Word-recognition processes in normal and dyslexic readers
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Chapter 3

Children use vowel digraphs as perceptual units in reading: Evidence from dyslexic and normal readers

Abstract

Digraphs are graphemes that are composed of two letters like the ou in soup. We hypothesized that the serial-reading strategy of dyslexic readers might interfere with the processing of digraphs. We used a letter-detection task to compare the processing of vowel digraphs in dyslexic and normal reading children. Both groups were found to be slower in detecting a letter within a vowel digraph than in detecting a letter of a single-letter grapheme. In addition, the dyslexic children were slowed down to a similar degree as the normal readers when detecting a letter embedded in a digraph. Finally, we found that the slower response to target letters embedded in a digraph was position independent in both groups. These results indicate that normal reading and dyslexic children process vowel digraphs as perceptual units.

3.1 Introduction

In alphabetic orthographies, graphemes are the orthographic counterpart of phonemes (Rey & Schiller, 2005). The word *stop* for example, consists of four different single-letter graphemes (*s/t/o/p*). However, most languages consist of more phonemes than letters to represent them. Therefore alphabetic orthographies often use two or more letters to express a single phoneme (Borgwaldt, Hellwig, & de Groot, 2004). The word *soup* for instance has also four letters, but only three graphemes (*s/ou/p*). The *ou* is an example of a digraph: two letters map onto one sound. There are two different kinds of digraphs. The first kind, the homogeneous digraph, consists of two equal letters (e.g., *oo*). The second kind, the heterogeneous digraph, is formed by two different letters (e.g., *ou* or *ch*).

The digraph forms an inconsistency that has to be resolved during reading. One way to solve this inconsistency is by processing the digraph as a perceptual unit instead of as two separate letters. Processing the digraph as a unit before the sound is linked to the orthographic form is an effective way to suppress the phonemes that are linked to the separate letters of the digraph (e.g., the *o* and *u* of *ou* in *soup*). The idea that skilled adult readers resolve the inconsistency of a digraph by processing it as a perceptual unit is also in line with the finding of Rey, Ziegler and Jacobs (2000) that graphemes, and not letters, are the functional reading units in alphabetic writing systems.

The issue of digraphs is also of interest to computational models of reading. In a recent computational model, the Connectionist Dual Process model (CDP+, Perry, Ziegler, & Zorzi, 2007), letter strings are visually parsed into graphemes before each of them is linked to their corresponding sound. However, according to the Dual Route Cascaded model (DRC, Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) letters and not graphemes are the functional units in the reading system. In contrast to the CDP+ model, the DRC model postulates a print-to-sound conversion system in which each letter is processed one by one. Whenever a word or pseudoword contains a grapheme that is spelled by a sequence of two letters, the phoneme belonging to the first letter of the digraph will be activated during the period that there is access to the first letter. Only at the time that the second letter of the grapheme comes into the view, the phoneme that belongs to the digraph begins to be activated (Jackson & Coltheart, 2001). It takes some time before the digraph phoneme has overruled the activation of the phoneme of the first letter. The delay caused by this activation was denoted as the “whammy effect” (Rastle & Coltheart, 1998).

Research on the processing of digraphs has mainly focused on skilled adult readers. Some of these studies used a letter-detection paradigm (Brand, Giroux, Puijalon, & Rey, 2007; Rey et al., 2000) or a phoneme-detection paradigm (Peereeman, Brand, & Rey, 2006) to examine whether digraphs are processed as perceptual units. The rationale behind the detection paradigm is that, if the reading
system processes certain letter clusters as a unit, detection of a target letter is relatively hard if the letter is embedded in a cluster (Gross, Treiman, & Inman, 2000; Healy, 1994). For example, the *a* in *class* should be easier to detect than the *a* in *peach*, because in the first case the letter corresponds to a single-letter grapheme whereas in the latter case the letter is embedded within a digraph. Thus far, all detection studies have showed that skilled adult readers are slower in detecting a letter when the target letter was embedded within a digraph than when it mapped on a single-letter grapheme thereby providing evidence for the use of digraphs as perceptual units by skilled adult readers.

Although digraphs seem to be treated as perceptual units, naming studies with skilled adult readers have demonstrated that the presence of digraphs nevertheless produces a processing cost relative to single-letter graphemes (Andrews, Woollams, & Bond, 2005; Rastle & Coltheart, 1998; Rey & Schiller, 2005). Rastle and Colthart argued that this delay is due to the letter-by-letter processing of the separate letters of a digraph (the whammy effect). Such a letter-by-letter processing hypothesis seems to be at odds with the findings of the detection studies.

