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# An analysis of the word naming errors of normal readers and reading disabled children in Spanish

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## *ABSTRACT*

In the current research the performance of children with and without reading disabilities was compared on a single word naming task. An analysis was carried out of the frequency and form of naming errors produced by the groups when naming real words and nonwords in a transparent orthography such as Spanish. A sample of 132 (45 normal readers, 87 reading disabled) Spanish children aged 9–10 years were selected, and an experiment was carried out to investigate if students with reading disabilities would have particular difficulties in naming words under conditions that require extensive phonological computation. While the children were performing the naming task, we recorded what they read to subsequently analyse the form, as well as the frequency, of naming errors as a function of lexicality, word frequency, word length and positional frequency of syllables. Disabled readers made more errors in nonwords, low frequency words and long nonwords. The findings support the hypothesis that poor phonological skills are a characteristic of reading disabled children.

## INTRODUCTION

Contemporary research on word recognition and on individuals with acquired dyslexia has led to the formulation of detailed models of reading single words. Word recognition is an important link in reading development and constitutes one of the main deficits in children with learning disabilities (Perfetti, 1986, 1989; Siegel, 1986). Among the theoretical models proposed to explain word recognition processes, the dual-route model has received considerable empirical support (Coltheart, 1978, 1985; Seidenberg, 1985). This model postulates two functionally different routes in lexical access: the lexical (or direct-access) route and the non-lexical (or phonological) route. The lexical route implies the visual recognition of a word without intermediate phonological processing. Therefore, only the words visually recognised by the reader and the words that belong to his or her orthographic lexicon can be read using this route, and unknown words and nonwords cannot be read. In the phonological or non-lexical route, the reader initiates a sublexical analysis of the word and applies grapheme-phoneme conversion (GPC) rules. Once the graphemes have been transformed into sounds, the meaning can be extracted from the semantic lexicon. When orthographic systems fail in the consistency of rules, the reader may be required to use the lexical or visual route in order to recognise irregular words.

Earlier versions of the dual-route theory (Coltheart, 1978, 1980) held that the two routes were completely independent. However, a modified dual-route theory assumes that the two routes are somewhat dependent on one another in terms of both knowledge structure and processes (Humphreys and Evett, 1985). The general view most commonly favoured in the literature (e.g. see Patterson and Coltheart, 1987) is that the presentation of a letter string activates both lexical and phonological routines. These routines, in parallel, more or less automatically compute a phonological code, and the decision mechanism selects the output from the routine that first makes a response available. The faster of the two routes determines access in any given case (Besner, 1990).

However, in recent years, the dual-process framework has been challenged on several grounds. Parallel Distributed Processing (PDP) models constrast with dual-route theories in postulating parallel activation along networks of distributed sublexical information. For instance, Seidenberg and McClelland (1989) have shown that a number of empirical findings hitherto interpreted in terms of cooperation and competition between separate processes could be accounted for within a single mechanism based on weighted distributed associations between orthographic and phonological codes. However, several authors have pointed out that Seidenberg and McClelland's (1989) model did not succeed in simulating some neuropsychological dissociations (e.g. Coltheart, Curtis, Atkins and Haller, 1993). Similarly, normal participants have been found to modulate their use of lexical and sublexical information as a function of experimental conditions in ways that suggest some degree of dissociation between the two knowledge sources (for a review see Leybaert and Content, 1995). Consequently, the dual-route framework appears to be superior to other frameworks as a way of accounting for a variety of facts about skilled reading and acquired dyslexia (Castles and Coltheart, 1993, pp. 152). Nevertheless, Seidenberg (1993, p.304) suggested that "...we need more detailed, theory-relevant information about the behavior of dyslexic children" where a connectionist approach would be promising.

On the other hand, many authors have suggested that differences in the depth of alphabetic codes imply different ways of processing written languages (Bridgemen, 1987; Frost, Katz and Bentin, 1987; Seidenberg, 1985). In the case of languages with a deep orthography, skilled readers are normally assumed to recognise words through the orthographic-graphemic code (e.g. Katz and Feldman, 1983), whereas in transparent orthographies readers are assumed to rely on the phonemic prelexical code (e.g. Lukatela, Savic, Gligorijevic, Ognjenovic and Turvey, 1978; Turvey, Feldman and Lukatela, 1984). Nevertheless, there is empirical evidence for the use of orthographic and phonemic cues in printed-word recognition in English (e.g. Baluch and Besner, 1991; Perfetti, Bell and Delaney, 1988) and in Spanish (de Vega and Carreiras, 1989; de Vega, Carreiras, Gutiérrez and Alonso-Quecuty, 1990; Defior, Justicia and Martos, 1996; García-Albea, Sánchez and del Viso-Pabón, 1982; Valle-Arroyo, 1989, 1996).

The dual-route theory of the reading process model is particularly useful because it has been used to explain the mechanisms underlying developmental dyslexics' word reading (e.g. Olson, Klieg, Davidson and Foltz, 1985), and the majority of recent research suggests that word identification problems are basically phonological route problems (Rack, Snowling and Olson, 1992; Siegel and Ryan, 1988; Stanovich, 1988; Wagner and Torgesen, 1987).

Perfetti and Hogaboam (1975) found that the differences between good readers and the reading disabled increased when nonwords or words with low frequency were used. The naming latencies were longer for the reading disabled than for good readers (Hogaboam and Perfetti, 1978). Also, similar results were found using lexical decision tasks; e.g. Perfetti (1985) reported that good readers performed better on words and nonwords than the reading disabled, and reaction times were slower for nonwords in the reading disabled.

