Word superiority, pseudoword superiority, and learning to read: A comparison of dyslexic and normal readers

Jonathan Grainger, Sébastien Bouttevin, Cathy Truc, Mireille Bastien, and Johannes Ziegler

Laboratoire de Psychologie Cognitive, Université de Provence, 29 Av. Robert Schuman, 13621 Aix-en-Provence, France

Accepted 6 May 2003

Abstract

Identification of letters embedded in briefly presented words (e.g., TABLE), pseudowords (e.g., TOBLE), and illegal nonwords (e.g., TPBFE) was measured using the Reicher–Wheeler paradigm. Children diagnosed as dyslexic and showing a clear disadvantage in recognizing and reading aloud words and pseudowords (compared to chronological age-matched controls) showed a pattern of results that was qualitatively identical to both reading age and chronological age control children. In all three groups a small nonsignificant advantage was obtained for letter identification in words compared to pseudowords, and a massive advantage for letter identification in pseudowords compared to illegal nonwords. A group of adult participants tested with the same materials showed the classic word superiority effect as well as a pseudoword advantage over illegal nonwords. These results suggest that the pseudoword superiority effect is subtended by regularities operating at the level of sublexical orthographic representations (orthotactic constraints). This phenomenon could provide a useful tool for future investigations of the development of orthotactic constraints during reading acquisition.

1. Introduction

The word superiority effect (WSE) was first established as a basic phenomenon related to reading ability in the work of Cattell (1886). Cattell showed that people could recall more letters from briefly presented words than briefly presented meaningless strings of letters. Cattell (and many others, see Henderson, 1982, for discussion) interpreted this finding as ruling out a letter-based account of visual word recognition. How could word recognition be letter based if a word can be recognized before its constituent letters?

In the second half of the 20th century, two major developments have helped improve our understanding of the WSE, one methodological and one theoretical. First, Reicher (1969) and Wheeler (1970) proposed an improved methodology for studying the WSE, now commonly referred to as the Reicher–Wheeler task. This methodological innovation was designed to counter two possible artifacts in the WSE reported by Cattell: (i) words can be held in memory better than unrelated strings of letters, and hence the WSE could be due to memory loss in letter report from pseudowords; and (ii) participants might be able to use partial letter information to guess word identities (a strategy that would not work for pseudoword stimuli). Reicher (1969) and Wheeler (1970) asked participants to respond using a two-alternative forced choice task, where they had to decide which of two possible letters was present at a given position in a briefly presented string of letters. Since only a single letter is tested, memory load can no longer affect performance. Furthermore, since the alternative letter always formed a word (when the target was a word, e.g., test for D and K in the last position of WORD), participants could not get the correct letter by simply guessing a word from partial letter information (e.g., WOR?).
Second, McClelland (1979) and McClelland and Rumelhart (1981) provided two means by which a letter-based model of visual word recognition could capture the WSE. One possibility is by using feedback from the word to the letter levels of representation (McClelland & Rumelhart, 1981). Activation of word units leads to a reinforcing of the activation of their component letter representations, thus allowing more accurate letter perception in words than in pseudowords. The other possibility arises from the cascaded nature of activation flow in interactive activation networks (McClelland, 1979). Cascaded activation provides the theoretical possibility that activation at higher levels of representation (e.g., words) can develop faster than at lower levels of representation (e.g., letters). Grainger and Jacobs (1994) implemented this possibility in their dual read-out model of word context effects on letter perception. In Grainger and Jacobs’ dual read-out model, responses in the two-alternative forced choice task are generated by a process of letter identification. Letters can be identified directly on the basis of activity in letter representations (letter read-out) or can be inferred following word identification (word read-out). If a letter is not identified by either of these processes, then a default “guess” strategy is applied. The WSE is explained by the advantage gained from having an additional “word” read-out mechanism that can be used when individual letter identification fails.

