Notes and discussion

Word length effect in early reading and in developmental dyslexia

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Abstract

Vocal reaction times were measured in Italian dyslexics and in proficient readers while they read single words. Three groups of control participants (for a total of 79) were tested. All were in the first, second or third grade of elementary school. Nine third graders with a low level of reading ability when assessed by standard reading procedures were also tested. Results indicated that vocal RTs of control participants were faster and less sensitive to word length as a function of age; also, there was a particularly marked change between first and second graders. Dyslexics’ vocal RTs and errors were much worse than those of peer control participants and resembled those of first grade controls. It is suggested that normal readers in an orthographically transparent language (Italian) adopt a lexical strategy quite early in their learning. On the contrary, dyslexics seem unable to learn this mode of processing and continue to use a sub-lexical reading procedure.

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1. Introduction

Developmental reading deficits in native speakers of languages characterized by regular orthographies, such as German and Italian (e.g., Job, Sartori, Masterton, & Coltheart, 1983; Wimmer, 1993), differ from those in languages with opaque orthographies (such as English or French). German and Italian dyslexics have a primary deficit in reading speed (Wimmer, 1993; Zoccolotti et al., 1999). The nature of this deficit has been investigated in Italian dyslexics using two different techniques: eye movement recording during text reading and vocal reaction time in naming words.

With regard to eye movements, proficient Italian readers scanned lines of text with only a few saccades (De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999). In contrast, dyslexics made a large number of small saccades, indicating a more fragmented word analysis. As a consequence, number of fixations depended on word length. The word length effect was present for both high and low frequency words. The finding of a large word length effect and its independence from word frequency was interpreted as an index of reliance on the sub-lexical procedure in dyslexic readers (De Luca et al., 1999). This idea was further investigated in a subsequent study examining the length effect in words and pseudo-words (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002).

In normal readers, the length of the item affected the number of saccades for pseudo-words, which require a sub-lexical procedure, but not for words, which can be accessed lexically. Dyslexics showed a clear length effect for both words and pseudo-words, consistent with the notion of reliance on the sub-lexical procedure regardless of stimulus material.

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Consistent findings were obtained by measuring vocal reaction times (RT) in naming single words. Dyslexics’ latencies monotonically depended on the number of letters in the word (Judica, De Luca, Spinelli, & Zoccolotti, 2002; Zoccolotti et al., 1999). The word length effect shown by dyslexics contrasted with the nearly flat curve of proficient readers (Zoccolotti et al., 1999).

Reliance on sub-lexical reading in dyslexics is also indicated by their defective performance on linguistic tasks requiring the use of the lexical procedure (such as orthographic decisions, discrimination of pseudo-homophone contrasts, and lexical decision; Job et al., 1983; Zoccolotti et al., 1999). In contrast, tasks mapping the sub-lexical procedure did not indicate specific impairments. Although performance in reading pseudo-words was not normal, it was affected to the same extent as reading words (Judica et al., 2002; Zoccolotti et al., 1999). To date, an abnormal proportion of errors in reading pseudo-words has only been reported in one case (Sartori & Job, 1983).

Overall, Italian dyslexics seem to use a sub-lexical procedure, and the presence of a word length effect may be a sensitive measure of this mode of processing. Models of reading acquisition (e.g., Frith, 1985) and current views about learning to read in Italian children (e.g., Orsolini, 2000) suggest that reliance on the sub-lexical procedure dominates in the early stages of learning to read. Therefore, there may be some resemblance between dyslexics’ mode of processing and that of children who are just learning to read. The above reported evidence regarding word length effect refers to dyslexics and controls who have been going to school for some time (i.e., ca. 6–7 years). At this point, the difference between normal readers and dyslexics is quite marked. However, the word frequency effect (a marker of lexical reading) has also been found in third graders (Burani, Marcolini, & Stella, 2002). This finding suggests that the difference between dyslexics and proficient readers is already present in third grade. For this reason, we examined vocal reaction times to different length words at an earlier stage of learning (first, second, and third grade) and compared them to the vocal reaction times of third grade dyslexics. It was expected that children in the early grades would show a word length effect similar to the one observed in older dyslexic readers.

