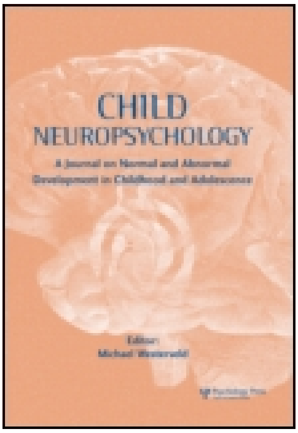

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List context manipulation reveals orthographic deficits in Italian readers with developmental dyslexia

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We tested the influence of list context on word frequency and length effects on the reading aloud of Italian developmental dyslexics and skilled peers. The stimuli were presented either in mixed blocks (alternating words and nonwords) or in pure blocks. The analyses based on the rate-and-amount model (Faust et al., 1999) indicated that group differences in reaction times between dyslexic and skilled readers (a) were well accounted for in terms of global components and (b) were modulated by context in the case of words but not in the case of nonwords. ANOVAs on *z*-transformed reaction time data further indicated the influence of stimulus length. Importantly, the frequency effect interacted with context: Controls showed a list context effect for high- and low-frequency words, while dyslexics showed a list context effect only for high-frequency words. The effect of length on reading times remained unaffected by context manipulation. It is proposed that this pattern of results may be accounted for by hypothesizing two separate deficits: An early graphemic impairment affecting performance independently of context and a later inefficiency in activating entries in the orthographic lexicon as a function of context demands.

Keywords: Developmental dyslexia; List context; word frequency; Stimulus length.

INTRODUCTION

Pinpointing the nature of the developmental reading deficits in children learning to read regular orthographies, such as German or Italian, has proven elusive. Wimmer (1993) first called attention to the presence of deficits in reading speed, in the absence of major deficits in accuracy. Accordingly, most subsequent studies focussed on measures connected with time, including reaction times (RT) to single words (and nonwords), naming times (such as in the rapid automatized naming paradigm), or fixation times (in eye movements studies). In contrast, research for different profiles of disturbances based on error patterns has not provided critical results, as it did for English-speaking children (see Share, 2008 for a discussion).

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In a series of studies, we have examined the RTs of Italian dyslexics to different orthographic (i.e., letters, bigrams, words varying for length and frequency, and nonwords) and nonorthographic (i.e., pictures) stimuli. In general, dyslexics show slower RTs across all conditions tested; accordingly, examining which conditions do or do not show a significant group difference by itself is not a sensitive approach to describe their deficit. In contrast, we looked for dimensions that cut across various tasks (hereto after global factors). To this aim, we applied the rate-and-amount model (RAM) proposed by Faust, Balota, Spieler, and Ferraro (1999). They proposed that conditions that share a common role in determining a group difference show predictable characteristics. Namely, if two groups are different in terms of a given global factor, the pertinent condition means of the slower group (in our case, dyslexics) will be linearly related to those of the faster group (control readers); the slope of this regression line will depend upon the size of the difference between the two groups. Based on the RAM, we tried to isolate the conditions that contribute to the global factor distinguishing between dyslexic and proficient readers.

Based on this approach, the main results can be summarized as follows. The global factor distinguishing dyslexics and proficient readers refers to reading (and making lexical decisions on) letter strings whether they have a lexical value or not (Di Filippo, De Luca, Judica, Spinelli, & Zoccolotti, 2006; Zoccolotti, De Luca, Judica, & Spinelli, 2008). By contrast, tasks requiring the identification or matching of single graphemes or bigrams do not consistently load on this global factor (De Luca, Burani, Paizi, Spinelli, & Zoccolotti, 2010). Furthermore, identification of pictures does not load on the global factor (Zoccolotti et al., 2008). Finally, deficits are present in dyslexics only for stimuli (words and nonwords) presented in the visual, but not in the auditory, modality (Marinelli, Angelelli, Di Filippo, & Zoccolotti, in press). Therefore, even though dyslexics and skilled young readers are different in a variety of conditions only some of them (i.e., the ability to visually process both words and nonwords) reliably mark the reading deficit. To interpret this finding, we have tentatively proposed that dyslexics are impaired in the prelexical analysis of letter strings (De Luca et al., 2010). This proposal is similar to those based on imaging and lesional studies of the so-called "visual word form area" (VWFA). For example, Marsh and Hillis (2005) propose that area BA37 is involved in the computation of a prelexical grapheme description that is independent of case, font, location, or orientation. Notably, such graphemic description does not require stored knowledge of spelling or spelling-sound correspondences. Some evidence on Italian dyslexics is in keeping with this idea. Firstly, the absence of a selective deficit in reading nonwords (Di Filippo et al., 2006; Zoccolotti et al., 2008) speaks against a specific deficit in grapheme-to-phoneme conversion. Secondly, Italian children with dyslexia are not impaired in phonological processing tasks, unless they had a previous language delay (Brizzolara et al., 2006). Finally, the introduction of a delay between stimulus presentation and participant's response (delayed naming paradigm) resulted in faster RTs and a progressive reduction of word-length influence in dyslexics (Zoccolotti, De Luca, Judica, & Burani, 2006). This latter finding is in keeping with the idea that the deficit is not linked to the slow generation of phonological output from print. Overall, there is evidence that at least part of the reading difficulties shown by children with dyslexia are associated with an impairment in forming a graphemic description. Recent neurophysiological data are in line with this proposal. Evidence on German developmental dyslexics indicates that they may show underactivation of the left VWFA (Kronbichler et al., 2006; Wimmer et al., 2010) as well as reduced grey matter volume in critical occipito-temporal cortex areas (Kronbichler et al., 2008).

Overall, these data indicate that Italian developmental dyslexics are impaired in effectively forming a pre-lexical graphemic description of letter strings presented visually. As a consequence, their performance in tasks, such as reading words or nonwords, will be slower (and less accurate) than that of proficient readers. In general, the actual difference in performance on a given task will depend on the global difference in prelexical analysis and the difficulty of the task; more difficult tasks will produce larger differences over and above the specific characteristics of the task, an effect known as "overadditivity."

The presence of overadditivity calls for caution in interpreting group differences in raw data at their face value. In fact, one may expect dyslexics to show larger influences of any variable that may make the task more difficult. For example, Ziegler, Perry, Ma-Wyatt, Ladner, and Schulte-Korne (2003) reported that dyslexics were more impaired in reading nonwords than words as compared to proficient readers (i.e., they showed larger effects of lexicality); similarly, they also showed larger effects of frequency and of stimulus length. All these effects were present for both German- and English-speaking dyslexics. Similarly, Barca, Burani, Di Filippo, and Zoccolotti (2006) found that the frequency effect was larger for dyslexics than for proficient readers. Martens and de Jong (2006) reported larger lexicality effects for dyslexics than control readers. In all these cases, it seems likely that at least part of the large group difference was due to an overadditivity effect. This is a metric consideration; in processing terms, this means that, every time the observer has to process a graphemic string (or to develop a graphemic description in Marsh and Hillis's terms) in order to carry out a given task, his/her performance will be severely delayed (by a factor of ca. 2–3) and the effect of any experimental manipulation will be greatly amplified.

However, this does not necessarily exclude that additional, specific deficits further qualify the dyslexic performance. One relevant question concerns the possibility to activate entries in the orthographic lexicon. Under which conditions do dyslexics show lexical activation? It has been originally proposed that reading in shallow orthographies can occur in the absence of lexical activation simply through the sublexical route (Raman, Baluch, & Sneddon, 1996). However, a large body of evidence strongly suggests that Italian readers do rely on lexical reading. For example, word frequency effects have been reported in reading-aloud experiments (Barca, Burani, & Arduino, 2002; Bates, Burani, D'Amico, & Barca, 2001; Burani, Arduino, & Barca, 2007; Burani, Barca, & Ellis, 2006; Colombo, 1992; Colombo, Pasini, & Balota, 2006). In a study examining sensitivity to word frequency and grapheme contextuality rules, Barca et al. (2006) reported that dyslexics showed a larger word frequency effect than controls. While the size of the effect presumably was related to an overadditivity effect, the presence itself of a difference in reading high- and low-frequency words speaks for (some kind of) orthographic lexical organization in these children (for frequency effects on Italian dyslexics' reading aloud, see also Marcolini, Traficante, Zoccolotti, & Burani, in press; Paizi, Zoccolotti, & Burani, in press; for a review see Paizi, Zoccolotti, & Burani, 2010b).