Research using the Reicher–Wheeler paradigm blossomed in the 1970s and gave rise to a complete account of the necessary and sufficient conditions for obtaining a WSE. This research also revealed the existence of related phenomena such as the pseudoword superiority effect (PSE): two-alternative forced-choice accuracy is higher for letters embedded in orthographically regular, pronounceable nonwords called pseudowords (e.g., TOBLE) compared to irregular, unpronounceable nonwords (e.g., TPBFE). Baron & Thurstone, 1973; Carr, Davidson, & Hawkins, 1978; Estes & Brunn, 1987; Grainger & Jacobs, 1994; McClelland, 1976; McClelland & Johnston, 1977; Paap, Newsome, McDonald, & Schvaneveldt, 1982). According to Grainger and Jacobs (1994), the PSE is the result of misperceiving a word that is similar to the pseudoword stimulus. When the stimulus TOBLE is presented very briefly with pattern masking, then on some trials participants may misperceive the stimulus as TABLE. This word misperception can then lead to correct letter report when the letter in the stimulus and the misperceived word match (e.g., the T in TOBLE). According to this account, exactly the same mechanism underlies the WSE and the PSE. Similarly, in the interactive-activation model (McClelland & Rumelhart, 1981), it is the same word–letter feedback mechanism that accounts for the WSE and the PSE. Pseudoword stimuli partially activate their real word neighbors (e.g., TOBLE activates TABLE) which then reinforce the activation of their component letters.

Alternatively, the PSE could reflect some sort of perceptual fluency that is generated by stimulus familiarity independently of lexical status (Carr, 1986; Henderson, 1982). One source of this fluency could be the pronounceability of the string (Ziegler & Jacobs, 1995). Alternatively, this hypothetical perceptual fluency could be related to uniquely orthographic aspects of processing, such as frequency of letter combinations (i.e., orthotactics). Of course, pronounceability is closely tied to orthotactic regularity: letter strings that are orthotactically irregular will tend to be unpronounceable. Hooper and Paap (1997) tested for phonological influences on the WSE and the PSE. They found that pseudowords that were homophonic with a real word (pseudohomophones, e.g., WERD that can be pronounced the same as WORD) produced lower levels of accuracy when the forced choice involved a letter from the real word counterpart (e.g., testing E/O at the second position in WERD). This is in line with the earlier finding of Hawkins, Reicher, Rogers, and Peterson (1976), showing a homophone disadvantage in the Reicher–Wheeler task (e.g., testing for E/A at the third position in WEAK, homophonic with WEEK, generates lower levels of performance compared to nonhomophonic words).

Nevertheless, these possible phonological influences on the PSE have been shown to be subject to strategic modification, since the effect is stronger when words are included in the experiment (Hooper & Paap, 1997). Furthermore, they may be specific to the very special type of stimuli (pseudohomophones) that were used to investigate them. Because it is quite difficult to tease apart the effects of orthographic redundancy from the effects of pronounceability by manipulating stimulus characteristics, in the present research we followed a different approach. Rather than manipulating stimulus characteristics, we studied the WSE and PSE with a group of dyslexic children who have a marked phonological deficit. Note that the majority of dyslexic children have a phonological deficit that can easily be detected in a variety of phonological tasks, such as short-term memory, phonological awareness, or rapid automatized naming (Goswami, 2000; Ramus, 2001; Snowling, 2000). All of these children would also exhibit a marked difficulty in reading pseudowords, which can be seen as the hallmark of developmental dyslexia.

The fact that dyslexic children exhibit poor phonological skills in the presence of rather normal and sometimes even superior orthographic skills (e.g., Siegel, Share, & Geva, 1995) provides an excellent way of studying whether word and pseudoword superiority effects are due to processes of phonological fluency (pronounceability), orthographic redundancy, or lexical feedback. In short, if word and pseudoword superiority

---

1 A similar pseudohomophone disadvantage was reported by Ziegler and Jacobs (1995) using a letter search task.
effects are based on phonological fluency, then dyslexic children should show a reduced PSE because of their phonological deficit that affects pseudoword reading. Instead, if the effects are based on exploiting orthographic regularities of the letter string, dyslexic children should show a PSE that is similar to that of a control group.