2. Materials and methods

2.1. Participants

Criteria for inclusion in the dyslexic sample were: marked reading delay on a standard reading test (see below); performance in the normal range (above 10th percentile; Pruneti, 1985) on Raven’s Coloured Progressive Matrices; normal or corrected to normal visual acuity. The dyslexic sample included 9 third grade participants (8 males) between 8.0 and 8.7 years of age ($X=8.4\pm0.3$ years). Mean performance on Raven’s test was $(23.0\pm3.9)$. On the Vocabulary sub-test of the WISC, dyslexics had a mean weighted score of 9.8 ($SD=1.2$; range 8–11), indicating normal semantic ability for verbal input.

We also tested three groups of participants with normal reading ability in first, second, and third grade. There were 27 participants (13 males: mean age of $6.9\pm0.3$ years) in first grade, 24 (14 males age of $7.7\pm0.3$) in the second grade, and 28 (14 males age of $8.7\pm0.3$) in the third grade.

2.2. Reading assessment

Reading level was examined using the MT Reading test (Cornoldi & Colpo, 1998). The participant had to read a passage aloud with a 4-min time limit; speed (time in seconds per syllable read) and accuracy (number of errors, adjusted for the amount of text read) were scored. To measure comprehension, the participant read a second passage without a time limit and responded to 10 multiple-choice questions. Stimulus materials (and related reference norms) varied by grade.

2.3. Single word reading

Words of 2, 3, 4, and 5 letters were used (54 words for each length). The beginning phoneme of each word was consistent across groups. Frequency did not vary among different word lengths (for details see Zoccolotti et al., 1999).

Words were presented on the PC screen after a fixation point displayed for 750 ms and a blank screen (250 ms). Each letter subtended 0.4 cm horizontally (0.4° of visual angle at a distance of 57 cm). One block of 10 practice stimuli and six experimental blocks of 36 stimuli were administered, interspersed with brief pauses. Word length was randomized within each block.

The subject’s task was to read the words aloud as quickly as possible. The stimulus remained on the screen until the subject responded. Performance was measured by the vocal RT (in ms) to correctly read words. Errors (incorrectly reported words) were also computed. In a few instances, trials were not valid due to outside noise or technical failures.

3. Results

3.1. Reading performance

Dyslexics’ and control participants’ performances on the MT battery are presented in Table 1. Dyslexics were severely impaired for speed and accuracy. Ability to
understand the text was only mildly impaired. This pattern confirms previous results indicating that the text can be comprehended despite errors and slowness if the participant is given enough time (Zoccolotti et al., 1999).

Mean $z$ scores of control participants were near zero for all three parameters.

### 3.2. Single word reading

Inspection of vocal RTs and errors in Figs. 1A and B reveals some main results:

(a) vocal RTs of control participants became faster and less sensitive to word length as a function of age (mean RT increase per letter was 173, 60, and 36 ms in first, second, and third grade, respectively);

(b) error rate of controls was quite low (i.e., less than 3%), although some improvement in performance was detectable between first and second grade (due to the presence of a floor effect, no statistical analysis was performed on error data);

(c) vocal RTs and errors of dyslexics were much worse than those of same age (third) grade controls, but the dyslexics’ performance was similar to that of the first grade controls (mean RT increase per letter was 170 ms and errors varied between 2 and 5%).

An ANOVA indicated a main effect of grade ($F_{(2,76)} = 19.35, p < .0001$) with faster RTs passing from first to second (Duncan’s post hoc, $p < .01$) but not from second to third grade. The main effect of word length ($F_{(3,228)} = 44.4, p < .0001$) indicated RT increases for each letter step ($p < .01$). The grade by word length interaction was significant ($F_{(6,628)} = 10.14, p < .0001$). For all length categories, RTs were shorter in second than in first grade ($p < .01$). Third graders’ RTs did not differ from those of second graders for two- and three-letter words; RTs were shorter in the case of four- ($p < .05$) and five-letter words ($p < .01$).