Still, the presence of a laborious, effortful, and slow graphemic processing raises questions regarding the ability to flexibly activate the lexical or sublexical routes according to task demands. Hendriks and Kolk (1997) have called attention to the importance of examining strategic control over reading of children with dyslexia. In the present study the focus is not merely the presence or absence of lexical effects, but the extent to which developmental dyslexics employ lexical reading. One effective means to control for readers' flexibility in processing lexical (words) and nonlexical (nonwords) stimuli is to examine reading within different contexts by presenting mixed versus pure lists of stimuli. At one extreme, words can be presented mixed with nonwords; this manipulation favors processing along the sublexical route that reads both words and nonwords, because the lexical status of the forthcoming trial is unpredictable. At the other extreme, the stimuli can be presented in pure blocks of either words or nonwords. When only words are presented (in pure blocks), reliance on lexical processing should be maximized.

Accordingly, it has been suggested that the magnitude of lexical effects, specifically word frequency, may be modulated as a function of the nature of the context in which stimuli are named. Manipulating the composition of the experimental lists can be informative as to readers' differential reliance on the lexical and sublexical pathways (Baluch & Besner, 1991; Monsell, Patterson, Graham, Hughes, & Milroy, 1992; see also Zevin & Balota, 2000).[1]

The route de-emphasis account (e.g., Monsell et al., 1992) has been framed within the dual-route theory of reading. The Dual Route Cascaded (DRC) model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) postulates two distinct processes that are activated in parallel to convert print input into speech output. The lexical route directly accesses word entries in the mental lexicon in a holistic fashion and is affected by word frequency. The nonlexical route computes print to sound via a set of grapheme-to-phoneme conversion rules. Stimuli, whose representations are not directly accessible in the lexicon, such as nonwords and low-frequency words, are typically subject to analytical (serial) processing along the nonlexical route, which is affected by stimulus length, but not word frequency.

Monsell et al. (1992) reported that English exception words were read faster in pure blocks than when mixed with nonwords. Their interpretation based on the time course of processing was that, when reading pure blocks of exception words for which the nonlexical route would produce incorrect output, readers de-emphasised the nonlexical route by slowing down its computation. Zevin and Balota (2000) used a priming naming task to test the route de-emphasis hypothesis. The effect of frequency increased for low-frequency words when primed by low-frequency irregular words, which favored attention to lexical information but decreased when primed by nonwords (Zevin & Balota, 2000). However, in the latter condition, the frequency effect was not absent, in spite of the fact that nonlexical information would be favored.

As for Italian, in a recent study using various list manipulations, we assessed the effects of frequency and length in reading aloud words and nonwords in Italian adult readers (Paizi, Burani, & Zoccolotti, 2010a). List context influenced the speed of word reading but the effect of word frequency remained constant irrespective of list composition and nonword characteristics. No effect of context was present in reading nonwords (see also Pagliuca, Arduino, Barca, & Burani, 2008). These results indicate that in Italian adult readers control over reading processing may be unnecessary (presumably because nonword reading is relatively easy for Italian readers).

However, there is no evidence regarding the effect of context in Italian typically developing and especially dyslexic children. The general purpose of the present study is to assess the effect of list context and whether or not it can differentiate lexical and nonlexical

[1]Blocking effects have also been interpreted on the basis of a "time criterion" for articulation, which refers to the process of transcoding from phonological to articulatory codes (Lupker, Brown, & Colombo, 1997). Readers set a time criterion for articulation for all stimuli to be named in a block. The processing difficulty of the stimuli determines the setting of the time criterion.

reading in developing readers. To this aim, we focus on a variable that is critical to assess lexical reading, namely word frequency, as well as a variable known to characterize the reading deficit, namely stimulus length.

Word Frequency Effects

List context can be relevant to the study of lexical reading in Italian developmental readers, because it can be informative as to the differential reliance on each of the reading routes in reading aloud as a response to task demands. In case dyslexics employ predominantly nonlexical reading and rely mostly on serial grapheme-to-phoneme conversion, the effect of frequency should not affect their reading performance.

Italian young skilled readers are affected by word frequency in reading both lists containing only words (Barca et al., 2006; Barca, Ellis, & Burani, 2007) and lists containing words and nonwords (Burani, Marcolini, & Stella, 2002). Italian developmental dyslexics are also affected by word frequency in word reading aloud (Barca et al., 2006; Marcolini et al., in press; Paizi et al., in press).

Yet, in the present study we adopt a much finer and novel manipulation. That is, performance in reading words mixed with nonwords is compared to performance in reading high-frequency words, low-frequency words, and nonwords when presented in separate (pure) blocks. Italian skilled readers are expected to be influenced by word frequency irrespective of context similar to adults (Paizi, Burani, et al., 2010).

It could be the case that dyslexics employ lexical reading similar to skilled readers only in the pure word blocks condition. In comparison to the pure (word) blocks condition the presence of nonwords in the mixed blocks could result in reduced, or even absent, frequency effects for dyslexic readers, who have been hypothesized to rely predominantly on nonlexical reading (Zoccolotti et al., 1999).

Stimulus Length Effects

The effect of stimulus length in developmental dyslexic readers is well documented (Marinus & de Jong, 2010; Martens & de Jong, 2006; Ziegler et al., 2003), including the literature on Italian children with reading difficulties (De Luca, Barca, Burani, & Zoccolotti, 2008; Judica, De Luca, Spinelli, & Zoccolotti, 2002; Spinelli, De Luca, Di Filippo, Mancini, Martelli, & Zoccolotti, 2005; Zoccolotti et al., 1999; Zoccolotti, De Luca, Gasperini, Judica, & Spinelli, 2005). Here, length is manipulated orthogonally with frequency, in order to investigate specifically the effect of word frequency on four different length conditions (4, 5, 6, 7 letters). Stimulus length is expected to mostly affect the performance of dyslexics rather than controls. Yet, a length by frequency interaction, with the effect of length limited to low-frequency words cannot be excluded on the basis of the predictions of the DRC model (Coltheart et al., 2001) and previous findings in the literature with adult readers (Juphard, Carbonnel, & Valdois, 2004; Weekes, 1997).

According to the DRC model (Coltheart et al., 2001), nonwords are necessarily read via the grapheme-to-phoneme rules of the nonlexical route. Consequently, as opposed to pure blocks, in mixed blocks serial, nonlexical processing is encouraged by the presence of nonwords. If the length effect is interpreted as expressing the contribution of the nonlexical route, it should be more marked in mixed blocks reading with respect to pure blocks.

In a recent study with adults, it was shown that in Portuguese — an orthography of intermediate depth — length effects can be modulated by list context (Lima & Castro, 2010). The effect of length was significant in lexical decision and in reading aloud but it was limited to the mixed blocks condition. In reading aloud pure word blocks, there was no length effect. The authors interpreted this result by assuming that Portuguese skilled readers rely on larger reading units when lexical reading is favored (pure word blocks) but switch to smaller units as a response to task demands (mixed blocks).

In a different perspective, the length effect can be seen as more closely linked to early perceptual difficulties experienced by dyslexics in carrying out prelexical analysis (Martelli, Di Filippo, Spinelli, & Zoccolotti, 2009); accordingly, it should be relatively insensitive to the influence of blocking manipulations.

Overall, we examined sixth grade Italian dyslexics and chronologically matched skilled readers[2] in reading aloud words varying in frequency and length and nonwords varying in length. By manipulating list context (pure vs. mixed) in interaction with word frequency and stimulus length we expected to obtain information on the flexibility with which dyslexics and proficient readers are able to activate lexical information in reading aloud.

METHODS

Participants

A group of 18 dyslexics (9 girls and 9 boys) with mean age 11.3 ($SD = 0.3$) years and a group of 36 (18 girls and 18 boys) typically developing readers (mean age: 11.3 years, $SD = 0.3$).