Domínguez and Cuetos (1992) studied which of the two reading procedures was responsible for the differences between Spanish good and poor readers using a lexical decision task. They found that the cause of difficulties experienced by the poor readers seems to reside in the grapheme-phoneme decomposition procedure. Jiménez and Rodrigo (1994) found that Spanish reading disabled children had more difficulty in lexical processing which was influenced by poor phonological skills.

Other studies, using the lexical decision paradigm, have also demonstrated that students with reading difficulties have slower access to the lexicon than good readers (Cirrin, 1984; Ellis, 1981; Rayner, 1988; Seymour, 1987; Seymour and Porpodas, 1980). These empirical data clearly indicate that the main reason for reading difficulties seems to be the deficient use of the phonological route, and that poor readers show deficiencies in phonological mediation (e.g. Rack, Snowling and Olson, 1992; Stanovich, 1988).

In this research we have used another methodology: 'Error Analysis'. Analyses of errors have constituted a topic of research in the field of reading (e.g. Allington and Strange, 1977; Beebe, 1980; Goodman, 1965; MacKinnon, 1959; Monroe, 1932; Weber, 1970). This method seems to be promising due to its high ecological value and because it evaluates one of the few observable manifestations of reading processes. Reading and spelling errors have also been a focus of attention and research in neuropsychology, and have led to classifications of dyslexic subtypes (e.g. Boder, 1973; Boder and Jarrico, 1982). This methodology is still evolving and it presents some challenges, the most important of which are the lack of agreement in definitions of error categories and the lack of control in text difficulty in relation to the type of errors (Artola, 1989). Nevertheless, taking into account the special cognitive requirements of reading, we might expect – as Cossu, Shankweiler, Liberman and Gugliotta (1995) have suggested – that the quality of errors produced in a word naming task should reveal the nature of the underlying processes

Hence, the purpose of this research was to study the differences between normal and reading disabled students with regard to the quality and type of errors they exhibit when naming words and nonwords in a transparent orthography such as Spanish. An hypothesis based on phonological mediation would predict that there would be differences between the groups in the word naming errors, as a function of variables such as lexicality, word frequency, positional syllable frequency (PSF) and word length. That is, individuals with reading disabilities, in comparison to normal readers, would be expected to produce more errors in unfamiliar and longer words, low PSF and nonwords.

## METHOD

### Participants

The participants in this study were 132 (45 normal readers and 87 reading disabled) Spanish children. The initial sample was obtained from a local population of 1,000 children believed by their teachers to have reading disabilities. The children came from urban areas, had average socio-economic backgrounds and attended several state schools. Although teachers initially nominated children for the reading disabled group, we used only those children who were good or disabled readers according to the results obtained from the administration of a standardised reading test. The children were classified into two groups according to their reading performance. The group of normal readers comprised 28 boys and 17 girls with an average age of 118 months (SD = 8.6); these were all above-average readers who scored at or above the 75th percentile on each of the subtests (i.e. letter, syllables, word decoding and comprehension) of the *Test de Análisis de Lectoescritura* (TALE) (Toro and Cervera, 1980). The reading disabled group (58 boys and 29 girls; average age 115 months, SD = 12.2) scored at or below the 25th percentile on all subtests of the TALE. In addition, the mean WISC-R Full Scale IQ (Wechsler, 1989) was for 99.78 the normal readers and 96.95 for the reading disabled children. Those with sensory deficits, acquired neurological deficits, or other problems traditionally used as exclusionary criteria for LD, were excluded. There were no statistical differences between the two groups in age($t = -0.88$, NS)

### Design

A mixed factorial design was used in the current study. For the analysis of words, it included a between-subject factor (reading level) and three orthogonal dimensions as within-subject factors: short vs. long length words, high vs. low frequency of the words, and high vs. low frequency of the syllables embedded in words. Each set contained 12 items. Also, for the analysis of nonwords it included a between-subject factor (reading level) and two orthogonal dimensions as within-subject factors: short vs. long length nonwords, and high vs. low frequency of the syllables embedded in nonwords. Each set contained 24 items. In total, there were 96 words and 96 nonwords. Examples of the stimuli are shown in the Appendix, and a complete list of stimuli used in this research is available from the second author (address at the end of the paper). We also used the following dependent variables: total errors and type of errors (i.e., conversions word-nonword, phonological, visual, morphological, substitutions, omissions, additions, repetitions and lexicalisations). These are described in detail below.

### Materials

#### *Reading Measures*

The Letter, Syllable, Word, and Comprehension subtests of the TALE (Toro and Cervera, 1980) were administrated. In the Letter subtest, the children read all the letters in the Spanish alphabet presented in lower and uppercase letters. The Syllable subtest includes a list of syllables with different structures (e.g. CV, VC, CVC). The

Word subtest requires correct identification of words. The Comprehension subtest included a short story and questions which were given to the children after reading.

### *Psycholinguistic Parameters*

By investigating the differences between the groups in word naming errors as a function of several key variables – such as lexicality, word frequency, positional syllable frequency (PSF), and word length – we were able test the use of the two routes (lexical and non-lexical). We hypothesised that if there is some independence among the routes, then positive or negative effects should be additive in nature, producing a consistent increment or decrement in word naming errors.

