

# Influence of position of the context sensitive graphemes and word frequency effect on reading speed: a performance analysis of developmental dyslexics and fluent readers

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## Abstract

*Several studies have reported how the presence of contextual letter-sound conversion rules influences both reading speed and accuracy and the effect of rule complexity holds for low frequency words only. We aimed to investigate the role of orthography complexity and, in particular, of context sensitive graphemes position and frequency of use on reading speed, analyzing the performance of developmental dyslexics and fluent readers. With regard to speed (reading speed of word lists), context sensitive graphemes position had an effect only for dyslexic children, who showed the worst performance if the context sensitive graphemes were in first position, regardless of word frequency. On the other hand, we found a frequency effect (in particular worst performance in the case of low frequency words) for both groups.*

**Keywords:** Developmental dyslexics, Word frequency, Reading speed

\* Received: October 06, 2010; Revised: April 05, 2011; Accepted: June 22, 2011.

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## 1. Introduction

In languages with shallow orthography, such as Italian and German, the majority of letters have only one pronunciation and words like *suppellettile* [furnishing] may be read through letter-sound conversion rules in a one-to-one, left to right, fashion (Barca, Burani, Di Filippo, & Zoccolotti, 2006; Barca, Ellis, & Burani, 2007).

Despite the apparent transparency of the Italian language, we translate some graphemes into different sounds depending on adjacent letters. The letter *c* is pronounced /k/ when followed by a consonant or vowels *a*, *o*, *u*, as in the words *crudo* [raw], *capra* [goat], *colore* [colour] and *cucina* [kitchen]. Equally, when *c* is followed by *h*, it is pronounced /k/, as in *chiesa* [church]. However, it takes the sound /tʃ/ when followed by the vowels *e* and *i*, as in *cesto* [basket] or *cibo* [food]. A similar rule applies to the letter *g*, whose pronunciation also changes depending on successive letter, as in: *gatto* [cat], *ghianda* [acorn] and *gelato* [ice-cream]. In addition, there are some cases wherein the pronunciation of certain orthographic groups is not dependent upon the combining of different sounds - as in the *gli* group, pronounced differently in *aglio* [garlic] or *glicine* [wistaria]. So, we can say that some words contain *context sensitive graphemes*, which are groups containing letters whose pronunciation changes in response to the letter that follows (Lepschy & Lepschy, 1991; Burani, Marcolini, & Stella, 2002; Barca, 2003; Burani, Barca, & Ellis, 2006; Barca *et al.*, 2007).

Several studies have highlighted the relative influence of not only the complexity of spelling, but also word frequency of the given linguistic stimulus. Seidenberg, Waters, Barnes, and Tanenhaus (1984) estimated that, individuals spend more time reading words that contain context sensitive graphemes rather than with more transparent spelling patterns, especially if these words are low frequency of use. In this regard, for high frequency use words, there wouldn't be differences between reading speed words that contain context sensitive graphemes and words that do not contain (Taraban & McClelland, 1987; Paap, Chen, & Noel, 1987; Paap & Noel, 1991; Burani *et al.*, 2006; Barca *et al.*, 2007).

Barca *et al.* (2007) gave to read normal-reading third and fifth grade children words characterized by a simple grapheme-phoneme conversion system (e.g., *mondo* [world]) and words characterized by what the authors define as *contextual letter-sound conversion rules*, or rather less predictable letter-sound conversion rules (e.g., *cane* [dog]). In the first experiment, both groups of subjects (third and fifth graders) were slower and less accurate in reading words containing context sensitive graphemes. Younger children were slower and less accurate than older children but the effect of rule contextuality was similar in the two groups in terms of both reading time and accuracy. However, the second experiment showed that, for both groups of children, the effect of orthographic complexity was significant (for accuracy and speed) for low frequency words only.

Comparing fluent readers and dyslexic children, Barca *et al.* (2006) discovered that, although dyslexics were slower and less accurate than controls, they were affected by word frequency, grapheme contextuality and their interaction in a similar manner as average readers. Specifically, word frequency effects were found in both groups, with high frequency words named faster and more accurately and dyslexics showing greater, not smaller, frequency effects. Contextuality, effects were also apparent for both groups: words containing contextual graphemes were named more slowly and less accurately than words with one-to-one mappings. For both groups, this difference was present only in the case of low frequency words. According to the authors, these results showed the use of lexical reading in Italian dyslexics and refute the claim of a deficit in whole-word processing (Wimmer, 1993; Zoccolotti, De Luca, Di Pace, Judica, Orlandi, & Spinelli, 1999).