The criteria for inclusion in the dyslexic group were scores of at least two standard deviations below norms for either speed or accuracy in a standardized test for Italian reading level examination (MT Reading test; Cornoldi & Colpo, 1995), nonverbal intelligence within normal range as assessed by the Raven Coloured Matrices test, and normal or corrected to normal visual acuity. Of the 18 dyslexic children, 4 were below the cutoff for both speed and accuracy and 14 for accuracy only. The two groups were matched (one-to-two) for chronological age, sex, and nonverbal IQ levels. Mean scores on screening tests for the two groups of participants are given in Table 1. Dyslexic and typically developing readers were not different in their performance in the Raven test, $t < 1$; by contrast, dyslexic children were slower, $t = 9.51$, $p < .0001$, and less accurate, $t = 17.77$, $p < .0001$, in reading the text passage from the MT Reading test (Cornoldi & Colpo, 1995).

Materials

A list of 60 high-frequency (HF) and 60 low-frequency (LF) words and a list of 120 nonwords, derived from the words (60 nonwords were generated from the HF set and 60

[2]In previous research, separating general from specific effects in developmental dyslexia has been frequently dealt with comparing dyslexics to reading-matched controls. We have proposed that reference to models such as RAM in chronologically matched samples of children represents a more powerful means of isolating global from specific factors (Zoccolotti et al., 2008). In particular, while the reading match paradigm controls for the general reading "delay" component, it is blind to its characteristics. By contrast, it is proposed that the identification of the tasks, which contribute to a given global factor, is instrumental in understanding the nature of the nontask-specific differences between children with and without reading disturbances. For these reasons, in the present study we chose to use a chronological match design.

Table 1 Mean Raw Scores (and z Values) at the Raven and MT Reading Tests for Dyslexics and Controls (Standard Deviations in Parentheses).

	Raven Test		Reading Speed		Accuracy	
	No. of correct responses	*z* scores	S/syllable	*z* scores	No. of errors	*z* scores
Dyslexics	30.5(3.2)	0.1(0.7)	0.39(0.09)	−1.3(1.0)	28.9(4.7)	−2.8(0.6)
Controls	30.3(3.1)	0.0(0.7)	0.22(0.04)	0.5($SD = 0.4$)	8.1(3.7)	0.0(0.5)
Student *t*-tests	0.18		9.51		17.77	
(*p* value)	*ns*		<.0001		<.0001	

Note. Reading performance is expressed both in terms of speed (s/syllable) and accuracy (number of errors). Student *t*-tests between dyslexics and controls (and probability values) are also reported.

from the LF set) by changing one or two letters, was generated for a total of 240 stimuli (see Paizi, Burani, et al., 2010).

In each word set (HF-LF), word frequency was varied orthogonally with length. The stimuli were four, five, six, and seven letters long (disyllabic and trisyllabic). All words were stressed with the most frequent stress pattern in Italian (on the penultimate syllable). There were 15 items in each length condition. The two frequency sets High Frequency Words-Low Frequency Words (HFW-LFW) were matched for orthographic neighborhood size (N-size), subjective neighbors' frequency (Baldi & Traficante, 2005), length in letters, bigram frequency, orthographic complexity (Burani et al., 2006), and initial phoneme. The four length conditions in each word set were matched for frequency, rated age of acquisition (AoA), familiarity, imageability, N-size, bigram frequency, and orthographic complexity. The measures of frequency, AoA, familiarity, and imageability were drawn from the LEXVAR database (Barca et al., 2002; available online at: http://www.istc.cnr.it/material/database/lexvar.shtml).

The two nonword sets (HF/LF-matched) were matched for length (in letters and phonemes), bigram frequency, orthographic complexity, N-size, and initial phoneme. Words and nonwords were matched across sets (all four sets) for length in letters and phonemes, bigram frequency, orthographic complexity, and initial phoneme. The characteristics of the stimuli can be found in Table 2. All stimuli can be found in the Appendix.

Procedure

The experiment was conducted in two sessions: one session for pure blocks reading and one for mixed blocks reading. In each session the participants were requested to read four blocks of 30 trials each. The (four) "pure" blocks consisted of two blocks of words (one block of HF and one of LF words) and two blocks of nonwords (one of HF-matched and one of LF-matched nonwords).There were also four "mixed" blocks administered in a different session, in which all types of stimuli (HF words, LF words, and the two sets of their corresponding nonwords) were equally divided in four blocks and presented mixed. Each block contained an equal number of high- and low-frequency words and nonwords (HF-/LF-matched).

Each participant saw all eight blocks (i.e., four pure and four mixed blocks), but the presentation order of the blocks was counterbalanced across participants, and the two sessions (pure and/or mixed blocks) were administered after an interval of at least one month. The experimental session ("pure"/"mixed") that the participants had to complete first was

Table 2 Descriptive Statistics for the Four-, Five-, Six- and Seven-letter High- and Low-Frequency Words and Their Corresponding Nonwords used in Experiments 1–4 (Mean Values).

Length	4 letters		5 letters		6 letters		7 letters	
Frequency[a]	HF	LF	HF	LF	HF	LF	HF	LF
WORDS								
Written Word Frequency	458.7	14.7	225.5	11.5	224.8	9.8	253.7	13.1
Age of acquisition	2.6	4.0	2.7	4.0	2.8	3.8	3.0	4.1
Familiarity	6.6	5.8	6.6	5.9	6.6	5.6	6.6	6.0
Imageability	5.4	5.0	5.5	4.9	5.3	5.2	5.6	5.2
N-size	2.8	3.1	1.3	1.9	1.1	1.3	0.4	0.3
Subjective Neighbors' Frequency	6.8	6.7	6.7	6.7	6.7	6.8	6.7	6.8
Bigram frequency	11.1	10.9	10.9	10.9	10.9	10.9	10.8	10.8
Contextual rules	0.3	0.3	0.3	0.3	0.3	0.3	0.8	0.9
Length in phonemes	4.0	3.9	4.7	4.7	5.7	5.7	6.4	6.5
Length	4 letters		5 letters		6 letters		7 letters	
Derived from word set:	HF	LF	HF	LF	HF	LF	HF	LF
NONWORDS								
N-size	3.5	2.9	2.1	3.3	0.6	0.7	0.4	0.3
Bigram frequency	10.9	10.8	10.9	10.9	10.8	10.9	10.7	10.9
Contextual rules	0.3	0.3	0.4	0.5	0.3	0.5	0.7	0.7
Length in phonemes	4.0	4.0	4.8	4.7	5.7	5.7	6.4	6.5

[a]HF = High-frequency words; LF = Low-frequency words.

Printed word frequency corresponds to child frequency counts out of 1,000,000 occurrences. Bigram frequency values are log transformed (natural logarithm). Age of acquisition, familiarity, imageability, and subjective neighbors frequency ratings are on a 7-point scale. All measures, except for N-size and subjective neighbor's frequency counts (Baldi & Traficante, 2005) were taken from the LEXVAR database (Barca et al., 2002), available on http://www.istc.cnr.it/material/database.

also counterbalanced across participants. The presentation order of the experimental trials within each block was automatically randomized by the software. Each block was preceded by a practice set of 10 trials appropriate for the block (i.e., 10 HF words preceded the pure block of HF words, 10 LF words preceded the block of LF words). For mixed blocks, the practice set (consisting of 10 trials) contained all types of stimuli and preceded the first mixed block (the practice session was not repeated for each block). The items used for the practice blocks were different from the items used for the experimental trials but had the same characteristics as the experimental items. Each block was followed by a short pause.

The participants were tested individually in a quiet room at their school. They were instructed to read aloud as fast and accurately as possible the stimuli that appeared in the center of the computer screen. The stimuli were displayed white on a black background and the font was Courier (18 point). A voice key connected to the computer (controlled by the E-Prime software) measured reaction times in milliseconds (ms) at the onset of pronunciation. Each stimulus disappeared at the onset of pronunciation or after 3500 ms had elapsed. There was an interstimulus interval of 1500 ms. The experimenter noted pronunciation errors.

RESULTS

Reaction times that exceeded the response time limit as well as missing RTs owed to technical failures were considered invalid and were discarded from the analyses. In the case of words, they accounted for 1.7% and 5.5% of trials for controls and dyslexics, respectively; for nonwords the percentages of invalid trials were 2.4% and 4.3% for controls and dyslexics, respectively. Only correct responses were considered for the analyses of reaction times.