These predictions were tested in a group of dyslexic children. Performance of the dyslexic children was compared to a group of younger children who were matched in terms of reading age (RA). Because dyslexic children lag behind in lexical development due to their limited exposure to written material, it was important to compare their performance to a group of readers who were reading at the same reading level (RA-controls). Lexical development and lexical knowledge should be fairly comparable in these two groups as indicated by the same reading level. Hypothetically, the only major difference between the dyslexic and the RA group was in terms of phonological skills and pseudoword reading, and this is the difference that we were most interested in with regard to testing the above predictions. Also, testing relatively young readers (i.e., the RA-control group) will allow us to investigate the impact of lexical influences on the PSE. What is critical here is whether or not a PSE can be observed in the absence of a WSE in younger readers. In all prior studies with adult participants that included a word, pseudoword, and nonword context in the Reicher–Wheeler paradigms, a PSE was always accompanied by a WSE (e.g., Estes & Brunn, 1987; Grainger & Jacobs, 1994; McClelland, 1976).

In summary, in the following experiment, we investigate letter identification accuracy in words, pseudowords, and nonwords in both dyslexic children and reading-age controls. In addition to the Reicher–Wheeler task, we included a lexical decision and a reading aloud task for the same item material. The lexical decision task was meant to provide a measure for lexical knowledge and lexical development for the two groups of participants. The reading aloud task was included as a control to check that the dyslexic children did indeed exhibit deficient pseudoword reading skills even in comparison to a younger group of readers. Below, we summarize the predictions generated by three possible interpretations of the PSE outlined above. The predictions are centered around whether or not the PSE can be dissociated from the WSE, and whether or not dyslexic children will show a PSE similar to reading-age and chronological-age controls.

1. Lexical interpretation. The PSE results from word misperception (Grainger & Jacobs, 1994), or word–letter feedback (McClelland & Rumelhart, 1981). According to this account, a PSE must necessarily be accompanied by a WSE, independently of the participants that are tested.

2. Sublexical–phonological interpretation. The PSE results from the better pronounceability of pseudowords compared to nonwords (Hooper & Paap, 1997). According to this account the PSE can be dissociated from the WSE (different underlying mechanisms), but the PSE effect should be smaller in the dyslexic children because they show a marked difficulty in pseudoword reading.

3. Sublexical–orthographic interpretation. The PSE results from the increased familiarity of letter combinations (orthotactics) in pseudoword compared to nonword stimuli (Massaro & Cohen, 1994). According to this account the PSE can be dissociated from the WSE and should be observed in the dyslexic and the normal readers.

2. Experiment 1

2.1. Method

2.1.1. Participants

Two groups of children were tested in this study; 18 children attending a specialized school for children diagnosed as dyslexic (Les Lavandes, Orpierre, France) and 18 children attending regular primary school (Ecole Sallier, Aix-en-Provence, France), and matched in reading age with the dyslexic children. The characteristics of the two groups of participants are given in Table 1. Reading age was measured using the “Alouette” test, a standardized test for the French language.

2.1.2. Design and stimuli

A set of 20 French 5-letter words were selected such that either the second or the fourth letter could be changed to form another 5-letter word (e.g., FORME-FERME; ROUTE-ROUGE). The other word that could be formed by a letter change at a given position determined the alternative letter given in the two-alternative forced-choice procedure (e.g., FORME: O/E at 2nd position; ROUTE: T/G at 4th position). Letter identification was tested at position 2 in half of the stimuli and position 4 in the other half. A pseudoword stimulus was generated from each word by changing one letter (e.g., ROUTE-ROUTE). All pseudowords were pronounceable, orthographically legal letter strings in French. Nonword stimuli were generated by keeping the critical letter (either the 2nd or the 4th) of the word and pseudoword stimuli and randomly adding consonants to

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Summary statistics (mean age in years and months, with range in parentheses) for the two groups of participants (dyslexic and reading age controls) tested in Experiment 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reading age</td>
</tr>
<tr>
<td>Dyslexic</td>
<td>7.6 (6.7–9.8)</td>
</tr>
<tr>
<td>Reading age controls</td>
<td>7.6 (6.7–9.1)</td>
</tr>
</tbody>
</table>
form illegal letter strings (e.g., TOVBR). Thus the same letter pairs (target plus alternative) were tested in three different contexts: word, pseudoword, and nonword.