Lexicality would be expected to have an effect on errors because only words (and not nonwords) can be known by the reader. Word length has been traditionally associated to phonological processing because the naming time is known to be increased by word length (Just and Carpenter, 1980). This has been interpreted as evidence that participants carry out a letter-by-letter phonological processing (de Vega et al, 1990). Word naming errors may be affected by this variable, which presumably reflects the use of the phonological route, since errors increase as a function of word length (Just and Carpenter, 1980). If the GPC rules are insufficiently learned, a greater number of errors is more likely to occur in longer rather than in shorter stimuli, because there will be more GPC rules in longer words than in shorter ones (Valle-Arroyo, 1996). Word frequency could have an effect on word naming errors and would implicate the use of direct access, since the phonological route is widely taken to be prelexical. It is well known that high-frequency words are recognised faster than low-frequency words (Coltheart, 1978; Frost et al, 1987).

PSF is the number of times that a syllable appears in a particular position in a word (first, second, final, etc.). This measure is also be related to phonological processing because it is expected to influence word naming errors, and it reflects the use of the phonological route in Spanish language. If reading of words and nonwords with low frequency syllables is poorer, this means that the less frequent a syllable is, the more likely it is that the conversions implied have not been used in the past and the less well-consolidated they will be. Some previous studies have shown that the positional frequency of syllables, but not the total frequency of syllables, influenced naming times for words (de Vega et al, 1990) and lexical decision times (de Vega and Carreiras, 1989; Jiménez and Rodrigo, 1994).

A normative study was carried out on a sample of 10,000 words obtained from different texts of juvenile literature. Nonwords were used from research by de Vega et al (1990). These authors created nonwords by mixing syllables from real words and classifying them as a function of frequency of syllables. In this way nonwords are not recognised because are very different from words (see Balota and Chumbley, 1984). Word length was measured by the number of letters, which is a better predictor than the number of syllables (Just and Carpenter, 1984). In this study, 'long words' were defined as those with seven or more letters and 'short words' those with six letters or less. Word frequency was measured using Juilland and Chang-Rodríguez Spanish word-frequency dictionary (1964), with 'familiar words' being defined in this study as those with a score equal to, or greater than, 31 and 'unfamiliar words' to be those with a score less than 13.

Syllables were selected by frequency according to the Spanish syllable-frequency dictionary (de Vega et al, 1990). The Spanish syllable-frequency dictionary was constructed from a sample of 10,000 Spanish words found in small paragraphs extracted from normal texts (modern books, newspapers and magazines). PSFs were calculated for each word used in the experiment, in order to determine the average PSF for each category. Syllables were considered to be of high frequency only when they had greater frequency than 27, and of low frequency when they had a frequency below 19.66.

There are several statistical approaches to orthography in English, including counting bigram frequencies (Solso and Juel, 1980), but this kind of approach is rare in Spanish, even when there are some linguistic units that seem to be important for word recognition. One of these units is the syllable, and thus we use syllabic frequency in words because Spanish syllables are well-defined. Furthermore, at this sub-lexical level there are no studies that use syllabic frequency (Alvarez, Carreiras and de Vega, 1992).

## Procedure

While the participants were carrying out the naming task, we recorded what they read in order to analyse the form, as well as the frequency, of naming errors. Some authors recommend that the lexical decision task would be more appropriate for studying lexical access because naming tasks do not guarantee that the person uses the mental lexicon when pronouncing a word. Nevertheless, there is evidence that naming is lexically mediated both in deep orthography (e.g. Balota and Chumbley, 1984; Baluch and Besner, 1991; Forster and Chambers, 1973; Seidenberg, Waters, Barnes and Tanenhaus, 1984) and in regular orthography (for a review, see Sebastián-Gallés, 1991). In addition, Haberlandt (1994) has suggested that a naming task is able to provide information convergent with that of a lexical decision task. In previous studies, we found converging evidence when we used both lexical decision (Jiménez and Rodrigo, 1994) and naming tasks (Rodrigo and Jiménez, in press).

A psychology student was trained in the analysis of errors, and the tapes were analysed without knowledge of the group to which the participants belonged. The children read aloud the stimuli that appeared individually on a computer screen. After reading the stimuli the child had to press a key to receive the following stimuli. First, we presented the participants with a block of words and then a block of nonwords, or vice versa. This allowed us to obtain data about which route the poor and the good readers used and how they were using them. We did not use a mixed presentation because of studies which have demonstrated that word recognition in at least some shallow orthographies can be very flexible. For instance, the presence of nonwords encourages participants to rely upon the output of the nonlexical routine. However, when nonwords are omitted, lexical processing dominates (Baluch and Besner, 1991). In some studies carried out in transparent orthography, it has also been demonstrated that when words and nonwords are presented in the same block, the use of the phonological route is the most effective strategy for the task (Alvarez et al, 1992; Domínguez, Cuetos and de Vega, 1993; Tabossi, 1989). We administered first the block of words and then the block of nonwords to half of the participants. The other half received the blocks in the reverse order. The presentation order of stimuli was determined randomly. Subsequently, the psychology student listened to each of the tapes recorded and registered the errors made for each of the stimuli.

**Method of error analysis**

Basing our approach on the dual-route framework (Colheart, 1978, 1980) we classified errors into the following categories: (a) errors that we would expect to find if a lexical procedure was used in reading aloud (e.g. lexicalisations, morphological, visual); and (b) errors that would appear to reflect a sublexical procedure for reading aloud (e.g. word – non-word conversion, substitution, omission, addition and repetition).