Main results are presented in Figure 1 (raw RTs in pure and mixed blocks for HF words, LF words, and nonwords) and Figure 2 (mean percentages of errors in pure and mixed blocks for HF words, LF words, and nonwords).

An inspection of Figure 1 illustrates the large differences in performance across conditions between dyslexics and controls in terms of RTs. In the case of words, both controls and dyslexics show clear effects of frequency and length. Dyslexics show context effects limited to high-frequency words while controls show context effects for both high- and low-frequency words. In the case of nonwords, the effect of length is clear in controls and more so in dyslexics. An inspection of Figure 2 confirms the large difference in performances between the two groups also in terms of accuracy. Note that, whenever present,

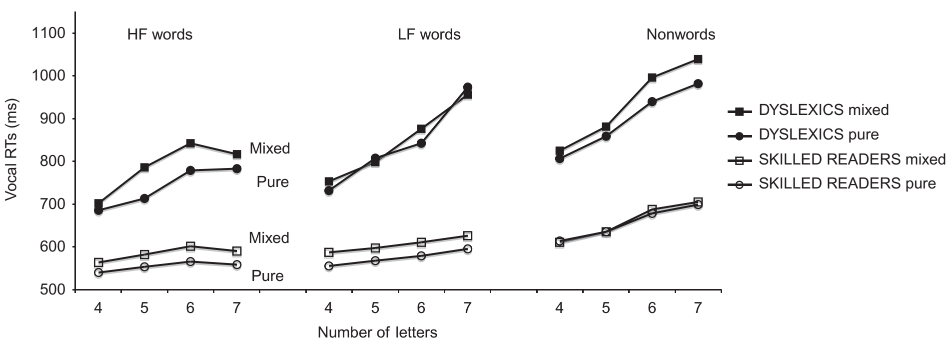

Figure 1 RTs in pure and mixed blocks for high-frequency words, low-frequency words, and nonwords as a function of length. Data are separately presented for dyslexic and skilled readers.

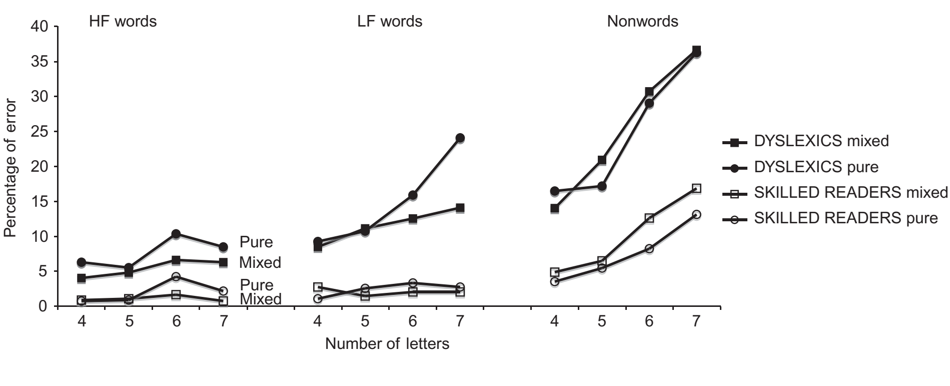

Figure 2 Mean percentages of errors in pure and mixed blocks for high-frequency words, low-frequency words, and nonwords as a function of length. Data are separately presented for dyslexic and skilled readers.

effects appear generally larger in dyslexics, which indicate that the results should be tested for the presence of overadditivity effects; for this reason, before passing to standard statistical analyses, we tested for the presence of global components in the data.

Testing the RAM Predictions

The RAM (Faust et al., 1999) predicts various linear relationships to define the presence of global components in the data. Here, we first tested the prediction of a linear relationship between the means of the two groups for conditions that varied in overall information-processing rate. Dyslexics' and skilled readers' condition means are plotted against each other in Figure 3, separately for the pure list (Figure 3a) and mixed list (Figure 3b) conditions. In the graph, a diagonal dotted line is plotted. Points lying on the diagonal indicate identical performance of the two groups and points above the line indicate worse performance of dyslexics. Therefore, since all data points lie above the diagonal dotted line, dyslexics were slower than skilled readers in all conditions.

Various observations can be made based on these graphs. First, differences between the two groups of children tend to increase as a function of task difficulty both in the pure (Figure 3a) and mixed (Figure 3b) list conditions; i.e., there is a general tendency for overadditivity. Second, a linear relationship between the means of dyslexics and skilled readers is apparent in all cases; although the pattern of data appears different in the case of pure and mixed blocks conditions. In the former case, good linear fits are obtained for both word ($y = 5.16x - 2122.5$; $R^2 = .95$) and nonword (NW: $y = 1.98x - 401.1$; $R^2 = .95$) conditions; in contrast, if a single linear regression is used a lower coefficient of determination is obtained ($y = 1.51x - 76.9$; $R^2 = .73$). Also in the mixed blocks conditions, a good interpretation of data can be obtained by using separate linear fits for word ($3.93x - 1519.1$; $R^2 = 0.93$) and nonword ($y = 2.24x - 544.1$; $R^2 = 0.98$) conditions. However, in this case, even a single linear regression ($y = 2.16x - 476.8$; $R^2 = .91$) is sufficient to adequately interpret the data points. Third, it is also interesting to examine the profile of response by replotting separately word and nonword data (see Figures 3c and d); it is apparent from the plots that the effect of context influences the group difference between controls and dyslexics in the case of words (Figure 3c) but much less so in the case of nonwords (Figure 3d). In fact, in the nonword conditions the data are remarkably similar in the case of pure and mixed list conditions (the slope of the regression is 1.98 in the case of the pure conditions and 2.24 in the case of the mixed conditions), and a single linear regression ($y = 2.14x - 495.1$; $R^2 = .93$) adequately fits the data points. In contrast, a difference is apparent in the case of the word conditions: The slope of the regression is steeper in the case of the pure ($b = 5.16$) conditions than in the case of the mixed conditions ($b = 3.93$); accordingly, a single regression line does not fit equally well these data points ($y = 2.87x - 862.5$; $R^2 = .66$).

Successively, we tested the prediction of a linear relationship between overall group means and standard deviations in the same conditions for the group as a whole. Plots for the pure and mixed lists are presented in Figures 4a and 4b, respectively. Note in both plots the general tendency for more difficult conditions to be associated with larger variability values, indicating a systematic deviation from the homogeneity of variance assumption (and in keeping with the presence of overadditivity). A linear relationship between means and standard deviations is apparent in all cases but, again, the pattern of data is different for pure and mixed list conditions. In the former case, good linear fits are obtained for both word ($y = 1.18x - 599.9.5$; $R^2 = .96$) and nonword (NW: $y = 0.55x - 223.2$; $R^2 = .93$)

