van Orden and Goldinger (1996) and Van Orden et al. (1990) reported that adults with dyslexia made more errors in a semantic-categorization task than any other reading group they tested. Thus, some tasks indicate that people with dyslexia have problems using phonology, as in pseudoword reading and pig-Latin tasks, whereas in other tasks phonology appears to dominate their reading process (semantic categorization and first-letter naming). How do we reconcile these apparently contradictory findings?

A possible solution for this paradox may be found by looking at the different grain sizes of the orthographic–phonologic relation in words. The coarsest grain size of the orthographic–phonological relation is the one between a word's spelling and its phonology; it refers to the holistic sound attributed to a word and is the least refined level of the orthographic–phonological relation (see Van Orden & Goldinger, 1994). An intermediate-grain size of the orthographic–phonologic relation is at the subword level. Many words consist of syllables, morphemes, or multiletters, which constitute a subword orthographic–phonologic relation. A fine-grain size of the orthographic–phonologic relation of a word is the grapheme–phoneme relation, which reflects the statistical relations between graphemes and phonemes. This is the most refined level of spelling–sound relation available to readers of Dutch and English (in fact, to most speakers of alphabetic languages).[3]

Successful reading of pseudowords requires the constructive use of phonology at the level of graphemes and phonemes. Stated differently, pseudoword reading requires knowledge of fine-grain

word-reading and pseudoword-reading levels were assessed with the same tests as in the present study. Their word-reading level was 22.1 (SD = 7.4), and their nonword-reading level was 17.0 (SD = 5.6). Experiment 1 contained the same set of word stimuli as Experiment 1 of the present study; Experiment 2 used the same nonword stimuli as Experiment 2 of the present study. The only difference in the procedure was that participants were asked to name the first letter of each stimulus using phonemes. This change in task demands causes the short-vowel words to be congruent and the long-vowel words to be incongruent. As expected, the first letters of short-vowel words (896 ms, SD = 178) were named faster than those of long-vowel words (963 ms, SD = 254): $F(1, 14) = 6.83$, $p < .05$ by subjects, and $F(1, 38) = 4.80$, $p < .05$ by items. The results of Experiment 2 showed the same pattern. Again, the change in task demand (i.e., using phonemes instead of letter names) caused the single-vowel stimuli (954 ms, SD = 205) to be congruent and the double-vowel stimuli (997 ms, SD = 227) and mixed-vowel stimuli (1,072 ms, SD = 243) to be incongruent. This effect was also significant in both analyses: $F(2, 28) = 6.01$, $p < .01$ by subjects, and $F(2, 57) = 7.61$, $p < .01$ by items.

[3] An example of an alphabetic language with finer-grain phonologic information than at the letter-phoneme level is Vietnamese. In addition to 37 letters, six diacritics are used to differentiate phonemic tones (see Coulmas, 1996).

orthographic–phonologic structure. However, reading of actual words (e.g., in naming or categorization tasks) does not require fully developed knowledge of the statistical relations between graphemes and phonemes. Thus, word reading is possible when merely intermediate- or coarse-grain levels of the orthographic–phonologic structure are present. Van Orden and his colleagues described how a recurrent network model can establish coarse-grain and perhaps also intermediate-grain orthographic–phonologic structure in the absence of fine-grain orthographic–phonologic structure (Van Orden, Bosman, Goldinger, & Farrar, 1997; Van Orden & Goldinger, 1996).

The present study showed that children with dyslexia, compared with a group of nondyslexic children with similar word-reading levels, had great trouble reading pseudowords, which suggests the relative absence of knowledge of fine-grain structure in the reading-impaired group. At the same time, however, these children were as susceptible to the phonological properties of words and wordlike letter strings in the first-letter-naming task as were the reading-match and age-match children, which suggests that they may have developed some (perhaps less refined) level of orthographic–phonologic structure.

The present account also accommodates findings reported in the literature on metaphonological skills. Illiterate people (e.g., Morais, Cary, Alegria, & Bertelson, 1979; Roazzi, Dowker, & Bryant, 1994; for a review, see Bertelson & de Gelder, 1989), preschoolers (e.g., Goswami & Bryant, 1990; Liberman, Shankweiler, Fischer, & Carter, 1974), and readers of nonalphabetic writing systems (e.g., de Gelder, Vroomen, & Bertelson, 1993; Read, Zhang, Nie, & Ding, 1986) do not have problems with linguistic tasks requiring rhyme judgment or rhyme production and the manipulation of syllables, a skill that in terms of our approach requires knowledge of coarse-grain and/or intermediate-grain phonological structure. However, these groups often fail at tasks that require knowledge of fine-grain structure, as in phoneme deletion, phoneme blending, and pig-Latin tasks (see Duncan, Seymour, & Hill, 1997, for a similar explanation). All of these findings point to problems with phonology, a hypothesis put forward by Mattingly (1972) and Liberman (1973; see also Liberman & Shankweiler, 1991).

Our conclusion is that phonology is a fundamental constraint in the visual word perception (at least given an alphabetic script) of readers of all levels and all skills but that readers differ in their ability to use phonology at various levels. It appears that skilled readers have developed a knowledge of orthographic–phonologic structure at all necessary levels, whereas less able readers lack knowledge of fine-grain orthographic–phonologic structure but may have developed knowledge of intermediate-grain and coarse-grain levels.

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Appendix A

Stimuli Used in Experiment 1 (Translations in Parentheses)

Initial vowel		Initial vowel	
Long	Short	Long	Short
adel (nobility)	album (album)	ever (wild boar)	eng (narrow/eerie)
adem (breath)	alles (everything)	ezel (donkey)	enkel (ankle/single)
akelig (nasty)	altijd (always)	ober (waiter)	erf (premises/lot)
amen (amen)	ander (other/another)	ogen (eyes)	etter (pus/pain in the neck)
avond (evening)	anker (anchor)	olie (oil)	oksel (armpit)
edel (noble)	appel (apple)	oma (grandma)	om (roundabout/at, for, to)
egel (hedgehog)	ark (ark/houseboat)	opa (grandpa)	ons (us/hectogramme)
eten (to eat/food)	echt (real)	open (open)	op (up/in, on, at, to)
eter (eater)	emmer (bucket)	oven (oven)	orgel (organ)
even (even/just)	en (and)	over (over)	otter (otter)

Appendix B

Stimuli Used in Experiment 2

Initial vowel			Initial vowel		
Double	Single	Mixed	Double	Single	Mixed
aab	ant	auf	oos	ost	out
aat	arg	aul	oob	orp	ouf
aaf	ast	aud	oop	olf	ouk
aam	arp	aup	oof	org	oup
aad	asp	auk	ool	orf	oul
eeb	elg	eum	uuf	uls	uik
eep	ers	euf	uum	urp	uip
eek	eps	eul	uud	ust	uis
ees	erp	eug	uun	urg	uif
eeg	est	euk	uut	urm	uid

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