Scoring of naming errors in words was based on the following criteria:

1. *Word non-word conversion* errors were scored when a word was read as a nonword (e.g. 'manantial' as 'mantiales').
2. *Phonological* errors resulted from a misapplication of context dependent on phonological rules and in this latter case produced a change in pronunciation (e.g. necesario' as 'nekesario'). In the Spanish language, the process of translating print to sound is never ambiguous because each letter of the alphabet (except the letters c, g and r) has a unique pronunciation.
3. *Visual* errors were scored when the response did not bear a semantic relationship to an inferred visually confusable mediator (e.g. 'camino' as 'canino').
4. *Morphological* errors could be found when the response and target words shared the same root or stem (e.g. 'presentar' as 'presente').
5. *Substitution* errors included all vowel or consonant substitutions (e.g. 'evitar' as 'evitan').
6. *Omission* errors were scored when a vowel or a consonant was not pronounced by the child (e.g. 'acabar' as 'acaba').
7. *Addition* errors were scored when a new phoneme was pronounced which did not belong to the word (e.g. 'distraído' as 'distraídos').
8. *Repetition* errors were scored when the child repeated parts of a word (e.g. 'fenómeno' as 'fe-fe-nómeno').

The scoring of naming errors in nonwords was based on the following criteria:

1. *Lexicalizations* arose in converting a nonword into a word (e.g. 'tora' as 'toro').
2. *Substitutions*, *omissions*, *additions* and *repetitions* errors were also computed in nonwords. The same scoring of naming errors for words was also used for nonwords.

More than one type of error could be scored for each word or nonword. If the subject gave more than one response, only the last one was analysed. This means that different separate errors on one stimulus could each be given one coding each, and no error could be coded in more than one category.

An hypothesis based on phonological mediation would predict that there would be differences in error performance between reading disabled and normal readers, and specifically in those errors in which a sublexical procedure is involved. If the error performance was greater in children with reading disabilities than in nondisabled readers, it would support the view that the reading disabled children have particular difficulties in naming words under conditions that require extensive phonological computation.

## RESULTS

### Words

A $(2 \times 2 \times 2 \times 2)$ Reading Level (reading disabled, normal readers) × Length (short, long) × Frequency (high, low) × PSF (high, low) mixed analysis of variance (ANOVA) was calculated separately across participants and items, on the total errors and on each type of error analysed in words. Table 1 contains means and standard deviations for the two groups in relation to each of the psycholinguistic variables.

This analysis yielded a significant main effect of Reading Level on Phonological errors [$F1(1,127) = 70.4$, $p<0.02$] [$F2(1,88) = 4.64$, $p<0.03$], Additions [$F1(1,127) = 6.57$, $p<0.01$] [$F2(1,88) = 7.32$, $p<0.008$] and Repetitions [$F1(1,127) = 20.9$, $p<0.001$] [$F2(1,88) = 47.4$, $p<0.001$], indicating that reading disabled children committed more errors than normal children. Also, a Reading Level × Frequency interaction was significant for Total errors [$F1(1,127) = 11.2$, $p<0.001$] [$F2(1,856) = 4.00$, $p<0.04$]. Tests of simple main effects confirmed that there were differences in total errors between familiar and unfamiliar words in the reading disabled children $F(1,127) = 13.6$, $p<0.001$ (see Figure 1).

There was a main effect of Length on Total Errors [$F1(1,127) = 13.1$, $p<0.004$] [$F2(1,856) = 3.91$, $p<0.04$] and Omissions [$F1(1,127) = 12.3$, $p<0.006$] [$F2(1,88) = 10.4$, $p<0.002$] indicating that there were more Total and Omissions errors for long words than for short ones. A Length × Frequency interaction was significant for Repetitions [$F1(1,127) = 11.0$, $p<0.001$] [$F2(1,88) = 7.64$, $p<0.007$] and Morphological errors [$F1(1,127) = 5.22$, $p<0.02$] [$F2(1,88) = 5.64$, $p<0.02$]. Tests of simple main effect confirmed that there were differences in the number of Repetitions between long and short words which were unfamiliar $F(1,127) = 33.4$, $p<0.001$, and there were differences in the number of morphological errors between long and short words which were unfamiliar $F(1,127) = 14.8$, $p<0.001$. In

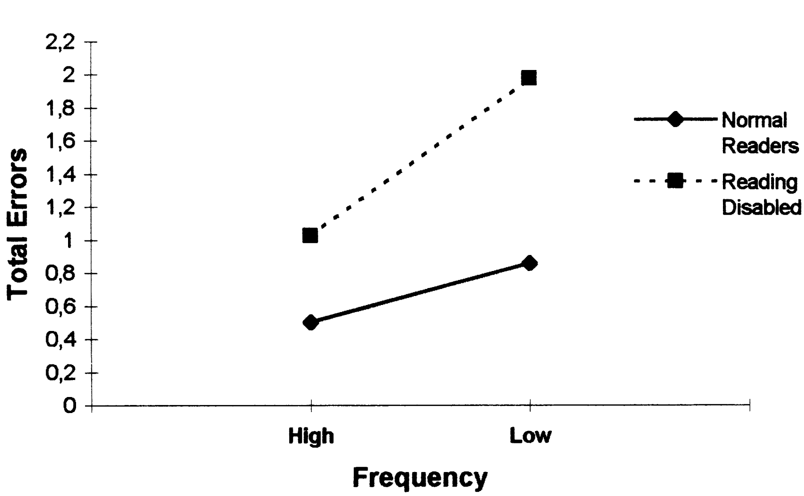


Figure 1. Total errors in words as a function of Reading Level and Frequency.