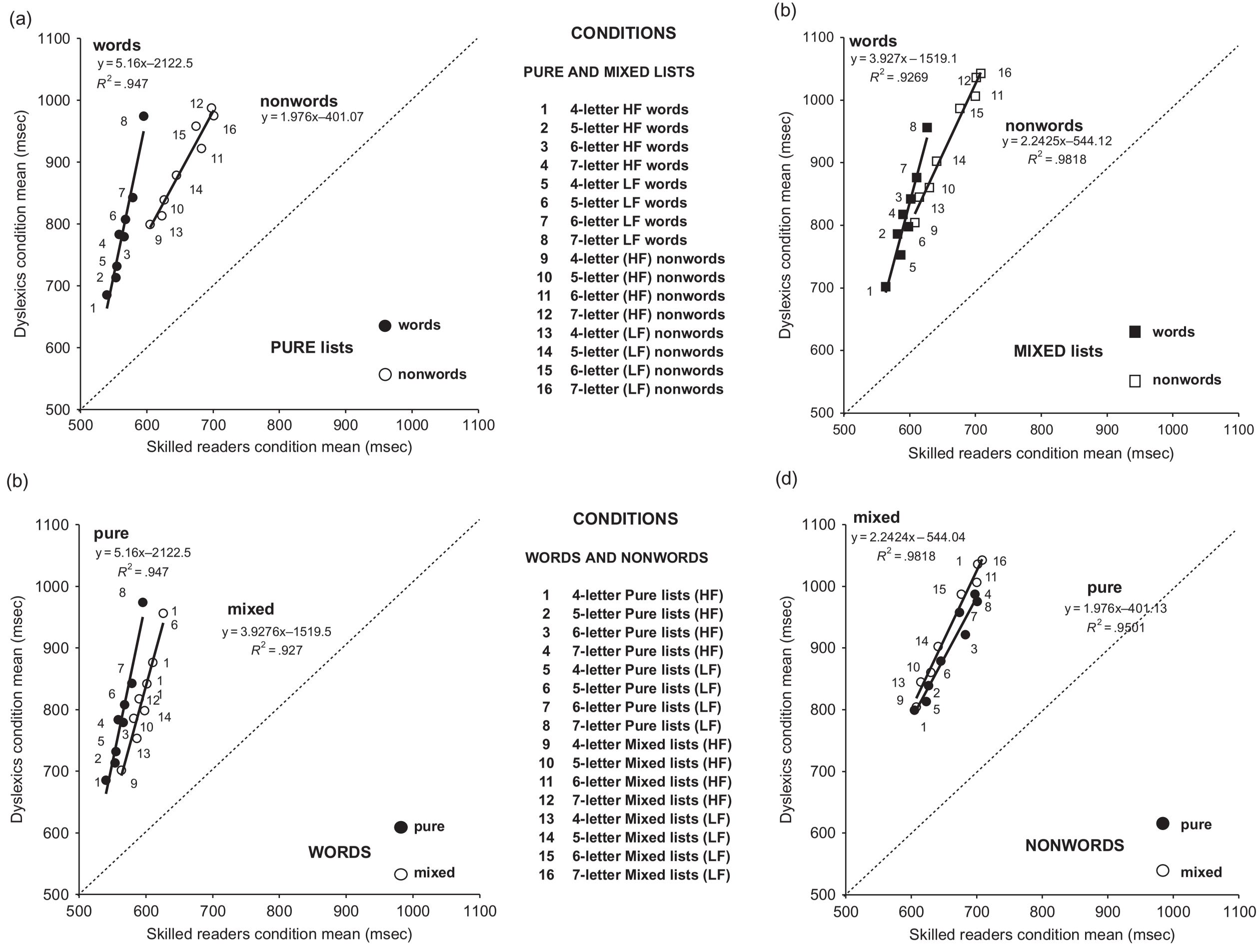

Figure 3 Dyslexics' and skilled readers' condition means are plotted against each other: (a) pure list conditions; (b) mixed list conditions; (c) word conditions; and (d) nonword conditions. The diagonal dotted line indicates the reference for identical performance of the two groups; points above this line indicate worse performance of dyslexics. Word and nonword conditions are presented in black and open symbols, respectively.

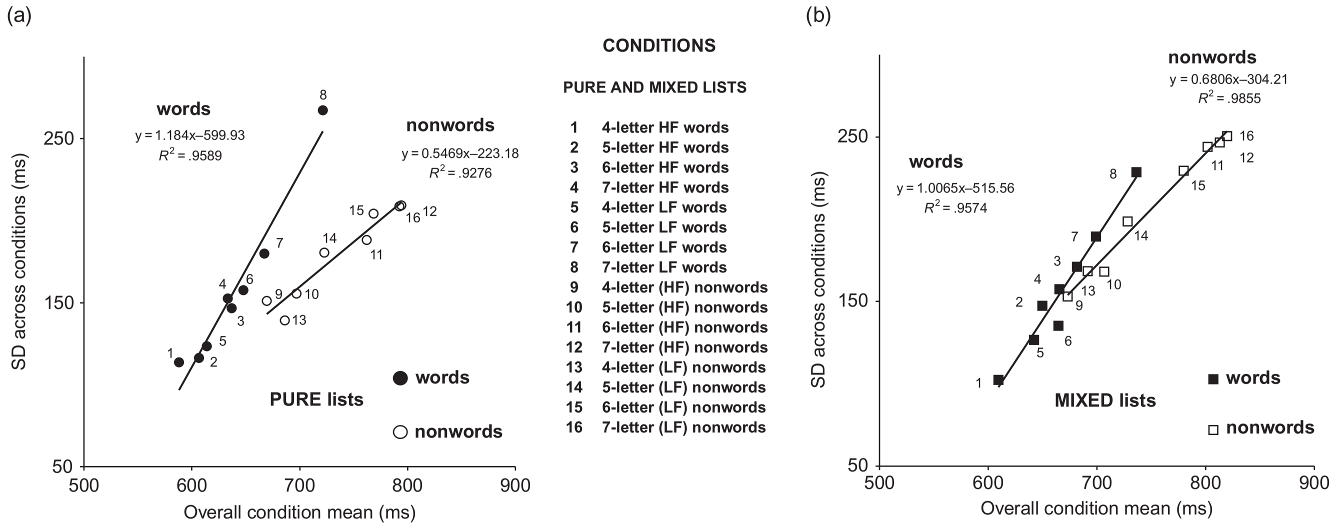

Figure 4 Condition means and standard deviations on the same conditions are plotted against each other: (a) pure list conditions and (b) mixed list conditions. Data refer to the whole group of participants. Word and nonword conditions are presented in black and open symbols, respectively.

conditions; in contrast, if a single linear regression is used, a lower coefficient of determination is obtained (y = 0.48x – 163.3; $R^2 = .62$). Also in the mixed list conditions, a good interpretation of data can be obtained by using separate linear fits for word (1.01x – 515.6; $R^2 = .96$) and nonword (y = 2.68x – 304.2; $R^2 = .98$) conditions. However, in this case, even a single linear regression (y = 0.70x – 314.2; $R^2 = .94$) adequately accounts for all data points.

Comments

The test of the RAM predictions indicates the presence of global components in the data, confirming previous evidence (Di Filippo et al., 2006; Zoccolotti et al., 2008). In particular, context modulates group differences in performance between dyslexics and skilled readers: Reading slowness is more pronounced (i.e., the slope is steeper) when the child has to read only words and less pronounced when words are intermingled with nonwords. When examined in terms of global influences, the effect of context is selective for words and it does not contribute to the group difference when reading nonwords. Evidently, skilled readers are able to benefit from the presence of lexical items; an ability that is underdeveloped among dyslexics.

Isolating the Specific Effects of Blocking Condition, Frequency, and Length

The tests of the predictions refer to large-scale components in performance and they do not exclude that the two critical groups are further discriminated by small-scale specific factors. To this aim, Faust et al. (1999) suggest comparing parametric analyses (such as ANOVAs) on raw versus *z*-transformed data. Interactions that were significant in both the raw score and *z*-transformed score analyses indicate the selective influence of a given parameter; in contrast, interactions that were significant only in the raw data, but not on the *z*-transformed values, indicate the presence of a spurious interaction (overadditivity effect).

Therefore, raw data were transformed into *z* scores by taking each individual's condition means, subtracting their overall mean and dividing it by the standard deviation of their condition means. The *z* scores indicate an individual participant's performance in a given condition relative to all other conditions based on the individual means of all conditions (therefore, each individual has an average of 0 across conditions and a $SD = 1$). This transformation re-scales individual performances to a common reference; hence, it allows controlling for global components while it preserves the information regarding individual variability across experimental conditions. We carried out the *z* score transformation separately for all word tasks and for all nonword conditions. It should be noted that these transformations may be applied to open scales, such as time, but they are not suited in the case of closed scales, such as accuracy.

ANOVAs were carried out on RTs and *z*-transformed values (separately for words and nonwords); for the sake of presentation, we present analyses on RTs and z-transformed values jointly to illustrate which interactions can be interpreted as overadditivity effects. In the word analysis, group (dyslexics, controls) was the unrepeated factor and blocking condition (pure, mixed), frequency (high, low), and length (4-, 5-, 6- and 7-letter words) the within group factors. It should be noted that frequency refers only to words. In the nonword analysis, group (dyslexics, controls) was the unrepeated factor and blocking condition (pure, mixed) and length (4-, 5-, 6- and 7-letter words) the within-participant factors.