These results were interpreted in the framework of the DRC - Dual Route Cascaded Model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) that assumes the existence of two different ways in the reading process: lexical (decoding the entire word) and non-lexical (conversion from grapheme to phoneme). The lexical route operates by accessing the whole-word, as in the case of high frequency words. On the other hand, the non lexical route operates serially by left to right letter-to-sound conversion rules. Words with context sensitive graphemes are read correctly only by the lexical route, but with dependence on word frequency. In fact, the lexical route guides to correct and rapid pronunciation in case of high frequency words. The non-lexical processing interferes in the case of low frequency or unknown words. Processing an unknown letter sequence incorporating context-sensitive graphemes could provoke mistakes about the correct reading of the irregular group (for example: /tza/ as /ka/).

In this respect, visual-lexical information (the global recognition of the word or group of context sensitive graphemes) is an important clue in bringing the subject to correct reading, both in typical (fluent readers) and atypical development (developmental dyslexics).

Here, we address the question of what may be the role of the position of the context sensitive grapheme within the word and word frequency influence on reading speed. Several studies (Sheerer, 1987; Coltheart & Rastle, 1994; Rastle & Coltheart, 1999; Mulatti & Job, 2003) showed that the effect of regularity is modulated by the context sensitive grapheme position in the word: the cost of irregularity decreases from the first to the last position in the word. Mulatti and Job (2003) analyzed the effect of phonetic regularity and irregularity in Italian college students, looking at regular (*fard*) and irregular (*photo*) foreign words. They hypothesized that, in naming time, the impact of the irregular morpheme would decrease according to its position in the word, from the first to the last (*photo*, *tour*, *free*, *saloon*, *buffet*). Based on the DRC (Coltheart *et al.*, 2001), Mulatti and Job (2003) forecast an interference between the two ways in reading irregular words and a modulation of this effect

depending on the position of the irregularity in the word. The results showed that the cost of irregularity decreased over the five positions tested.

Other studies showed that the time needed to read a nonword (derived from a word by changing a letter) depends upon the position of the diverging letter: first letter diverging nonwords (bunto derived from punto/point) were read more slowly than fourth letter diverging nonwords (monso, derived from mondo/ world). The impact of lexical activation on sublexical processing would modulate this effect also depending on the level literacy of the observers (Mulatti, Peressotti, & Job, 2007; Peressotti, Mulatti, & Job, 2010).

## 2. Aims and Hypothesis

In the present study, we used Italian words considering the number of syllables (*ba-si-li-sco* [basil]), not that of letters. The objective was to assess the effect of the presence of context sensitive graphemes (e.g., *sca-te-na-to* [wild]) and their position within the target word (first position vs. last position: *sco-lo-pen-dra* [centipede] vs *ba-si-li-sco* [basil]) in relation to the word frequency (high vs. low: *sca-te-na-to* [wild] vs *sco-lo-pen-dra* [centipede]) on reading speed (reading speed of word lists).

Since low frequency words tend to activate a non-lexical procedure, we hypothesized that both controls and dyslexic children would show worse performance in reading speed (reading speed of word lists) in the case of low frequency words. Furthermore, both groups should be influenced by the context sensitive grapheme position with lower reading speed with context sensitive graphemes in first position (especially in the case of low frequency words).

## 3. Method

### 3.1 Participants

Forty eight children participated to the study (24 males and 24 females). Of these, 24 were developmental dyslexics (12 males and 12 females) and 24 fluent readers (12 males and 12 females), attending the third grade of two state-run elementary schools in Palermo. The participants were aged between 7 years and 7 months (91 months) and 8 years and 6 months (102 months), average = 96.8,  $SD = 2.86$ . Children were selected from a sample of 200 children (see below).

### 3.2 Materials and Procedure

#### *Screening procedures*

At the beginning of the study, a screening was done on all third graders from two public schools located in a medium-high socio-economic district. The screening was carried out over a period of three months.

First, each child was given a sociological evaluation form to ensure that no socio-cultural disadvantage might interfere with reading ability. In particular, we included in our sample only children whose both parents had completed at least high school.