Table 1. Mean and standard deviations (SDs) in each of the errors analysed in words as a function of word length, word frequency and Positional Syllable Frequency (PSF) in reading disabled and normal readers.

| | | Reading disabled | | | | Normal readers | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | high PSF | | low PSF | | high PSF | | low PSF | |
| | | M | SD | M | SD | M | SD | M | SD |
| **Nonlexical reading** | | | | | | | | | |
| *Word-nonword conversion* | | | | | | | | | |
| Shorter | Familiar | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| | Unfamiliar | .08 | .46 | .03 | .18 | .00 | .00 | .00 | .00 |
| Longer | Familiar | .01 | .10 | .00 | .00 | .00 | .00 | .00 | .00 |
| | Unfamiliar | .03 | .18 | .05 | .43 | .00 | .00 | .00 | .00 |
| *Phonological* | | | | | | | | | |
| Shorter | Familiar | .10 | .34 | .04 | .20 | .04 | .31 | .07 | .26 |
| | Unfamiliar | .75 | .98 | .26 | .57 | .46 | .71 | .14 | .35 |
| Longer | Familiar | .02 | .14 | .40 | .73 | .05 | .21 | .19 | .46 |
| | Unfamiliar | .55 | .73 | .22 | .51 | .32 | .65 | .02 | .16 |
| *Substitutions* | | | | | | | | | |
| Shorter | Familiar | .08 | .31 | .37 | .51 | .07 | .35 | .46 | .55 |
| | Unfamiliar | .08 | .31 | .02 | .14 | .02 | .16 | .07 | .26 |
| Longer | Familiar | .05 | .21 | .11 | .35 | .00 | .00 | .05 | .22 |
| | Unfamiliar | .19 | .44 | .16 | .43 | .10 | .30 | .05 | .22 |
| *Omissions* | | | | | | | | | |
| Shorter | Familiar | .02 | .15 | .03 | .18 | .00 | .00 | .05 | .22 |
| | Unfamiliar | .01 | .11 | .07 | .25 | .00 | .00 | .02 | .16 |
| Longer | Familiar | .05 | .21 | .22 | .47 | .00 | .00 | .02 | .16 |
| | Unfamiliar | .17 | .41 | .17 | .46 | .10 | .37 | .05 | .22 |
| *Additions* | | | | | | | | | |
| Shorter | Familiar | .08 | .31 | .01 | .11 | .05 | .22 | .02 | .16 |
| | Unfamiliar | .19 | .48 | .12 | .45 | .00 | .00 | .05 | .22 |
| Longer | Familiar | .03 | .18 | .05 | .21 | .02 | .16 | .05 | .22 |
| | Unfamiliar | .09 | .29 | .23 | .45 | .00 | .00 | .05 | .22 |
| *Repetitions* | | | | | | | | | |
| Shorter | Familiar | .48 | .76 | .28 | .59 | .17 | .38 | .07 | .26 |
| | Unfamiliar | .57 | .80 | .39 | .70 | .32 | .72 | .22 | .48 |
| Longer | Familiar | .38 | .70 | .82 | 1.13 | .07 | .26 | .24 | .49 |
| | Unfamiliar | 1.28 | 1.31 | 1.31 | 1.32 | .49 | .78 | .54 | .87 |
| **Lexical reading** | | | | | | | | | |
| *Visual* | | | | | | | | | |
| Shorter | Familiar | .09 | .29 | .05 | .26 | .10 | .37 | .05 | .22 |
| | Unfamiliar | .10 | .37 | .20 | .59 | .02 | .16 | .10 | .30 |
| Longer | Familiar | .06 | .23 | .00 | .00 | .05 | .22 | .00 | .00 |
| | Unfamiliar | .06 | .27 | .14 | .68 | .07 | .26 | .07 | .35 |
| *Morphological* | | | | | | | | | |
| Shorter | Familiar | .06 | .23 | .02 | .15 | .02 | .16 | .00 | .00 |
| | Unfamiliar | .02 | .15 | .00 | .00 | .00 | .00 | .00 | .00 |
| Longer | Familiar | .05 | .21 | .10 | .34 | .00 | .00 | .02 | .16 |
| | Unfamiliar | .08 | .27 | .16 | .43 | .00 | .00 | .12 | .33 |
| *Total errors* | | | | | | | | | |
| Shorter | Familiar | .92 | 1.12 | .83 | 1.00 | .46 | 1.20 | .76 | .89 |
| | Unfamiliar | 1.83 | 1.80 | 1.17 | 1.55 | .83 | 1.00 | .61 | .99 |
| Longer | Familiar | .65 | 1.02 | 1.70 | 1.96 | .20 | .64 | .59 | .81 |
| | Unfamiliar | 2.45 | 1.90 | 2.45 | 2.14 | 1.07 | 1.29 | .93 | 1.23 |

addition, a Length × PSF interaction was significant on Morphological errors [$F1(1,127) = 9.90$, $p < 0.002$] [$F2(1,88) = 5.56$, $p < 0.02$]. Subsequent tests of simple main effects confirmed that there were differences in the number of Morphological errors between long words with low and high PSF [$F(1,127) = 7.19$, $p < 0.008$]. Moreover, a significant main effect of Frequency [$F1(1,127) = 7.38$, $p < 0.007$] [$F2(1,88) = 4.34$, $p < 0.04$] indicated that there were more additions for unfamiliar words than for familiar words. Finally, a Frequency × PSF interaction was significant for Phonological errors [$F1(1,127) = 56.9$, $p < 0.001$] [$F2(1,88) = 5.43$, $p < 0.02$]. Tests of simple main effect confirmed that there were differences in the number of Phonological errors between familiar and unfamiliar words with high PSF [$F(1,127) = 56.1$; $p < 0.001$].