Words

The ANOVA on mean RTs showed a main significant effect of group in the raw, $F_{rt}(1, 52) = 50.88$, $p < .0001$, but (due to the transformation process) not in the z-transformed analysis, $F_z < 1$, *ns*. The effect of blocking condition, $F_{rt}(1, 52) = 14.12$, $p < .0001$; $F_z(1, 52) = 18.70$, $p < .0001$, word frequency, $F_{rt}(1, 52) = 134.72$, $p < .0001$; $F_z(1, 52) = 155.58$, $p < .0001$, and length, $F_{rt}(3, 156) = 77.91$, $p < .0001$; $F_z(3, 156) = 115.45$, $p < .0001$, were all significant (here and elsewhere F_{rt} refers to the raw data analysis and F_z to the z-transformed analysis).

The interaction between group and length was significant, $F_{rt}(3, 156) = 35.17$, $p < .0001$; $F_z(3, 156) = 12.09$, $p < .0001$: dyslexics showed a larger length effect than controls (see Figure 5a, raw data, and 5b, z values). In terms of RTs, the millisecond increase per letter was 10.8 for controls and 55.3 for dyslexics. In terms of z values, the increase was −.27 z units per ms for controls and −0.54 for dyslexics.

The group-by-frequency interaction was significant, F_{rt} $(1, 52) = 46.29$, $p < .0001$; F_z $(1, 52) = 6.32$, $p = .01$. This interaction was qualified by the presence of the three-way interaction between group, frequency, and blocking condition, F_{rt} $(1, 52) = 6.80$, $p < .05$; $F_z(1, 52) = 4.67$, $p < .05$: Controls showed a context effect for high-frequency (29.7 ms; $p < .001$; see Figure 6a) and low-frequency (30.9 ms; $p < .0001$) words. Dyslexics showed a context effect only for HF words (46.4 ms; $p < .0001$) but not LF words (6.8 ms; $p = ns$). Figure 6b shows the interaction in terms of z scores. Controls showed a context effect for HF (−0.64 z units; $p < .0001$) and LF (−0.75 z units; $p < .0001$) words; dyslexics showed a context effect for HF (−0.53 z units; $p < .005$) but not LF (−0.18 z units; *ns*) words.

The interaction between length and frequency was significant, $F_{rt}(3, 156) = 30.3$, $p < .0001$; $F_z(3, 156) = 24.64$, $p < .0001$, indicating larger length effects for low-frequency (42.9 ms per letter) than for high-frequency (23.2 ms per letter) words.

Several interactions were significant in the RT but not in the z score analyses presumably because of overadditivity effects; therefore, they are not discussed here. This was the case for the interaction between blocking condition and frequency, $F_{rt}(1, 52) = 6.06$, $p < .05$; $F_z(1, 52) = 1.11$, *ns*, blocking condition and length, F_{rt} $(3, 156) = 2.98$, $p < .05$;

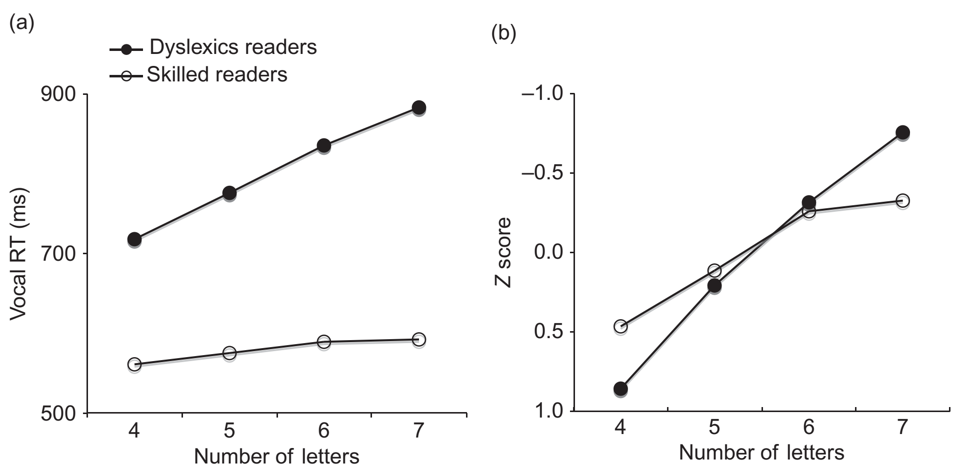

Figure 5 Group by length interaction: (a) RTs and (b) z-transformed values.

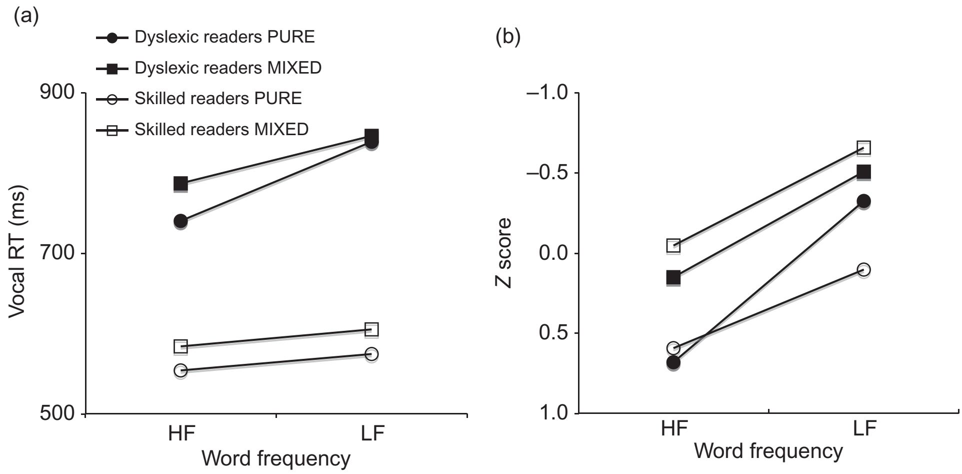

Figure 6 Group by blocking condition by frequency interaction: (a) RTs and (b) z-transformed values.

$F_z(1, 52) < 1$, *ns*, blocking condition, frequency and length, $F_{rt}(1, 52) = 3.24$, $p < .05$; $F_z(1, 52) = 1.64$, *ns*, and group, frequency and length, $F_{rt}(3, 156) = 14.21$, $p < .0001$; $F_z(1, 52) = 1.45$, *ns*. All other interactions were not significant.

Nonwords

The ANOVAs showed a main effect of length, $F_{rt}(3, 156) = 87.83$, $p < .0001$; $F_z(3, 156) = 238.36$, $p < .0001$. The main effects of group and blocking condition were significant only in the raw RT analysis, group: $F_{rt}(1, 52) = 44.03$, $p < .0001$; $F_z < 1$, *ns*; blocking condition: $F_{rt}(1, 52) = 6.59$, $p < .05$; $F_z(1, 52) < 1$, *ns*.

The group by length, $F_{rt}(3, 156) = 11.40$, $p < .0001$; $F_z(3, 156) < 1$, *ns*, blocking condition by length, $F_{rt}(3, 156) = 25.43$, $p < .0001$; $F_z(3, 156) = 2.14$, $p = .09$, and group by blocking condition by length, $F_{rt}(3, 156) = 5.72$, $p < .0001$; $F_z(3, 156) < 1$, *ns,* were significant in the RT, but not in the z score, analyses.

Comments

Overall, applying the procedures based on RAM allowed discriminating interactions with the group factor that were selective from interactions that can be interpreted as due to overadditivity. In the case of words, the group by length and the group by frequency interactions were significant in both the raw and z-transformed score analyses indicating that they are not due to overadditivity; by contrast, in the case of nonwords, no interaction with the group factor was significant in the z-transformed score analysis.

The specific effect of length in reading words confirms previous evidence (Zoccolotti et al., 2008). Note that, in the raw data, length also interacted with list context manipulation as reported by Lima and Castro (2010). However, this interaction was not present in the z-transformed analysis indicating that it may be due to overadditivity. Furthermore, even though length interacts with frequency (with greater length effects for low-frequency words), its influence on the group factor is direct (i.e., not mediated by frequency). In contrast, the influence of word frequency on group differences is dependent on blocking condition. Dyslexics do not show a pure blocks advantage for low-frequency words.