Children were tested on a whole battery of reading and spelling tests commonly used in the assessment of reading disability in Italy. This battery included the Non-Verbal Intelligence Test (TNIV; Hammill, Pearson, & Wiederholt, 1998), the MT Text Comprehension and Decoding Test (Cornoldi, Colpo, & Gruppo M.T., 1998) and the Dyslexic and Dysgraphic Evaluation Test (Sartori, Job, & Tressoldi, 1995).

The Non-Verbal Intelligence Test (Hammill, Pearson, & Wiederholt, 1998) is particularly suited for children with language and reading disabilities because it evaluates the development of logical thinking limiting the influence of cultural and linguistic aspects. It consists of 150 items, subdivided into three areas of logical operations: analogies, categories and sequences. Each area includes tasks of object illustration and geometric picture. For each item, evaluation was binary, with a mark of 1 attributed to each correct item, and 0 to incorrect items. The raw data obtained were transformed into a measure of mental age on the basis of conversion tables. The average intelligence was 100 with standard deviation 15. The reliability coefficient of the test was  $\alpha = .90$ . Moreover, this test presents good validity since the correlation with the Wechsler Intelligence Scale for Children is .81.

In the MT test (Cornoldi *et al.*, 1998), the first story is suited to and standardized for the children's school grade, followed by 10 multiple choice questions relating to the characters and events mentioned in the story. Participants were asked to choose the correct response based on their understanding of the story. Scoring comprised 1 point for each correct response. Normal performance is five or more correct choices. This test was administered to select students with normal reading comprehension abilities. The reliability coefficient of the test is  $\alpha = .60$  (Cornoldi *et al.*, 1998). The Decoding reading test (Cornoldi *et al.*, 1998) required the subjects to read a text aloud. The number and type of errors made were evaluated. Separate scores were calculated for speed and accuracy. With regard to accuracy, a score of 1 was attributed for each long pause, or addition or omission of syllables, words, or lines. A score of 0.5 was attributed for each stress error, hesitation, or self-correction. Normal performance is 6 or less errors. With regard to speed, the total score was obtained by calculating the seconds per number of syllables of text read. Normal performance was a score of .80 s/syllable or less. This test was administered to identify participants with reading decoding difficulties. The reliability coefficient of test is  $\alpha = .75$  for accuracy and  $\alpha = .64$  for speed (Cornoldi *et al.*, 1998).

Finally, the Battery for the Assessment of Developmental Reading and Spelling Disorders (Sartori *et al.*, 1995) consisted of 12 sub-tasks. Here, accuracy and speed were evaluated for the grapheme and number reading,

grapheme comparison, lexical decision and word and nonword reading tasks. Accuracy was evaluated for each task with a score of 1 being attributed to each correct item, and 0 to incorrect items. The raw data thus obtained were then compared to the appropriate conversion tables. Performance under the 5<sup>th</sup> percentile indicated reading disability. The test-retest reliability of the battery was  $r = .56$  for accuracy and  $r = .77$  for speed.

The battery for the Assessment of Developmental Reading and Spelling Disorder were not fully administered: task 4 (reading lists of words aloud), task 5 (reading lists of non-words aloud), task 7 (recognition of non-homograph homophones) and task 8 (detection of fusion and separation of words errors within sentences) were administered only to the readers with disabilities decoding, to ascertain, more precisely, the types of difficulties encountered during the deciphering of the text.

With regard to normative criteria, we selected children who achieved scores in the middle range (between 85 and 115) on the TINV, made at least seven errors in the correctness test (MT), achieved at least .81 s/syllable in the MT test and responded to at least seven correct responses out of 10 in the MT comprehension test. Then, four tasks (4, 5, 7 e 8) of the Battery for the Assessment of Developmental Reading and Spelling Disorders (Sartori *et al.*, 1995) were administered to all children who had a defective performance in Correctness and Speed at the MT tests (seven errors or more for Correctness test and .81 s/syllable or more for Speed test). We included in our sample, therefore, only those children who, in these tasks (4, 5, 7 and 8) reported scores lower than the 5<sup>th</sup> percentile.

With regard to fluent readers, we selected children who achieved scores in the middle range (between 85 and 115) on the TINV, made less than seven errors in the correctness test (MT), achieved less than .81 s/syllable in speed test (MT) and responded to at least seven correct responses out of 10 in the Comprehension test (MT).