## Nonwords

A (2 × 2 × 2) Reading Level (reading disabled, normal readers) × Length (short, long) × PSF (high, low) mixed analysis of variance (ANOVA) was performed on the Total errors and on each error in nonwords. It was also calculated separately across participants and items. Table 2 contains means and standard deviations for the two groups in each of the psycholinguistic variables analysed in nonwords.

Table 2. Mean and standard deviations (SDs) in each of the errors analysed in nonwords as function of length and PSF in reading disabled and normal readers.

| | Reading disabled | | | | Normal readers | | | |
|---|---|---|---|---|---|---|---|---|
| | high PSF | | low PSF | | high PSF | | low PSF | |
| | M | SD | M | SD | M | SD | M | SD |
| **Nonlexical reading** | | | | | | | | |
| *Substitutions* | | | | | | | | |
| Shorter | .78 | 1.43 | .40 | .71 | .35 | .69 | .16 | .53 |
| Longer | 2.42 | 1.91 | .92 | 1.14 | 1.35 | 1.66 | .26 | .49 |
| *Omissions* | | | | | | | | |
| Shorter | .40 | .67 | .30 | .68 | .09 | .29 | .70 | .26 |
| Longer | 1.91 | 2.02 | .28 | .67 | .47 | .70 | .02 | .15 |
| *Additions* | | | | | | | | |
| Shorter | .11 | .32 | .17 | .40 | .09 | .37 | .00 | .00 |
| Longer | .32 | .62 | .34 | .68 | .14 | .41 | .12 | .32 |
| *Repetitions* | | | | | | | | |
| Shorter | 1.66 | 1.76 | .99 | 1.14 | 1.09 | 1.25 | .40 | .70 |
| Longer | 2.82 | 2.30 | 1.99 | 1.84 | 2.79 | 2.12 | 1.02 | .99 |
| **Lexical reading** | | | | | | | | |
| *Lexicalisations* | | | | | | | | |
| Shorter | .25 | .77 | .40 | .70 | .07 | .26 | .21 | .51 |
| Longer | .49 | .79 | .42 | .76 | .37 | .95 | .12 | .32 |
| *Total errors* | | | | | | | | |
| Shorter | .77 | 1.43 | .40 | .70 | .35 | .69 | .16 | .53 |
| Longer | 2.42 | 1.91 | .92 | 1.14 | 1.35 | 1.66 | .26 | .49 |

This analysis yielded a significant main effect of Reading Level on Substitutions [F1(1,129) = 14.4, $p<0.002$] [F2(1,92) = 20.0, $p<0.001$], Omissions [F1(1,129) = 20.2, $p<0.001$] [F2(1,92) = 8.68, $p<0.004$], Additions [F1(1,129) = 9.02, $p<0.003$] [F2(1,92) = 12.6, $p<0.001$], Repetitions [F1(1,129) = 5.3, $p<0.002$] [F2(1,92) = 14.6, $p<0.001$], and Lexicalisations [F1(1,129) = 4.84, $p<0.02$] [F2(1,92) = 26.1, $p<0.001$] indicating that there were more errors in reading disabled children than in normal readers. Also, a Reading Level × Length interaction was significant for Total errors [F1(1,129) = 8.58, $p<0.004$] [F2(1,476) = 4.44, $p<0.03$]. Tests of simple main effect confirmed that there were differences in the number of total errors between long nonwords and short nonwords in the reading disabled children [F(1,129) = 49.4, $p<0.001$] (see Figure 2).

A main effect of Length on Substitutions [F1(1,129) = 58.1, $p<.001$] [F2(1,92) = 36.9, $p<.001$], Additions [F1(1,129) = 11.3, $p<.001$] [F2(1,92) = 13.3, $p<.001$], and Repetitions [F1(1,129) = 105.2, $p<.001$] [F2(1,92) = 33.2, $p<0.001$] indicated that there were more errors for long nonwords than for short ones. In addition, a Length × FSP interaction was significant for Omissions [F1(1,129) = 36.5, $p<.001$] [F2(1,92) = 15.2, $p<.001$]. Tests of simple main effect confirmed that there were differences in the number of Omissions between words with high and low PSF which were long F(1,129) = 49.8, $p<.001$. Finally, a significant main effect of FSP on Total errors [F1(1,129) = 639.1, $p<.001$] [F2(1,476) = 29.6, $p<.001$], Substitutions [F1(1,129) = 63.4, $p<.001$] [F2(1,92) = 22.5, $p<.001$], and Repetitions [F1(1,129) = 62.6, $p<.001$] [F2(1,92) = 23.2, $p<.001$] indicated that there were more errors for nonwords with high PSF than nonwords with low PSF.