Overall, it appears that length and word frequency exert specific but independent effects that presumably act at different levels of processing. Conceivably, length affects early stages of information processing and marks the perceptual limitations of dyslexics in dealing with complex letter strings; word frequency marks lexical processing and is sensitive to list context. The presence of a word frequency effect in dyslexics, together with the lack of influence of list context on low-frequency word reading, may indicate that lexical organization in these children is similar to that of skilled readers but is underdeveloped. This is expressed in limitations concerning the lexical representations for low-frequency words that are processed similarly irrespective of the presence or absence of nonwords in the experimental list. In the case of low-frequency words, dyslexic readers are not as flexible as in the case of high-frequency words in switching to lexical reading.

It should be added that the pattern of results discussed here does not confirm the extreme hypothesis that in languages with transparent orthography, such as Italian and Turkish (see Raman et al., 1996; Raman, Baluch, & Besner, 2004), the word frequency effect can be eliminated in reading mixed blocks of words and nonwords. By contrast, the present results are consistent with the recent findings by Paizi, Burani, et al. (2010): Using four different blocking conditions, they showed that the word frequency effect remains in reading mixed blocks when words and nonwords are matched on several variables, such as bigram frequency, orthographic neighborhood size, etc. According to Paizi, Burani, et al. (2010), if the nonlexical route is faster in Italian than English (see also Paap & Noel, 1991), it may be less resource demanding. In this case, there would be no reason to shut it down in order to free up resources for the lexical route; consequently, Italian readers should be more flexible than English readers in switching from lexical to nonlexical reading according to task demands.

As for nonwords, the only reliable effect, which is independent of overadditivity, is the influence of length that holds for both groups of children. Therefore, when the global effect in reading nonwords is taken into account, no residual specific effect of the blocking manipulation is present for either group of children. This is in line with previous findings with adult Italian readers (Pagliuca et al., 2008; Paizi, Burani, et al., 2010).

Accuracy

An ANOVA was carried out on mean percentages of errors on words. Group was the unrepeated factor and blocking condition (pure, mixed), frequency (high, low), and length (four, five, six, and seven letters) were the within-participant factors. A similar ANOVA was carried out on nonwords with group as unrepeated factor and blocking condition and length as the within-participant factors.

Words

The ANOVA showed main effects of group, $F(1, 52) = 40.54$, $p < .0001$, blocking condition, $F(1, 52) = 5.44$, $p < .05$, frequency, $F(1, 52) = 54.34$, $p < .0001$, and length, $F(3, 156) = 20.94$, $p < .0001$.

There was a significant interaction between group and frequency, $F(1, 52) = 35.84$, $p < .0001$. Both groups made more errors on low- than high-frequency words, but the difference was greater for dyslexics (HFW: 6, 6%, LFW: 13, 3%) than controls (HFW: 1, 6%, LFW: 2, 3%). The interaction between blocking condition and length was significant, $F(3, 156) = 4.48$, $p < .005$. In the case of four- and five-letter words there was no difference between pure and mixed blocks; in the case of six- and seven-letter words, there were more errors in the pure than in the mixed blocks (*p*s at least < .001). The frequency by length interaction was significant, $F(3, 156) = 5.18$, $p < .005$. Errors increased significantly with length for low-frequency but not for high-frequency words ($p < .001$). The three-way interaction between group, frequency, and length was significant, $F(3, 156) = 4.89$ $p < .05$. Both groups made significantly more errors on long low-frequency than (short and) high-frequency words, but the difference was greater for dyslexics than controls ($p < .05$).

Nonwords

The ANOVA showed main significant effects of group, $F(1, 52) = 61.46$, $p < .0001$, and length, $F(3, 156) = 94.47$, $p < .0001$. The interaction between length and group was significant, $F(3, 156) = 11.09$, $p < .0001$. For dyslexics, the length effect was significant for all nonword lengths (all *p*s < .001). For controls, the effect of length was significant only for six- and seven-letter nonwords ($p < .01$) but not between four- and five-letter nonwords. The effect of list composition was not significant ($p > 1$) and did not interact with any of the experimental factors.

Comments

In general, the results in terms of accuracy paralleled those of RTs. However, some differences also emerged. In particular, in both groups there were more errors in the pure than in the mixed blocks condition in the case of the long (six- and seven-letter) words; i.e., in mixed blocks, children read more slowly but with fewer errors. Possibly, the greater accuracy in mixed blocks may be due to a tendency to read nonlexically that may yield greater accuracy in a highly regular language such as Italian, an effect more evident in the case of longer words.

It must be noted that the measure of accuracy is not independent of overadditivity and this may well account for some of the interactions observed with the group factor.

DISCUSSION

Dyslexics were impaired in reading aloud both words and nonwords as compared to skilled readers. However, list context modulated differences in performance between the two groups of readers.

The slowness of dyslexics (as compared to controls) in reading nonwords was similar whether they were presented in pure blocks or mixed with words. In contrast, word reading was sensitive to the context in which the stimuli were presented. In terms of global influences on the data, the conditions involving words mixed with nonwords (mixed blocks were expected to favor nonlexical reading) produced group differences between dyslexic and control readers very similar to those obtained in conditions involving (only) nonword reading. These findings add to previous observations indicating similar deficits in reading and lexical decision tasks with letter strings independent of whether or not they have a lexical value (Di Filippo et al., 2006; Zoccolotti et al., 2008). De Luca et al. (2010) have tentatively proposed that this pattern may be accounted for by a deficit in forming graphemic descriptions, a prelexical stage necessary for the processing of all letter strings

(Marsh & Hillis, 2005). However, reading words in pure lists produced a distinctly greater deficit; that is, dyslexics were impaired in this case more so than when reading nonwords or words in mixed blocks. This deficit cannot be easily accounted for by the impairment in graphemic analysis, since it specifically affected word reading. Alternatively, one may posit that dyslexics are less efficient than peer skilled readers in activating the orthographic lexicon. Note that considering global influences in the data allowed examining these influences independently of (absolute) task difficulty, as it happens in the case of raw data analyses.

The analyses on *z*-transformed data allowed detecting the residual joint influence of word frequency and blocking manipulation on this relationship: Children with dyslexia were faster in reading high-frequency words in pure as compared to mixed blocks, but this effect was not present in the case of low-frequency words. Therefore, even if low-frequency words are present in the lexicon, their representations are not readily available or are less likely to be activated than high-frequency words and are thus difficult to be lexically retrieved in reading aloud.

The crucial role of stimulus length for the performance of dyslexics was confirmed here (Marinus & de Jong, 2010; Martens & de Jong, 2006; Spinelli et al. 2005; Ziegler et al., 2003). Dyslexics were much more affected by stimulus length than controls. The striking length effect persisted in the *z* scores analyses, suggesting that it is over and above specific tasks and conditions, and confirmed previous studies that have adopted the RAM approach (e.g., Di Filippo et al., 2006; Zoccolotti et al., 2008). Notably, the effect of length was independent of list context manipulations once the global influences were controlled for. This pattern seems compatible with an interpretation of this effect as due to early perceptual difficulties (Martelli et al., 2009), possibly influencing prelexical analysis of the orthographic strings. In fact, based on the alternative hypothesis that the length effect marks the contribution of the nonlexical route, one would have expected length effects to be present in the case of the mixed blocks condition, as has been reported for Portuguese adult readers (Lima & Castro, 2010).

We have originally proposed that Italian children with dyslexia behave as surface dyslexics (Zoccolotti et al., 1999); that is, they tend to read words nonlexically. Some evidence seemed to fit this proposal; for example, they tended to make more errors in stress assignment, one of the very few sources of irregularity in the Italian orthography (Zoccolotti et al., 1999; but see Paizi et al., in press). However, findings accrued that dyslexics show lexical access in reading aloud, as is the case for skilled readers. Barca et al. (2006) looked at the effect of word frequency (in interaction with rule contextuality) and concluded that dyslexics employed lexical reading to the same extent as controls, at least as far as high-frequency words are concerned (Barca et al., 2006). Also, the present results clearly indicate the presence of a word frequency effect in dyslexic children, thus confirming previous results (see Marcolini et al., in press; Paizi et al., in press). Therefore, the view that dyslexics read sublexically should be abandoned, since dyslexics seem to have spared lexical access similar to skilled readers. However, the present study indicates an important difference that can distinguish the performance of proficient and dyslexic readers in lexical activation: low-frequency word reading. Namely, dyslexics appear to be less flexible than skilled readers in switching between reading modes for low-frequency word reading.