In addition, the results of the letter-detection studies are not entirely consistent. Brand et al. (2007) found some evidence for the serial reading of the letters in a digraph. Brand et al. showed that the slower detection of a letter in a digraph was restricted to the letter on the second position. The detection speed of skilled adult readers for the first letter of a digraph did not differ from the detection speed for the same letter as a single-letter grapheme in the same position in another word of similar length. However, the detection speed for the second letter of a digraph was slower than for its single-letter grapheme counterpart in a matched word. This response pattern is not in accordance with the view that digraphs are processed as perceptual units and supports a serial letter-by-letter process as postulated by the DRC model (Coltheart et al., 2001). In contrast, results of a study by Peereman et al. (2006) provided evidence for digraphs as perceptual units. Peereman et al. found that it was equally difficult for skilled adult readers to give a NO response to the phoneme belonging to the first letter as to the phoneme belonging to the second letter of a heterogeneous vowel digraph. This finding is at odds with the predictions of the DRC model, as the phoneme belonging to the second letter of the digraph should never become activated in the serial letter-by-letter processing mechanism. Peereman et al. suggested that during the processing of a digraph the phonological codes corresponding to both the single letters and the letter cluster are activated in the phoneme system. In terms of treating digraphs as perceptual units this would mean that, although there is a preference for the reading system to treat digraphs as a unit, the sounds belonging to the separate letters of the digraph are still causing interference.

The few digraph studies that have been conducted with children show that words containing digraphs are challenging for beginning readers across different orthographies. Elbro (2005) examined the acquisition of consonant digraphs
in Danish, English and German children (grade 1 to 4). It was found that the beginning readers made more errors in pseudowords with complex consonant graphemes than in pseudowords consisting of single-letter graphemes only. In addition, research with English children (Davis & Bryant, 2006) has shown that seven year old children had little difficulty in reading or spelling short vowel CVC words, but made many mistakes with words containing digraphs. Davis and Bryant did find a developmental change in the children’s appropriate use of split digraphs (e.g., the \textit{a-e} in \textit{fate}) over two years, however, there was a lack of progression in the use of non-split digraphs (e.g., the \textit{oa} in \textit{goat}).

Beginning readers’ difficulties with the processing of digraphs might be explained by their use of a letter-by-letter strategy to decode words (Zoccolotti et al., 2005). Such serial reading strategies have also been found in dyslexic readers (Martens & de Jong, 2006; Spinelli et al., 2005; Zoccolotti et al., 2005). It could be that digraphs pose a challenge for beginning and dyslexic readers because their letter-by-letter reading strategy interferes with the processing of digraphs as perceptual units. However, Marinus and de Jong (2008) recently found that normal and dyslexic readers were equally hampered by the visual distortion of a digraph. Although the general reading speed of the dyslexic children was slower than that of the normal readers, they were slowed down to the same degree when a digraph unit was visually distorted.

The aim of the current study was to replicate the finding that both normal and dyslexic readers process digraphs as perceptual units with the letter-detection paradigm. To our knowledge, this is the first study examining unification processes in normal reading and dyslexic children by means of a letter-detection task. In a naming task, Bosman, Leerdam, and de Gelder (2000) found Dutch normal reading and dyslexic children to be faster in naming the first letter of a three-letter pseudoword when the letter corresponded to a single-letter grapheme (e.g., the \textit{a} in \textit{arg}) than when the letter corresponded to a digraph (e.g., the \textit{a} in \textit{aug}). Based on their findings and the findings of previous studies with skilled adult readers (Brand et al., 2007; Rey et al., 2000), we predicted that both normal reading and dyslexic children would be slower in detecting a letter within a digraph as compared to a letter corresponding to a single-letter grapheme. If dyslexic children have difficulties in processing digraphs as perceptual units, we expected that this delay would be \textit{less strong} for the dyslexic children. However, if dyslexic children are equally proficient in processing digraphs as perceptual units, a similar delay should be expected in normal and dyslexic readers.