## Lexicality

A (2 × 2) Reading Level (reading disabled, normal readers) × Lexicality (words, nonwords) mixed analysis of variance (ANOVA) was performed on total errors, and

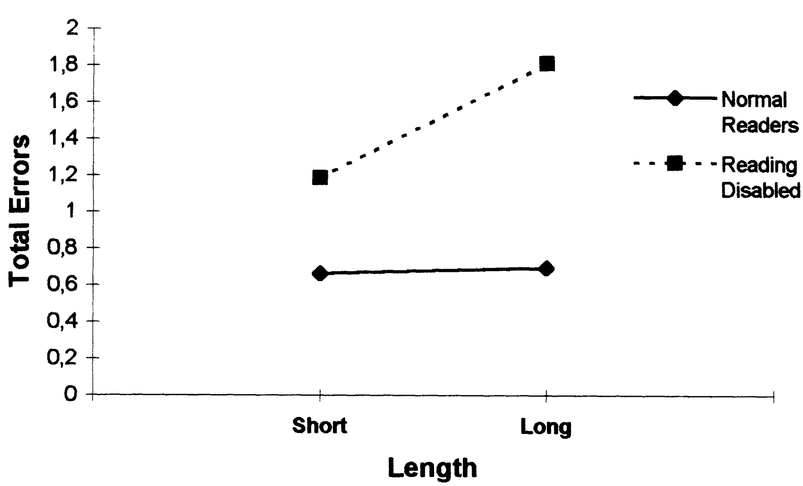


Figure 2. Total errors in nonwords as a function of Reading Level and Length.

on each of these errors analysed in words and nonwords. This was also calculated separately across participants and items. Table 3 contains means and standard deviations for the two groups as a function of lexicality.

The main effect of Reading Level was significant on Total errors [F1(1,127) = 21.8, p < .001] [F2(1,766) = 100.8, p < .001], Substitutions [F1(1,127) = 5.23, p < .001] [F2(1,190) = 27.4, p < .001], Additions [F1(1,127) = 2.77, p < .03] [F2(1,190) = 18.2, p < .001], and Repetitions [F1(1,127) = 5.66, p < .001] [F2(1,190) = 51.8, p < .001] indicating that there were more errors in reading disabled children than in the normal readers. In addition, a Reading Level × Lexicality interaction was significant for Omissions [F1(1,127) = 4.47, p < .002] [F2(1,190) = 3.98, p < .04]. Subsequent tests of simple main effects confirmed that there were differences in the number of Omissions between words and nonwords in the reading disabled children F(1,127) = 27.1, p < .001, indicating that there were more Omissions in the reading disabled children in nonwords (see Figure 3).

Finally, a main effect of Lexicality on Total errors [F1(1,129) = 159.7, p < .001] [F2(1,766) = 45.5, p < .001], Substitutions [F1(1,129) = 159.7, p < .001] [F2(1,766) = 45.5, p < .001] and Repetitions [F1(1,129) = 159.7, p < .001] [F2(1,766) = 45.5, p < .001] indicated that there were a greater number of errors for nonwords than for words.

## DISCUSSION

This study was designed to test whether there would be differences between reading disabled children and normal readers in word naming errors, as a function of

Table 3. Mean and standard deviations (SDs) in each of the errors analysed as a function of lexicality in reading disabled and normal readers

| | Reading disabled | | Normal readers | |
|---|---|---|---|---|
| | M | SD | M | SD |
| *Substitutions* | | | | |
| Words | .26 | .35 | .21 | .24 |
| Nonwords | 1.13 | .94 | .53 | .62 |
| *Omissions* | | | | |
| Words | .18 | .27 | .06 | .15 |
| Nonwords | .72 | .80 | .16 | .21 |
| *Additions* | | | | |
| Words | .20 | .33 | .06 | .16 |
| Nonwords | .23 | .33 | .08 | .15 |
| *Repetitions* | | | | |
| Words | 1.38 | 1.09 | .53 | .65 |
| Nonwords | 1.86 | 1.37 | 1.32 | .96 |
| *Total errors* | | | | |
| Words | 2.02 | 1.46 | .86 | .83 |
| Nonwords | 3.95 | 2.36 | 2.10 | 1.33 |

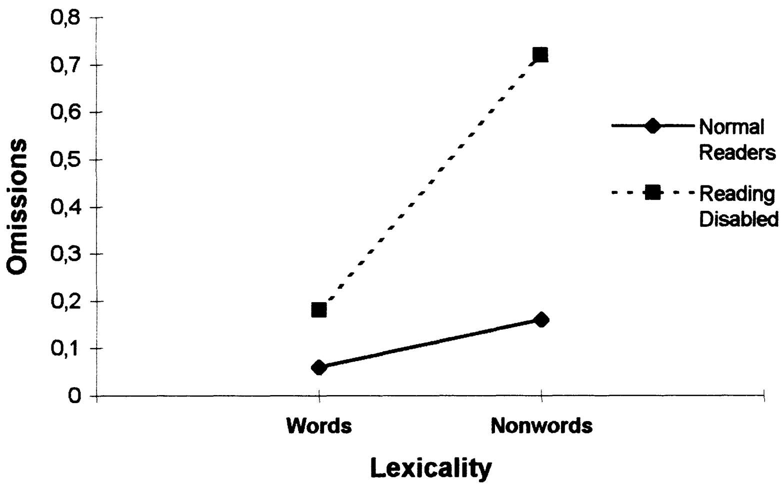


Figure 3. Omission errors as a function of Reading Level and Lexicality.

variables such as lexicality, word frequency, PSF and word length. That is, individuals with reading disabilities were predicted to have more errors on unfamiliar and longer words, low PSF words and nonwords in comparison to nondisabled readers.