Reference to surface dyslexia seemed a way to interpret in a unitary fashion the reading deficit of Italian children (Zoccolotti et al., 1999). In that vein, the large length effect shown by dyslexics would indicate sequential analysis, which is characteristic of processing along the nonlexical route, indirectly pointing to the lack of lexical representations. However, a recent large body of evidence indicates the need to postulate at least two deficits to account for the manifestations of the reading speed disorder in Italian dyslexic children. An impairment in prelexical analysis marks the difficulty in forming graphemic descriptions that represent a necessary stage for further analysis of the orthographic input. Most likely, the large effect of length, marking perceptual difficulties in these children, contributes to determining the deficit at this level of processing. A second difficulty marks the inefficiency in activating low-frequency entries in the lexicon. Entries for low-frequency words may not be readily available in the orthographic lexicon of children with dyslexia; accordingly, for these stimuli, dyslexics are not able to benefit from the pure word block conditions, as proficient readers do.

Recent evidence is consistent with the presence of a selective deficit of the orthographic lexicon in children native speakers of a transparent orthography. Bergmann and Wimmer (2008) reported that Austrian children with dyslexia were severely impaired in the orthographic distinction between words and pseudo-homophones (such as Taxi and Taksi) while they had little difficulty in differentiating pseudo-homophones from nonwords (such as Tazi). Hawelka, Gagl, and Wimmer (2010) reported that peculiar patterns of eye movements in reading were associated to a dysfunction of the lexical route resulting in frequent failures of orthographic whole-word recognition.

The source of the lexical deficit evidenced in the present study is not entirely clear. A first possibility is that dyslexic children have reduced lexical knowledge not limited to written presentation; i.e., they have defective auditory comprehension. We have no pertinent data concerning the present children; however, in previous studies with similar populations of dyslexic children, we failed to find any deficit in oral vocabulary (e.g., Judica et al., 2002; Zoccolotti et al., 1999). Furthermore, when tested systematically, English-speaking dyslexic children with lexical orthographic deficits did not show any impairment in auditory comprehension of the words they had been unable to read (Castles & Coltheart, 1993). Alternatively, it could be hypothesized that this limitation is due to a delay in reading acquisition, which in turn is a consequence of the reduced exposure to print typical of children with reading difficulties. In fact, this type of interpretation has sometimes been advanced to explain profiles of surface dyslexia even in the case of irregular orthographies, such as English (e.g., Stanovich, Siegel, & Gottardo, 1997). Finally, it could be suggested that the difficulties with low-frequency words are due to the fact that dyslexics have difficulties in using efficient graphemic descriptions to form lexical entries. Clearly, these two latter hypotheses are not mutually exclusive but they can both contribute to an explanation of this pattern of findings. The present evidence does not allow distinguishing between them. At any rate, it has been observed that children with peripheral dyslexia do regularly present surface-type errors in their reading (Prior & Mc Corriston, 1983), an effect that is quite apparent in an opaque orthography, such as unpointed Hebrew (Friedmann, Kerbel, & Shvimer, 2010).

Overall, children with dyslexia were impaired in reading aloud both words and nonwords. In terms of global influences on the data, their slowness in reading nonwords was similar whether these were presented in pure blocks or mixed with words; by contrast, reading words in pure lists produced a greater deficit than reading nonwords or words in mixed blocks. Thus, reading words in pure lists appears to be a particularly demanding task for dyslexics, indicating inefficiency in activating lexical orthographic entries. We propose that these findings may be accounted for by hypothesizing two separate deficits: An early prelexical impairment affecting performance independently of lexicality and context and a later inefficiency in activating entries of the orthographic lexicon as a function of context demands.

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APPENDIX

HF Words		LF Words		HF-matched Nonwords	LF-matched Nonwords
ACQUA	water	ABISSO	abyss	ALAMMO	ABIO
ALBERGO	hotel	ACETO	vinegar	ALDIRGO	ACATO
ALUNNO	student	AGGUATO	ambush	ARBE	AGGUENO
ARGENTO	silver	AGIO	comfort	ARDESTO	AGRIO
ARTE	art	ARNESE	tool	ASQUA	ALISTO
AULA	classroom	ASFALTO	asphalt	AUCA	ARCUSE
BALCONE	balcony	ASMA	asthma	BIRTIA	ASCA
BESTIA	beast	ATRIO	foyer	BOMELLA	ASFUNTO
CAMINO	fireplace	BAVA	froth	CAMA	BELCA
CANDELA	candle	BEFANA	epiphany	CANDIMA	BOLANA
CANE	dog	BRODO	broth	CONNA	BUVA
CANZONE	song	CANGURO	kangaroo	COPO	CABA
CAPRA	goat	CATINO	basin	CRASE	CADUCIA
CASA	house	CLERO	clergy	CRECCIA	CATTOGA
CAVALLO	horse	COMETA	comet	CUMIPO	CLENO
COLORE	colour	COMIZIO	campaign	CUMORE	CODO
CUORE	heart	CORALLO	coral	CUNALLO	COMATA
DONNA	woman	CORO	choir	DAPRA	COTENTE
ESTATE	summer	CRANIO	skull	ESTOLE	CRUNIO
FAME	hunger	CUBO	cube	FARATA	CUATO
FATA	fate	CUOIO	leather	FEBBIA	CUTINO
FESTA	celebration	DEMONIO	demon	FEDIA	DOCALLO
FIAMMA	flame	FAMA	fame	FEME	FAMANE
FIGLIO	son	FANALE	traffic light	FERTA	FARTONE
FORESTA	forest	FIDUCIA	trust	FIME	FENO
FRASE	phrase	FLOTTA	fleet	FOCENDA	FEPE
FRECCIA	arrow	FOGNA	sewer	FOVERTA	FERTO
GARA	race	FUNE	rope	GUSA	FICCHIO
LIBRO	book	FURGONE	van	LICRO	FIGNA
MUCCA	cow	FURTO	theft	MACCA	FIPONE
NEBBIA	fog	LACCIO	lace	NAROLA	LIDE
NEGOZIO	shop	LATTUGA	lettuce	NEPE	LIGRAMA
NEVE	snow	LIDO	shore	NIAGGIA	LIRTA
ODORE	smell	LISTA	list	OGORE	LOMETA
PACE	peace	MUMMIA	mummy	PABE	MIOTTA
PALAZZO	building	PACCO	package	PARENA	PALSA
PANE	bread	PADELLA	frying pan	PASE	PAMA
PARETE	wall	PALA	ball	PEGOZIO	PAMO
PAROLA	word	PALATO	palate	PIAMMA	PANGORO
PATATA	potato	PALO	pole	PIOGRA	PEMONIO
PIETRA	stone	PATENTE	license	PIOMA	PIRONE
PIOGGIA	rain	PATTO	pact	POLTE	PODILLA
PIUMA	feather	PEPE	pepper	PONGUE	POPA
PONTE	bridge	PIGIAMA	pyjamas	PONZANE	PORSO
RAGAZZO	boy	PIPA	pipe	ROLORE	PUBO
RIVA	river bank	POLPA	pulp	RUNAZZO	PUCCO
RUMORE	noise	POMATA	ointment	RUVA	PUMMIA
SANGUE	blood	ROMANZO	novel	SALCONE	RELA

(*Continued*)

APPENDIX (*Continued*)

HF Words		LF Words		HF-matched Nonwords	LF-matched Nonwords
SEDIA	chair	ROSPO	toad	SATA	RITRO
SEME	seed	RUGA	wrinkle	SEGLIO	ROLANZO
SORELLA	sister	SAPONE	soap	SETRO	SACATO
TAPPETO	carpet	SECCHIO	bucket	TERO	SATTO
TOPO	mouse	SENO	breast	TONE	SOMIRIO
TORO	bull	SUORA	nun	TOPPETA	SUNE
TORRE	tower	TALPA	mole	TUORE	TAGONE
TURNO	turn	TIMONE	tiller	TURRA	TILPA
VAPORE	vapour	VAGONE	carriage	VELAZZO	VACCIO
VETRO	glass	VALANGA	avalanche	VENO	VALONTA
VICENDA	story	VELA	sail	VIPOLE	VATTO
VINO	wine	VETTA	summit	VURNO	VUGA