3

The Role of Phonological Processing in Dyslexia in the Spanish Language

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1. Introduction

This chapter presents theoretical arguments and empirical evidence to support the idea that the phonological deficit in dyslexia in a language with a transparent orthography such as Spanish is at the phoneme level in the phonological awareness continuum, suggesting that a phonemic deficit is curtailing the development of phonological decoding. Results of two studies are presented to demonstrate the role of phonological processing in dyslexia in the Spanish language. The first study examines the dyslexic subtypes within the context of a reading-level match in a transparent orthography. In this research we explored whether developmental dyslexics form a homogeneous population, with a unique underlying impairment, or whether they form distinct subgroups. The second study examines the effects of a computer-assisted intervention designed to improve the visual word recognition of Spanish-speaking children identified with a learning disability (LD).

The classical phonological explanation ascribes dyslexics' reading deficit to a specific cognitive deficiency in phonological processing, primarily, in phonemic awareness and in phonological short-term memory.

Nevertheless, other current non-phonological explanations according to which dyslexics' phonological deficit is secondary to more basic sensori-motor impairment: a deficiency in either rapid auditory processing, or in the visual magnocellular pathway, or in motor skills (see for a review, Sprenger-Charolles, Colé, & Serniclaes, 2006).

Deficits in phonological awareness have been identified as the critical factor underlying the severe word decoding problems displayed by individuals with reading difficulties in languages with an opaque orthography such as English (Goswami & Bryant, 1990). Studies in English have found phonemic deficits in dyslexic children compared to children matched by chronological age (CA) or by reading level (RL) (Olson, 1994). In addition, dyslexic children appear to have more difficulty reading nonwords than nondisabled readers matched in age or in reading level supporting the deficit model in phonological processing (Rack, Snowling, & Olson, 1992). However, Goswami (2002, p. 150) suggests that "the consistency of the phoneme-grapheme correspondences in languages with a transparent orthography such as Spanish should facilitate the further development of both phonemic awareness and grapheme-phoneme recoding skills. These skills would, therefore, be expected to develop more slowly in dyslexic children learning to read in such consistent orthographies, but they would not be expected to be massively disrupted".

However, empirical evidence in Spanish indicates that dyslexic children exhibit the same difficulties in phonemic segmentation exhibited by older English dyslexic children (Jiménez, 1997). For example, Jiménez (1997) analyzed phoneme awareness within the context of a reading-level match design, demonstrating a deficit in the Spanish reading disabled (RD) children in phonemic tasks, but not in intrasyllabic tasks. In another study, Jiménez et al. (2005) examined the effects of linguistic complexity (e.g., complexity in the syllable structure) and task differences without taking into account verbal working memory. The assumption was that if students, identified as dyslexic, performed worse in a phonemic task compared to RL and CA matched children, the hypothesis of a phonemic deficit in explaining dyslexia in a transparent orthography would be confirmed. Results indicated that the complexity of the syllable structure had no particularly marked effect on the dyslexic children. Rather, the isolation task revealed the phonological deficit across all syllable structures.

Jiménez, García and Venegas (2008) examined whether phonological processes are the same or different in low literacy adults and children with or without reading disabilities in a transparent orthography. They selected a sample of 150 subjects organized into four different groups: (1) 53 low literacy adults, (2) 29 reading disabled children, (3) 27 younger normal readers at the same reading level as those with reading disabilities and low literacy adults, and (4) 41 normal readers matched in age with the reading disabled group. Phonological awareness tasks that included different complexities of the syllable structure (e.g., words with CV and CCV structure) were administered. Results indicated that the complexity of the syllable structure did not have a significant effect on low literacy adults. These adults appear to experience more difficulty in deleting phonemes irrespective of the complexity of the syllable structure.