The current study was conducted with Dutch normal reading and dyslexic children. Dutch is an interesting orthography to examine the processing of digraphs. Firstly, digraphs are a highly frequent phenomenon in the Dutch language. According to the CELEX database, half of the Dutch monosyllabic words contains a digraph (Baayen, Piepenbrock, & van Rijn, 1993), making it a highly salient unit from a statistical point of view (Pacton, Perruchet, Fayol, & Cleeremans, 2001).
Secondly, the pronunciation of Dutch digraphs is very consistent. Whereas the *ea* digraph in English can be pronounced in several ways (compare, for instance, *steak* and *heal*), Dutch digraphs are always pronounced the same. Thirdly, in Dutch educational methods digraphs are explicitly taught as blended units. Together these three factors make it highly plausible that the reading system of Dutch children processes digraphs as perceptual units.

For the current study we used three and four-letter words with and without heterogeneous vowel digraphs. We had two reasons to restrict the study to heterogeneous vowel digraphs. Firstly, the pronunciation of Dutch homogenous digraphs is similar to the name of the target letter. Secondly, heterogeneous vowel digraphs seem to pose the largest problems to beginning readers. We decided to focus on heterogeneous *vowel* and not on heterogeneous *consonant* digraphs. In Dutch vowel digraphs are more numerous and diverse, making it easier to select a representative sample of target words. In the original letter-detection experiment of Rey et al. (2000) the digraph presence and absent conditions were matched for number of letters. We also added three letter words without a digraph to match for number of phonemes.

### 3.2 Method

#### 3.2.1 Participants

Twenty-four dyslexic grade-4 children (11 boys and 13 girls) and 24 normal reading children (11 boys and 13 girls) were selected for participation. All children attended regular education and had normal or corrected to normal vision. The ages of the dyslexic children ranged from 9 years and 2 months to 10 years and 11 months, with a mean age of 9 years and 11 months. The ages of the normal reading children ranged from 9 years and 4 months to 10 years and 7 months, with a mean age of 9 years and 11 months. The dyslexic children were individually matched with the normal reading children on receptive vocabulary, non-verbal intelligence, age and gender.

The dyslexic and normal reading children were selected from a group of 498 grade-4 children of 15 different schools in the area of Purmerend (The Netherlands). Normal word reading ability was defined to range from three months below to three months above the average reading level. For the dyslexic group, children with a reading lag of at least 1.5 years were selected. As a consequence, their reading level equaled the level of normal reading children in the beginning of or halfway grade 2. The characteristics of the groups are presented in Table 3.1.

Word reading ability was assessed with the Dutch One-minute test (Brus & Voeten, 1995), a speeded test for single-word reading. This test is commonly used to determine the reading level of children in Dutch primary schools. The test consists of 116 words of increasing difficulty. The children were instructed to read
the words aloud as quickly as possible, without making errors. The score is the number of words read correctly within one minute. This score was transformed into a norm score expressing the reading age of the child in months. All children read both the A and the B version of the test. The final score was the average of the norm scores of the two versions.

Table 3.1
Descriptive statistics of the characteristics of the dyslexic and normal readers: mean (M) and standard deviation (SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dyslexic</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>9.9 (0.4)</td>
<td>9.9 (0.4)</td>
</tr>
<tr>
<td>Reading level (standard score)</td>
<td>62.8 (5.1)</td>
<td>99.6 (2.0)</td>
</tr>
<tr>
<td>Vocabulary score</td>
<td>45.3 (3.2)</td>
<td>45.6 (4.5)</td>
</tr>
<tr>
<td>Nonverbal reasoning score</td>
<td>36.4 (7.4)</td>
<td>37.0 (6.5)</td>
</tr>
</tbody>
</table>

Receptive vocabulary of the children was measured with the subtest Vocabulary of the RAKIT, a Dutch intelligence test battery for children (Bleichrodt, Drenth, Zaal, & Resing, 1987). This test consists of 60 words of increasing difficulty. For each word the children had to choose the corresponding picture out of four alternatives. When a child made four errors in a row, the administration of the test was stopped. The score was the number of correct answers.

Finally, nonverbal reasoning was assessed with the Raven Standard Progressive Matrices (Raven, Court, & Raven, 1986). This test consists of 60 items. On each item the children had to choose a pattern from a set of answer options to complete a series of patterns. The score was the number of correct answers.