In the analysis of word naming errors, significant individual differences were found. As we expected, the reading disabled children exhibited more errors than the normal readers in the word and nonword naming task. Also, the reading disabled children were more affected than the normal readers by the length of nonwords. The reading disabled children also made more errors when the words were of low frequency. Finally, the reading disabled children were more affected by lexicality than the normal readers, since they made more Omissions in nonwords. In another study, we also analysed reaction times in the same groups and the results demonstrated that there were differences in the naming task. We found that the reading disabled group showed a longer latency of naming than the normal group, for both words and nonwords (Rodrigo and Jiménez, in press).

Overall, we can observe the phonological problems exhibited by that poor readers. This reinforces the hypothesis that the basis of reading problems is a difficulty in phonological processing. Also, these results indicate that normal readers prefer the lexical route, although they call for some qualification of Coltheart's (1980) assertion that phonological mediation plays no role in the performance of good readers. This is probably because normal readers have a good repertoire of orthographic representations compared to poor readers, who most of the time have to resort to the phonological route. Nevertheless, when the use of the phonological route is necessary (as happens in the reading of nonwords), normal readers are superior because they are also good phonological decoders and therefore will make fewer errors (Ehri, 1975; Ehri and Wilce, 1983; Hogaboam and Perfetti, 1978; Siegel and Faux, 1989).

The analyses of errors carried out in this study demonstrated that the individuals with reading disabilities made significantly more phonological, addition, and repetition errors when reading nonwords than the normal readers, and the effect of reading level was greater in comparison to words. In all types of errors analysed in nonword performance, the reading disabled group made significantly more substitutions, omissions, additions, and repetitions. Once again, a phonological processing problem is posited as the cause of these errors in the reading disabled children. Many studies using the reading level match design have found empirical evidence in favour of the deficit model in phonological processing because individuals with reading disabilities have more difficulty in reading nonwords than normal readers matched either in age or in reading level (Beech and Awaida, 1992; Ehri and Wilce, 1983; Felton and Wood, 1992; Jiménez and Hernández, in press; Olson, Wise, Conners, Rack and Fulker, 1989; Rack et al, 1992; Siegel and Faux, 1989).

The reading disabled group produced more lexicalisations in nonword reading, and these were of the sort that is consistent with the hypothesis that they have a bias for lexical over phonological routes for naming. This result is also consistent with the data obtained both in English and in Spanish studies which used a reading level match design. In these studies, the disabled readers' greater print exposure may have compensated for their deficits in phonological decoding, allowing word recognition and orthographic coding to advance in spite of their phonological deficits (Jiménez y Hernández, in press; Olson, Wise, Conners and Rack, 1990; Rack et al, 1992).

Finally, taking into account the above data, we conclude in this study that there are differences in error performance between reading disabled and normal readers, and specifically in those errors in which a sublexical procedure is involved. That is, the error rate was greater in children with reading disabilities than in nondisabled readers,in terms of word length, word frequency and lexicality, i.e. they made more errors in long nonwords, unfamiliar words and nonwords. These data support the idea that reading disabled children have particular difficulties in naming words under conditions that require extensive phonological computation.

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## APPENDIX

### Examples of stimuli used in the experiment

| **Words (N = 12 per set)** | Length | Frequency | PSF |
|---|---|---|---|
| *Set 1: Length: Shorter; Frequency: Low; PSF: Low.* | | | |
| carbón (coal) | 6 | 12 | 4 |
| hacer (to make) | 5 | 8 | 5.5 |
| *Set 2: Length: Shorter; Frequency: Low; PSF: High.* | | | |
| águila (eagle) | 6 | 10 | 76.7 |
| durar (to last) | 5 | 10 | 28.5 |
| *Set 3: Length: Shorter; Frequency: High; PSF: Low.* | | | |
| carne (meat) | 5 | 57 | 18.5 |
| beber (to drink) | 5 | 45 | 8 |
| *Set 4: Length: Shorter; Frequency: High; PSF: High.* | | | |
| cabeza (head) | 6 | 142 | 42.3 |
| comer (to eat) | 5 | 95 | 36 |
| *Set 5: Length: Longer; Frequency: Low; PSF: Low.* | | | |
| manantial (source) | 9 | 1 | 15.25 |
| petróleo (oil) | 8 | 11 | 15.25 |
| *Set 6: Length: Longer; Frequency: Low; PSF: High.* | | | |
| agricultura (agriculture) | 11 | 11 | 48.4 |
| explorar (to explore) | 8 | 6 | 17 |
| *Set 7: Length: Longer; Frequency: High; PSF: Low.* | | | |
| ambiente (environment) | 8 | 63 | 13.33 |
| terminar (to finish) | 8 | 95 | 18.66 |
| *Set 8: Length: Longer; Frequency: High; PSF: High.* | | | |
| aparato (machine) | 7 | 38 | 79.25 |
| escribir (to write) | 8 | 251 | 32.6 |

| **Nonwords (N = 24 per set)** | Length | PSF |
|---|---|---|
| *Set 1: Length: Shorter; PSF: High.* | | |
| unca | 4 | 106 |
| esce | 4 | 165 |
| sedad | 5 | 166 |
| *Set 2: Length: Shorter; PSF: Low.* | | |
| lartia | 6 | 1 |
| merzal | 6 | 5 |
| prallo | 6 | 9 |
| *Set 3: Length: Longer; PSF: High.* | | |
| codidas | 7 | 75 |
| telatos | 7 | 80 |
| delnico | 7 | 97 |
| *Set 4: Length: Longer; PSF: Low* | | |
| liartranse | 11 | 1 |
| mezyencia | 9 | 6 |
| sortalsis | 9 | 7 |