2.1.3. Procedure
Each participant was tested first in the Reicher–Wheeler task, followed by a lexical decision and word naming task. In the Reicher–Wheeler task, each trial began with the presentation of a pattern mask composed of five hash marks accompanied by fixation bars aligned above and below the center of the mask. The forward mask with fixation bars was presented for 500 ms and immediately followed by a string of five letters in upper case for a duration of 200 ms. The letter strings were replaced by a second string of hash marks accompanied by two letters positioned above and below either the 2nd or the 4th position of the string. The post-mask with two letters remained on the screen until participants responded by selecting which of the two letters had been present on the screen at the indicated position (2nd or 4th). Participants were under no time pressure to respond. Stimulus presentation was randomized with a different order for each participant. After performing the Reicher–Wheeler task, the children were then asked to perform a lexical decision task (with no time restrictions) on the same set of word and pseudoword stimuli that were tested in the Reicher–Wheeler task. Immediately after classifying a given stimulus as a word or a pseudoword, the child had to read the stimulus aloud. The words and pseudowords remained on the screen until the experimenter initiated the following trial. Incorrect pronunciations were noted by the experimenter. Correct pseudoword pronunciation was determined by the standard rules of French spelling-to-sound correspondences. The words and pseudowords were presented in a different random order to each participant.

2.2. Results

2.2.1. Reicher–Wheeler task
The mean percent correct letter recognition scores as a function of context and group are given in Fig. 1. An ANOVA was performed on these data with participants as the random variable, and context (word, pseudoword, nonword) and group (dyslexics and RA-controls) as main factors. There was a main effect of context on letter identification scores \(F(2, 68) = 35.49, p < .001\). As can be seen in the figure, the dyslexic group showed a small advantage over the RA-controls but this difference was not significant \(F(1, 34) = 1.63\). The Group \times Context interaction was not significant \(F < 1\). Planned comparisons indicated that the difference between the word and pseudoword contexts was not significant \(F(1, 34) = 1.07\), while the difference between the pseudoword and nonword contexts was highly significant \(F(1, 34) = 42.12, p < .0001\).

Fig. 1. Performance of the dyslexic children and the reading age control (RA-control) children in the Reicher–Wheeler task of Experiment 1.

2.2.2. Lexical decision task
The data from the lexical decision task are illustrated in Fig. 2A. As can be seen in the figure, there was no difference between the dyslexic and the control children. This was confirmed in the statistical analysis, which showed no significant effect of Group \(F < 1\), and no significant interaction between the effects of Group and Lexicality \(F(1, 34) = 1.19\). Only the main effect of Lexicality was significant \(F(1, 34) = 9.04, p < .01\), which reflected the fact that more errors were made to pseudowords (incorrectly classified as being a word) than to words. Together then, lexical knowledge for the two group of participants was fairly similar, at least for the items used in the present study. This is what would have been expected given that these groups were matched for reading age.

2.2.3. Reading aloud
The reading aloud data are presented in Fig. 2B. The analysis showed that the dyslexic children read slightly less well than the control children although this difference failed to reach significance \(F(1, 34) = 2.81\). Most importantly, however, the dyslexic children were much poorer in reading pseudowords than their controls, which is reflected in the significant interaction between the effects of Group and Lexicality \(F(1, 34) = 5.37, p < .05\). In general, words were read aloud correctly more often than pseudowords in both groups \(F(1, 34) = 57.03, p < .0001\).