### *Experimental test*

Sixty four-syllable words were selected (20 nouns, 20 verbs and 20 adjectives). Half (30) were of high frequency: 10 had context sensitive graphemes (*c* or *sc*) in the first position (e.g., *scivolare* [to slide]), 10 in the final position (e.g., *solletico* [tickling]) and 10 were fillers words, characterized by the absence of context sensitive graphemes. The other half (30) were of low frequency: 10 had context sensitive graphemes (*c* or *sc*) in the first position (e.g., *cospirare* [to conspire]), 10 in the final position (e.g., *odalisca* [odalisque]) and 10 were fillers words, characterized by the absence of context sensitive graphemes. In total, we constructed four lists, each consisting of 15 words - 10 target and 5 filler words: the first list consisted of 15 high frequency words with context sensitive graphemes in the final position; the second list consisted of 15 high frequency words with context sensitive graphemes in the first position; the third of 15 low frequency words with

context sensitive graphemes in the final position; and the fourth list of 15 low frequency words with context sensitive graphemes in the first position.

The 60 target words were selected based on the Dictionary of Basic Italian (D.I.B.; De Mauro & Moroni, 2000), a specific Italian dictionary for children from 8 to 11 years: 30 words were defined as either basic, strategic or of high frequency use; the other 30 were of a lesser use (i.e., in the D.I.B., they are not part of the groups of basic, strategic and high frequency use words).

The children were called out of the class during regular class hours and were accompanied to the place set up for testing (away from other activities within the school). During this period, children read the four lists of words for a total of 60 words. We balanced the administration of the four lists among participants according to a *latin square* design: the first child read the lists in the order 1, 2, 3 and 4; the second in the order 2, 3, 4 and 1; the third in the order 3, 4, 1 and 2 and so on.

#### 4. Results

First, we conducted t tests to assess the effects of context sensitive graphemes position (first vs. last position) and word frequency (high vs. low) on reading speed. There were significant differences in developmental dyslexics' speed of reading in terms of the position of the context sensitive graphemes ( $t(23) = 4.98, p < .001$ ), with lower performance if the context sensitive graphemes were in the first ( $M = 99.46$  s) than in the last position ( $M = 87.21$  s, see Table 1). We also found significant differences regarding the word frequency ( $t(23) = -7.44, p < .001$ ), with lower performance when the target words were of a low ( $M = 105.67$  seconds) than high frequency ( $M = 81$  s, see Table 1). On the other hand, fluent readers revealed no significant difference in reading speed as a function of the position of the context sensitive graphemes. Significant differences arose concerning word frequency ( $t(23) = -10.9, p < .001$ ), with lower performance if the target words were of low ( $M = 57.62$  s) rather than high frequency ( $M = 30.5$  s, see Table 1).

Table 1 - *Effect of the position of the context sensitive grapheme on speed (reading lists of words) and effect of word frequency on speed (reading speed of words) in Dyslexics Fluent readers: average speed in seconds (Av.) and standard deviation (Sd.)*

	1 <sup>st</sup> Position		Last Position		A.f.d.		B.f.d.	
	Av.	Sd.	Av.	Sd.	Av.	Sd.	Av.	Sd.
Dyslexics	99.46	30.29	87.21	24.16	81	28	105.67	27.81
Fluent readers	44.5	12.46	43.62	10.29	30.5	9.53	57.62	15.08

The analysis within groups showed significant differences in reading speed for developmental dyslexics as a function of the position of the context sensitive graphemes for both high and low frequency words: in the case of high frequency, there was lower performance for words with context sensitive graphemes in first ( $M = 42.42$  seconds) than in last position ( $M = 38.58$  seconds;  $t(23) = 2.47, p = .022$ ); similarly, in the case of low frequency, there was lower performance for context sensitive graphemes in first ( $M = 57.04$  s) than last position ( $M = 48.63$  s;  $t(23) = 3.95, p = .001$ ). As to the effect of frequency, ( $t(23) = -6.47, p < .001$ ) there was lower performance low frequency ( $M = 57.04$  s) than high frequency words ( $M = 42.42$  s) for stimuli with context sensitive graphemes in first position ( $t(23) = -6.47, p < .001$ ); similarly for stimuli with context sensitive graphemes in last position there was lower performance for low ( $M = 48.63$  s) than high frequency ( $M = 38.58$  s) words ( $t(23) = -4.83, p < .001$ ).