3.2.2 Materials and design
Sixty target-presence words, containing the target letter, and 60 target-absent words were selected. The target-present and target-absent words consisted of three types of words: 20 three-letter words with three graphemes (3L3G, e.g., *mes* [knife]), 20 four-letter words with three graphemes (4L3G, e.g., *voet* [foot]) and 20 four-letter words with four graphemes (4L4G, e.g., *fles* [bottle]). The 4L3G and 4L4G words were pair-wisely matched for position of target vowel. For instance, in both *fles* [bottle] and *voet* [foot] the target letter *e* occurs in the third position. We did not match the different word conditions for word frequency because Rey et al. (2000) demonstrated that letter detection latencies are unaffected by the frequency of the target word. However, the majority of the words were highly frequent (Baayen et al., 1993) and familiar to grade-4 children (Schrooten & Vermeer, 1994). The words are presented in Appendix B.

The 120 words were divided into four blocks in which the target letter differed (*e*, *i*, *o* and *u*). Each block consisted of an equal number of target-present and
target-absent words and an equal number of each word type (3L3G, 4L3G and 4L4G). We only selected words with the following heterogeneous vowel digraphs as a nucleus: oe, ie, eu, ei, ui and ou. The digraph ie has the same pronunciation as the letter name i. It might therefore be expected that it is easier to detect the i in ie than in ei of ui. To avoid such facilitating phonemic similarity effects (see also Rey et al., 2000), we did not present words with an ie digraph in the block in which i was the target letter. Finally, the Dutch pronunciation of the single-letter vowels (a, e, i, o, u) differs from the sound of the letter names of the vowel. Therefore, possible advantages in letter-detection speed for target letters in single-letter grapheme words cannot be attributed to phonemic similarity effects.

3.2.3 Procedure

The letter-detection task was administered during school hours. There were four versions of the letter-detection task in which the order of the different blocks with different target letters was systematically varied. The normal and dyslexic readers were randomly assigned to one of the four versions of the task.

The c key of the keyboard was covered by a red sticker and the m key was covered by a green sticker. For left-handed children the stickers were reversed. The children were instructed to push the green button when the target letter occurred in the word they saw on the screen and to push the red button when the target letter was absent. Before each block the children were asked to write down the target letter to make sure that they knew the target letter and to minimize confusion which letter was the target in the block at hand. The words within a block were presented in random order. Each block was preceded by five practice trials.

The words were presented one by one in the middle of a 14.1-inch XGA LCD screen of a D600 Pentium-M 1.3-GHz computer. The words were printed in 46-point lower-case black Arial font, on a white background. A fixation point (+) was projected in the middle of the screen and the word appeared 750 ms later.

The computer registered latencies and responses. The latencies were defined as the time between the appearance of the stimulus and the moment that the child hit one of the keys. The stimuli disappeared as soon as the child touched one of the keys.

3.3 Results

Trials with response times below 325 ms (premature responses) and outliers were omitted. An outlier was defined as a latency that differed by more than three standard deviations from a child’s mean. Outliers were calculated separately for the target-present and target-absent trials and the different word types.

For each child, a mean latency score was computed for each word type by
target-present/target-absent condition. Mean latencies were calculated over correct trials only. On average mean latency scores were based on 92.4% ($SD = 3.8$) of the total of twenty trials in a condition.

The error percentages and mean latencies for the dyslexic and normal reading children in each word condition are presented in Table 3.2. Both groups showed the highest error percentage in the digraph condition. However, because of ceiling effects (accuracy scores were higher than 90% for all conditions), we did not further analyze the error percentages. In addition, we only analyzed the responses to target-present trials (see Rey et al., 2000).

Table 3.2

<table>
<thead>
<tr>
<th>Latency</th>
<th>L3G3</th>
<th>L4G3</th>
<th>L4G4</th>
<th>Percentage of Errors</th>
<th>L3G3</th>
<th>L4G3</th>
<th>L4G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>708</td>
<td>805</td>
<td>734</td>
<td>3.3</td>
<td>8.2</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(123)</td>
<td>(157)</td>
<td>(153)</td>
<td>(4.1)</td>
<td>(8.9)</td>
<td>(4.6)</td>
<td></td>
</tr>
<tr>
<td>Dyslexic</td>
<td>746</td>
<td>830</td>
<td>757</td>
<td>2.1</td>
<td>4.6</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(127)</td>
<td>(176)</td>
<td>(116)</td>
<td>(2.9)</td>
<td>(3.3)</td>
<td>(4.0)</td>
<td></td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses.