2.3. Discussion
The results of Experiment 1 show a massive pseudoword superiority effect in the absence of a word superiority effect (over and above the pseudoword context) in both groups of children. This result allows us to rule out a word misperception account of the PSE, as
proposed by Grainger and Jacobs (1994), at least for the present testing conditions and participants. Any lexically based account of the PSE would predict a healthy advantage for word contexts compared to pseudoword contexts, as is typically observed in experiments testing adult participants. The fact that this is not found in the present experiment suggests that, at least for the children tested here, the PSE is generated by differences in sublexical regularities across the pseudoword and nonword contexts. The fact that the dyslexic children showed the same PSE as the reading age control children, while showing a significant handicap in reading aloud pseudoword stimuli, suggests that the sublexical regularities subtending the PSE are different from the sublexical regularities involved in spelling-to-sound conversion.

3. Experiment 2

The absence of a WSE in Experiment 1 could have been due to the limited lexical development of the children in Experiment 1, who had an average reading age of only 7.6 years. Thus, in Experiment 2 we asked older children, who had the same chronological age as the dyslexic children, to perform the same tasks. Older children with higher reading abilities might be expected to show a WSE in association with the PSE. A further failure to observe this pattern would provide strong evidence against a lexical interpretation of the PSE.

3.1. Method

3.1.1. Participants

Eighteen children individually matched in chronological age to the dyslexic children and pursuing regular primary (Ecole Sallier, Aix-en-Provence) or secondary education (College Mignet, Aix-en-Provence). The mean chronological age was 11.4 years (range 9.4–12.7, see Table 1 for the corresponding values for the dyslexic children). These children were not tested for reading age, but none were designated by their teachers as having any particular difficulty at school.

3.1.2. Design and stimuli

These were the same as in Experiment 1, except that only one group of participants was tested.

3.1.3. Procedure

An initial group of chronological age control children showed performance levels close to ceiling (100%) for the word context when using the same stimulus presentation duration as for the two previous groups. It was therefore decided to reduce the stimulus duration (from 200 to 100 ms) for this group in order to avoid problems in interpreting any potential differences across groups. The procedure was otherwise identical to the previous experiment.

3.2. Results and discussion

The mean percent correct letter recognition scores as a function of context in the Reicher–Wheeler task are given in the left-hand panel of Fig. 3. An ANOVA was performed on these data with participants as the random variable and context (word, pseudoword, nonword) as main factor. There was a main effect of context on letter identification scores (F(2, 34 = 33.60, p < .001). Planned comparisons showed that there was no significant difference between the word and pseudoword contexts (F < 1), but a highly significant difference between the pseudoword and nonword contexts (F(1, 17) = 45.13, p < .0001). An ANOVA including the data from the dyslexic children from Experiment 1 showed that there was no overall difference in performance between the two groups (F < 1), and the
Group × Context interaction was not significant ($F < 1$).

The chronological control children performed the untimed lexical decision task with high accuracy (99.2% accuracy for words, 95.3% for pseudowords). An ANOVA was performed combining the data from this control group and the dyslexic children tested in Experiment 1. This showed a main effect of group, with the chronological age controls being more accurate than the dyslexic children ($F(1,34) = 11.21, p < .01$). There was a main effect of stimulus type with superior performance on words compared to pseudowords ($F(1,34) = 10.35, p < .01$) and no interaction between these two factors. The reading aloud data from the chronological control group were near ceiling performance and were therefore not submitted to any further analysis.

The results of Experiment 2 indicate that a group of children matched in chronological age to the dyslexic children tested in Experiment 1 show the same pattern of results in the Reicher–Wheeler paradigm. Stimulus presentation was reduced from 200 (Experiment 1) to 100 ms with the chronological age controls tested in Experiment 2, thus showing the superior overall performance of these participants. Furthermore, as expected the chronological control children performed with higher levels of accuracy than the dyslexic children in both the lexical decision task and the reading aloud tasks. However, an analysis comparing the effects of context on letter perception in the dyslexic and chronological control groups showed no interaction. Just like in Experiment 1, the chronological age control children of Experiment 2 showed a massive PSE in the absence of a significant WSE.

An important characteristic of the pattern of results observed in all groups of participants tested in Experiments 1 and 2 is the absence of the classic WSE when using pseudowords as the comparison. Although prior studies using similar stimuli and testing conditions have systematically observed a WSE in adult participants, it appeared important to demonstrate that this was indeed the case with the stimuli tested in the present experiments. This was examined in Experiment 3.