Table 2 - *Effect of the position of the context sensitive grapheme and word frequency on speed (reading speed of words): average speed in seconds (Av.) and standard deviation (Sd.)*

	1 <sup>st</sup> Position		Last Position		1 <sup>st</sup> Position		Last Position	
	A.f.d.		A.f.d.		B.f.d.		B.f.d.	
	Av.	Sd.	Av.	Sd.	Av.	Sd.	Av.	Sd.
Dyslexics	42.42	15.1	38.58	13.89	57.04	17.08	48.63	12.27
Fluent readers	15.45	5.13	15.04	4.58	29.04	8.58	28.58	7.28

With respect to fluent readers, differences were observed only for frequency (but not position) with lower performance for low ( $M = 29.04$  s) than high frequency words ( $M = 15.46$  s) in the case of stimuli with context sensitive graphemes in first position ( $t(23) = -9.95, p < .001$ ) as well as in the case of stimuli with context sensitive graphemes in last position ( $t(23) = -10.21, p < .001$ ); low frequency words:  $M = 28.58$  s; high frequency words:  $M = 15.04$  s). Results are presented in Table 2.

## 5. Discussion

The lexical route operates in parallel and quickly, while the non lexical route works serially from left to right. According to Mulatti and Job (2003), this diversity is the basis for explaining the irregularity position effect. They argue that, if the irregular grapheme is at the end of the word, when the

non-lexical route begins to process, the lexical route has already processed the whole word. The interference between the two ways would be minimal and there would not be delays in naming. By contrast, if the irregular grapheme is in the first position, the two ways compete for the selection of the critical group and naming time would increase (Mulatti & Job, 2003).

In the present study, we selected high- and low-frequency Italian words and considered a division into syllabic groups, selecting less transparent syllabic groups, located in either the first or last position. In fact, several studies showed that the effect is present only for low frequency words. The presence of contextual sensitive graphemes would not affect the reading of high frequency words because the lexical procedure allows for immediate word recognition. On the other hand, the processing of low frequency words is slowed by the competing phonemes activated in the non-lexical route by the context sensitive graphemes (Barca *et al.*, 2006; Burani *et al.*, 2006; Barca *et al.*, 2007). However, it might be the case that the dependent variable used in our study (list reading time) is less sensitive with respect to the measure used in previous studies (voice onset reaction time for single words).

In the present study, when comparing context sensitive graphemes placed in first and last position, only dyslexic children showed significant differences with lower performance if the context sensitive graphemes were placed in first position (independent of frequency). Contrary to our hypothesis, no significant difference appeared for fluent readers comparing context sensitive graphemes placed in first and in last position. The only case in which a significant difference emerged was comparing low and high frequency words (with worse performance for the latter). Probably, for fluent readers, in the case of high frequency words, there is a quick recognition of the whole word or, in the case of low frequency words, there may be an effective identification of the critical syllabic group and its position may not be so important. It should also be added that the more familiar Italian word structure (compared to that of foreign languages such as English) may have contributed to the good performance of fluent readers (Mulatti & Job, 2003).

According to DRC model (Coltheart *et al.*, 2001), there would be an interference between the two ways in reading irregular words (with context sensitive graphemes) and a modulation of this effect depending on the position of the irregularity in the word (Mulatti & Job, 2003). Lexical route would guide to a good pronunciation, particularly for high frequency words.

Furthermore, although also dyslexic children tend to activate a lexical procedure in the case of high frequency words, slower performance emerged when the context sensitive graphemes were in first position not only in the case of low frequency words but also in the case of high frequency words. This findings shows that, for dyslexic children, before the activation of one of two ways and beyond which way is activated (lexical or non lexical), the context sensitive graphemes in first position, would create a slowdown in time designation. This would be even in the case of high fre-

quency words, demonstrating a specific difficulty not only in decoding complex words but also in global recognition of familiar words.

The linguistic analysis that emerges from this research offers some interesting clues and innovative features in a research area that increasingly stresses the importance of words being split in the decoding process into syllables (sca) or group of letters (sc), over and above the role of the lexical and non-lexical routes (Traficante, Barca, & Burani, 2004; Marcolini, Donato, Stella, & Burani, 2006; Barca, *et al.*, 2007; Burani, Marcolini, De Luca, & Zoccolotti, 2008; Zoccolotti, De Luca, Judica, & Spinelli, 2008). Particularly relevant is the demonstration of the influence of the context sensitive grapheme position on the fast decoding of developmental dyslexics. In a diagnostic and rehabilitation context, attention to the linguistic materials should allow a more accurate analysis of the various morpho-syntactic and orthographic characteristics that make some words more accessible than others, especially in the absence of an automatic decoding process.

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