The mean latencies of the target-present trials were separately subjected to a multivariate analyses of variance for repeated measures with Reading Group (dyslexic or normal) as a between-subjects factor, and Condition (three-letters-no-digraph, four-letters-digraph and four-letters-no-digraph) as the within-subjects factor. To test the hypothesis that the children were slower in detecting a target letter within a digraph, two contrasts were specified on the Condition factor. The first concerned the comparison of the three-letter and four-letter words without a digraph. The aim of this contrast was to determine whether it was more difficult to find a target letter in a three-letter as compared to a four-letter word and to examine whether the baseline letter-detection effects were position dependent. This contrast will further be denoted as the “Length contrast”. The second, and most important, contrast compared the responses to the four-letter words with a digraph with the four-letter words without a digraph. This contrast will be referred to as “Digraph contrast”. For all contrasts, a significant main effect indicated a mean score difference between the conditions that were compared, whereas a significant contrast by Reading Group interaction implied that the magnitude of this difference varied between the dyslexic and normal reading children.

There was no significant main effect for Reading Group in the analysis across groups, $F_1 < 1$, $ns$. However, across items the main effect for Reading Group did reach significance, $F_2 (1, 57) = 12.18, p < .01, \eta_p^2 = .18$. These different outcomes were probably due to the larger power of the item analysis. The main effect for Condition was also significant, $F_1 (2, 45) = 20.41, p < .001, \eta_p^2 = .48$,
$F_2 (2, 57) = 18.78, p < .001, \eta^2_p = .40$. Follow-up contrasts were specified to further examine this effect.

We did not find a significant effect for the Length contrast, $F_1 (1, 46) = 1.86, p > .10, F_2 (1, 57) = 1.32, p > .10$, nor did we find a significant interaction of Length and Reading Group, $F_1 < 1, ns, F_2 < 1, ns$. The detection speed did not differ for letters embedded in a three-letter or four-letter word without a digraph and this effect did not differ between the groups. In all three-letter words, the target letter was always on the second position in the word (e.g., mes [knife]). In the four-letter words the target letter could be either on the second or the third position (e.g., best vs. fles [bottle]). To further examine whether the detection speed was position independent, we specified an additional contrast on the four-letter words, comparing the words with the target letter on the second position (e.g., best) and third position (e.g., fles [bottle]). The position effect nor the interaction with Reading group was significant, $F_1 < 1, ns, F_2 < 1, ns$.

The Digraph contrast was significant, $F_1 (1, 46) = 27.53, p < .001, \eta^2_p = .37, F_2 (1, 57) = 21.52, p < .001, \eta^2_p = .27$. The children were significantly slower in detecting a target letter within a digraph unit than detecting a target letter in a word with an equal amount of letters but without a digraph. The Digraph by Reading Group interaction was not significant, $F_1 < 1, ns, F_2 < 1, ns$. The effect did not differ for the normal reading and dyslexic children.

Following Brand et al. (2007), we conducted an additional analysis to investigate whether the slower response to a target letter embedded in a digraph was position dependent. Two separate mean latency scores for position 2 (based on nine trials for both the digraph and single-letter grapheme words) and two separate mean latency scores for position 3 (based on eleven trials for both the digraph and single-letter grapheme words), were computed (see Table 3.3).

### Table 3.3

Mean response times (in ms) for the normal reading and dyslexic children in the different position and word-type conditions of the four-letter words.

<table>
<thead>
<tr>
<th>Position 2</th>
<th>Position 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single-letter</td>
</tr>
<tr>
<td>Normal</td>
<td>721 (127)</td>
</tr>
<tr>
<td>Dyslexic</td>
<td>776 (127)</td>
</tr>
</tbody>
</table>

*Note. Standard deviations are in parentheses.*

As reported by Brand et al., we specified two contrasts. The first contrast examined the digraph effect for the first position and the second contrast for the second position. In contrast to Brand et al. we found slower responses to target letters in both the first, $F_1 (1, 46) = 25.97, p < .001, \eta^2_p = .36, F_2 (1, 36) = 15.15, p < .001, \eta^2_p = .30$, and the second position of the digraph, $F_1 (1, 46) = 9.06, p < .01, \eta^2_p = .17, F_2 (1, 36) = 6.34, p < .05, \eta^2_p = .15$. Although the effects seemed to be stronger for the first position, the two position effects did not differ
significantly, $F_1 \ (1, \ 46) = 2.09, \ p > .10, \ F_2 \ (1, \ 36) = 1.44, \ p > .10$. No significant Position by Reading Group interaction effects were found, $F_1 < 1, \ ns, \ F_2 < 1, \ ns$.