### 4. Experiment 3

#### 4.1. Method

##### 4.1.1. Participants

Eighteen students at the University of Provence participated for course credit. All were native speakers of French and reported having normal or corrected-to-normal vision.

##### 4.1.2. Design and stimuli

These were the same as in the previous experiments.

##### 4.1.3. Procedure

Stimulus exposure duration was varied in a preliminary test phase in an attempt to have average performance levels similar to those of the children tested in the previous experiments. In order to equate performance levels, average stimulus exposure was shorter for the adult participants (approximately 50 ms). The procedure was otherwise identical to the previous experiment, except that only the Reicher–Wheeler task was used.

#### 4.2. Results and discussion

The mean percent correct letter recognition scores as a function of context in the Reicher–Wheeler task are given in the right-hand panel of Fig. 3. An ANOVA was performed on these data with participants as the random variable and context (word, pseudoword, nonword) as main factor. There was a main effect of context on letter identification scores ($F(2, 34) = 17.73, p < .001$). Planned comparisons showed that there was a significant difference between the word and pseudoword contexts ($F(1, 17) = 7.26, p < .01$) and a significant difference between the pseudoword and nonword contexts ($F(1, 17) = 12.20, p < .01$). An ANOVA including the data from Experiment 2 (chronological age control children) showed that, given our efforts to equate performance levels by adjusting stimulus duration, there was no significant difference across the groups ($F < 1$), and the Group × Context interaction was not significant ($F(2, 68) = 1.59$).

The results of Experiment 3 show that the standard pattern of word and pseudoword superiority effects is observed in adult participants using the same stimuli as tested in the previous experiments with children. The pattern observed with adult participants is very similar to that reported by McClelland (1976) testing the same...
three conditions in the Reicher–Wheeler paradigm (0.85, 0.78, 0.69 for the word, pseudoword, and nonword contexts in McClelland’s study, compared to 0.86, 0.80, and 0.70, in Experiment 3). The lack of a significant difference between the word and the pseudoword contexts observed in Experiments 1 and 2 was not therefore due to the particular stimuli that were tested. Nevertheless, the effects of context failed to interact significantly with group (children vs. adults) in an analysis combining the data of Experiments 2 and 3. This implies that, when equated for overall levels of performance, the children and adult participants generated similar effects: a massive pseudoword superiority compared to nonword contexts, and a small advantage for word contexts compared to pseudowords that is only statistically significant when analyzed separately for the adult participants.

4.3. General discussion

In three experiments a group of dyslexic children, their corresponding reading age and chronological age control children, and one group of adult participants were tested with the Reicher–Wheeler task (Reicher, 1969; Wheeler, 1970). Forced-choice accuracy in deciding which of two possible letters was present at a particular position (either the 2nd or the 4th position) in a string of 5-letters varied mostly as a function of the orthographic regularity of the string (pseudowords versus illegal nonwords) reflecting a phenomenon referred to as the pseudoword superiority effect (PSE). The fact that the letter string formed a familiar word did not influence performance over and above the pseudoword condition in the three groups of children that were tested, reflecting an absence of the classic WSE in these participants. However, the WSE was observed in Experiment 3 with a group of skilled adult readers. It is the dissociation (a PSE in the absence of a WSE) found in three groups of children that is the first critical finding of the present study. The second critical finding concerns the pattern of results obtained with a group of dyslexic children. These participants showed a significant disadvantage in reading pseudowords aloud compared to reading-age matched control children, yet showed the same pattern of results in the Reicher–Wheeler task.