An ANOVA on vocal RTs of dyslexics and same grade control participants indicated a significant effect of group ($F_{(1,35)} = 14.10, p < .0001$), word length ($F_{(3,105)} = 19.56, p < .0001$), and a significant interaction ($F_{(3,105)} = 8.47, p < .0001$). Inspection of Fig. 1A indicates that the difference in RTs between the two groups increased with increasing word length. A posteriori comparisons indicated that the difference was reliable in all cases ($p < .05$ for two-letter words and $<.01$ in all other cases).

### 4. Discussion

Two main findings emerged from the present experiment. First, in control participants the word length effect on vocal reaction times dramatically decreased passing from first to second grade; a much less marked reduction was present passing from second to third grade. Second,
the size of the effect in first grade was very similar to that observed in dyslexics with two additional years of reading experience.

Reading improvement can be due either to improvement in the efficiency of the sub-lexical procedure or to acquisition of the lexical procedure. While both changes presumably co-exist, the abrupt transition observed from first to second grade suggests that in normal development the lexical procedure is already predominant in second grade, at least for the relatively short and frequent words used in the present experiment. If reading improvement is due exclusively to an increase in efficiency of the sub-lexical procedure, the RT curve should shift downward with a minimal change in slope. Thus, the transition from a sub-lexical to a lexical procedure takes place early in learning to read Italian. Consistently, Burani et al. (2002) reported a word frequency effect from third to fifth grade. To the extent to which the word frequency effect marks the use of the lexical procedure, their findings show that this route was already functioning in third grade. The present data suggest that for high frequency words the lexical procedure may already be efficient in second grade. In contrast, even after 3 years of school, dyslexics do not have the ability to process a word globally and are blocked at an early stage of analytical processing. Therefore, they appear to fail in the transition from a sub-lexical to a lexical procedure.

The present results offer some insights on the early stages of learning to read in a regular orthography language and may contribute to understanding the genesis of developmental reading disorders. Learning to read in languages with shallow orthography, such as Italian (Orsolini, 2000), German (Wimmer & Goswami, 1994) or Dutch (Bosman & de Groot, 1996) starts with alphabetic decoding. Due to the relatively high consistency of these languages, this phase is quite brief and children rapidly start to develop a lexical procedure, as shown here. In principle, this change is not necessary since nearly all words can be identified by grapheme-phoneme correspondence. However, in this way reading becomes more fluent and rapid. Since the correspondence rules are easy in Italian, early alphabetic decoding is acquired adequately by virtually all children. Thus, Italian first graders read slowly but accurately (Cornoldi & Colpo, 1998). This is similar to what has been described in Austrian children (Wimmer & Hummer, 1990) but different from what has been observed in English-speaking children, where accuracy in early phases of learning is lower, even when only regular words are considered (e.g., Coltheart & Leahy, 1996).

Previous work (Job et al., 1983; Judica et al., 2002; Zoccolotti et al., 1999) as well as the present results indicate that developing a lexical reading procedure is a relatively common problem among Italian readers. Thus, some children remain anchored to the early sub-lexical procedure. In contrast, a selective deficit of the sub-lexical procedure has only been described as an exception (Sartori & Job, 1983). Reading problems in opaque orthographies, such as English or French, may originate from more than one source. In these languages, grapheme-to-phoneme conversion rules are considerably complex and difficult to learn. Thus, a large corpus of irregular words and homophones might call for an early attempt to use the lexical procedure in reading, regardless of whether or not the grapheme-to-phoneme rules have been fully acquired. This could give rise to a larger variety of disturbances than in regular orthographies. Some children might fail to learn a lexical procedure after having acquired grapheme-to-phoneme correspondence rules, or problems might arise from the prevalent adoption of the lexical procedure when the sub-lexical procedure has not yet been fully mastered. The quickness and ease of alphabetic decoding makes this second alternative unlikely among Italian-speaking children.

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References