### 3.4 Discussion

The aim of the current study was to examine whether normal reading and dyslexic children process digraphs as perceptual units. Following Rey et al. (2000), we used a letter-detection task. The critical question in this paradigm is whether the children are faster in detecting a target letter in a word corresponding to a single-letter grapheme (e.g., *e* in *best*) as compared to detecting a target letter that was embedded within a digraph unit (e.g., *e* in *boek* [book]). Slower reaction times in the digraph condition would indicate that the children were processing the digraph as a perceptual unit. If dyslexic children were having difficulties processing digraphs as perceptual units, this delay should be less strong for the dyslexic children. However, it was found that both groups were slower in detecting target letters in digraphs and that this effect was equally strong for the normal and dyslexic children. It was therefore concluded that both normal reading and dyslexic children process digraphs as perceptual units. This conclusion is in line with the finding that the reading of normal reading children is hampered to a similar degree by the visual distortion of a digraph (Marinus & de Jong, 2008).

In addition, we found that the slower response to target letters embedded in a digraph was position independent, lending further support that digraphs are not processed letter-by-letter. This outcome is in contrast to what was reported by Brand et al. (2007). Brand et al. found that the unitization effect was restricted to the second letter of a digraph and interpreted these results as evidence for the serial letter-by-letter processing mechanism as postulated by the DRC model (Coltheart et al., 2001). However, and in line with the naming results of Bosman et al. (2000), we also found a unitization effect for the first letter of a digraph for the normal reading and dyslexic children in our study. The different outcomes might be explained by differences in language and educational background of the participants.

In the Introduction we explained that Dutch digraphs are both highly frequent and consistent in terms of print-to-sound correspondences, making it practically and statistically highly salient units (Pacton et al., 2001). Moreover, in Dutch education, children are explicitly taught to decode digraphs as units. We therefore assume that the reading system of Dutch children is strongly attuned to processing digraphs as perceptual units. Finally, it might be that the mode of stimulus presentation influenced the unitization process. Brand et al. presented the digraph and single-letter grapheme words in separate lists, whereas in the current study the different word types were presented in mixed lists.

In the CDP+ model (Perry et al., 2007), the parsing of letters into graphemes has been implemented as a serial process. However, in the current study it was
found that the children were equally fast in detecting a letter in a three-phoneme as in a four-phoneme word. In addition, we demonstrated that the detection speed did not differ for letters matching on single-letter graphemes of the second or third position in a word (e.g., e in best vs. e in fles [bottle]). In terms of computational modeling, these findings suggest that the grapheme buffer parses all graphemes of a word in parallel instead of in a serial way.

Surprisingly, we found very little differences in overall detection speed between the normal and dyslexic readers. This finding is at odds with the results of a number of studies showing that dyslexic children perform weaker on visual-processing tasks than normal reading children (Hawelka, Huber, & Wimmer, 2006; Hawelka & Wimmer, 2005; Valdois, Bosse, & Tainturier, 2004). However, in all these studies dyslexic readers had to give a verbal response to a presented stimulus. Recently, Hawelka and Wimmer (2008) demonstrated that on a visual task that did not require a verbal response, dyslexic readers did not differ from normal readers. The negligible differences that we found thus may be a consequence of the fact that our letter-detection task did not involve verbal responses either. The lack of influence of frequency effects on detection latencies as found by Rey et al. (2000) can also be interpreted as evidence that the letter-detection paradigm taps preverbal or prelexical processes, which in the current study were found to be intact in dyslexic readers.

However, when a verbal response is required then differences in the processing of a digraph between normal and dyslexic children might become apparent. Indeed, Marinus and de Jong (submitted) recently found in a study with dyslexic children and normal readers that pseudowords with a digraph were named more slowly than pseudowords without a digraph. In contrast to adult readers (Andrews et al., 2005; Rastle & Coltheart, 1998; Rey & Schiller, 2005), however, the naming delay in these children was found to be on top of the grapheme-length instead of on top of the letter-length effect. Interestingly, this effect was stronger in beginning grade-2 and dyslexic readers than in normal grade-4 readers. The findings of the current study suggest that, as long as dyslexic children do not have to link the sounds to the presented letter or letter string, their processing of digraphs does not differ from their normal reading peers. However, as soon as a naming response is required, the differences become apparent.