In all the groups of children tested in the present study, a PSE was obtained in the absence of a WSE. As noted in the introduction, prior studies with adult participants showing a significant PSE also systematically showed an advantage for the word context compared to the pseudoword context (WSE). This led Grainger and Jacobs (1994) to propose a word misperception account of the PSE, whereby a pseudoword (e.g., TOBLE) would (on some trials) be misperceived as a word (e.g., TABLE), thus improving forced-choice accuracy (e.g., L/R at fourth position). In support of this account, in unpublished experiments we have demonstrated a “pseudoword inferiority effect” where forced-choice performance is worse in pseudowords compared to nonword stimuli when the neighboring word provides the wrong information (e.g., testing for A/O at the second position in TOBLE). However, similar to the pseudohomophone disadvantage reported by Hooper and Paap (1997), the pseudoword inferiority effect is probably the result of a “word identification” strategy that participants can apply in certain experimental conditions. Such strategies can certainly influence the size of observed word and pseudoword superiority effects, but may not be the main causal factor.

The present results clearly rule out any interpretation of the PSE observed in these experiments in terms of word misperception. If this were the case, then a clear advantage for words compared to pseudowords should have been observed. Similarly, this pattern of results cannot be accounted for by word–letter feedback in an interactive-activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Word stimuli always provide more feedback than pseudoword stimuli in such a model. Both of these accounts of performance in the Reicher–Wheeler task cannot capture the critical dissociation observed in the present study: a superiority for pseudowords (PSE) in the absence of a superiority for words (WSE). It is important to note at this point that all participants in the present study performed the lexical decision task with very high levels of accuracy for the word stimuli (91, 93, and 99% for the dyslexic, reading age, and chronological age control children, respectively). The absence of a WSE cannot therefore be attributed to poor lexical knowledge in these children.

In the Reicher–Wheeler task, dyslexic children produced a pattern of results that strongly resembled that of the reading age control children. The chronological age control children also showed the same pattern when shorter stimulus exposures were used. The dyslexic children also performed comparably to reading age control children in the lexical decision task, and when asked to read words aloud. They were, however, notably worse when asked to read aloud pseudowords. This result is in line with the many other reports of dyslexic children having particular difficulty with this specific task (Frith, Wimmer, & Landerl, 1998, for reviews see Goswami, 2000; Snowling, 2000). The performance of dyslexic children reading aloud pseudowords is generally taken as evidence for impaired processing/representation in the sublexical translation of spelling to sound. This is precisely the processing route that is hypothesized to subtend the PSE, according to the sublexical–phonology account of this phenomenon. One would therefore have expected a diminished PSE in the dyslexic children. This was not the case. These children
were just as sensitive to the pseudoword context as the reading-age controls.

So far, the results of the present study have allowed us to exclude a lexically based account, and a sublexical–phonology account of the PSE (as observed in the present testing conditions). This leaves us with the sublexical–orthography account as a remaining viable possibility. According to this account, letter perceptibility is improved when the adjacent letters form a typical orthographic context for a given letter in a given position (Massaro & Cohen, 1994). This account of the PSE is in line with recent evidence on how skilled readers code letter position information. The empirical data at present strongly suggest that letter position is coded relative to other letters in a string, such that the B in TABLE, for example, is coded as being left of L and right of A (Peressotti & Grainger, 1999). One possible implementation of this relative position coding scheme is to use bigram units such as AB and BL (Whitney, 2001). Here we hypothesize that it is precisely the units that code relative letter position in a string that form the locus of pseudoword superiority effects. Illegal nonwords activate relatively fewer relative position codes (be they bigrams, trigrams, or some other form of coding unit). This leads to a much higher degree of positional uncertainty for letters in irregular nonwords, hence making it much harder to identify a letter at a given position.

One final comment is necessary concerning the fact that the children tested in the present study did not show an advantage for letter perception in words compared to pseudowords in the Reicher–Wheeler task. One explanation for this is that the WSE reflects a process whereby letter identity is inferred following word recognition (Grainger & Jacobs, 1994), a process that would cumulate with the facilitatory effects of orthotactic constraints. Since Experiment 3 demonstrated that adult participants do show a WSE with the same stimuli, we can conclude that such inferential processes are more readily available to adults than to children. In conclusion, it appears that the orthotactic information present in words and pseudowords facilitates letter perception in these stimuli relative to irregular nonwords, but that this basic facilitatory effect can be modulated by inferential processes operating subsequent to word identification.

References


Cattell, J. M. (1886). The time it takes to see and name objects. Mind, 11, 53–65.