Moreover, findings from studies that looked at whether phonological processes or lexical processes differentiated Spanish readers with and without reading difficulties indicated that the cause of the reading difficulties appeared to reside in the grapheme-phoneme decomposition procedure than in the lexical processes (Domínguez & Cuetos, 1992; Jiménez & Hernández-Valle, 2000; Rodrigo & Jiménez, 1999). This finding reinforces the hypothesis that the basis of reading problems is a difficulty in phonological processing, indicating that a lack of phonemic awareness is curtailing the acquisition of word recognition skill.

A major question posed by researchers relates to whether a major variable affecting the level of difficulty in learning to read also depends on the transparency/opacity of the writing system (e.g., Wydell & Butterworth, 1999). Specifically, the question relates to whether the effect of the transparency/opacity of the writing system is not only quantitative, but also qualitative. For instance, research indicated that English-speaking children perform reading tasks worse than do children who speak Spanish, French or German. A plausible reason is because the dissociation between sublexical and lexical procedures is greater for English-speaking children than for children who speak other languages. Sprenger-Charolles et al. (2006) reviewed cross-linguistic studies and longitudinal studies that examined the stability of dyslexic performance patterns across languages, and over time as reading develops. Group studies, single case studies, and multiple case studies conducted in various languages to evaluate the reliability and prevalence of the dyslexic performance pattern were included in the review. Assessments to determine the lexical and sublexical routes used both high frequency irregular word reading, and pseudoword reading. However, not

all studies included a standard measure of lexical processing (i.e., irregular word reading) because it is impossible to find enough irregular words in some of the languages (e.g., Spanish) included in the review. Findings indicated a higher incidence rate of phonological dyslexia in English in comparison to other languages (e.g., Wydell & Butterworth, 1999; Wydell & Kondo 2003) where researchers found a higher incidence of surface dyslexia. Note that surface dyslexia is characterized by impaired orthographic skills and fairly well-preserved phonological skills (Stanovich, et al., 1997b), while a phonological dyslexia is characterized by impaired phonological skills and fairly well-preserved orthographic skills (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBridge-Chang & Petersen, 1996; Stanovich, Siegel & Gottardo, 1997b).

Thus, studies that indicate the extent to which the dual-route hypothesis (i.e., differences between phonological and surface dyslexia (e.g., Manis, et al, 1996; Stanovich, et al, 1997b) is also applicable to languages with a transparent orthography, are still necessary. Moreover, studies designed to demonstrate that the consistency of mappings from graphemes to phonemes in different languages has a marked effect on the development of phonemic awareness and of grapheme-phoneme recoding strategies in dyslexic children are necessary. Two Spanish studies of dyslexic subtypes and computer-assisted practice on visual word recognition are presented here to provide empirical evidence in favor of the deficit model in phonological processing in a transparent orthography. Next we report results of the two studies.

2. Study 1: Identifying dyslexic subtypes in a transparent orthography

A question posed by reading researchers is whether readers with developmental dyslexia form a homogeneous group with a unique underlying impairment, or whether this group actually consists of distinct subgroups. In English, research indicates the existence of two distinct profiles of developmental dyslexia. In our own review of studies of dyslexic performance patterns, we have found the opposite pattern when we reviewed studies conducted in orthographies less opaque than English (e.g., Swedish: Wolff, 2009). These discrepancies between the Spanish versus the anglophone or francophone studies may be due to (a) linguistic factors, (b) the measures used, and (c) differences in the dyslexics' chronological age. Given that grapheme-phoneme correspondences are more regular in Spanish than in English and in French, Spanish-speaking dyslexics may manage to use the sublexical reading route with less difficulty than English-speaking or French speaking dyslexics. This could explain why fewer phonological dyslexics were found in languages that are less opaque than English. A similar trend was observed when time measures were used in Spanish or in French (Genard et al., 1998) suggesting that the phonological deficit of Spanish-speaking dyslexics manifests itself as slow processing more than in accuracy.

The study presented here was first published by Jiménez and Ramirez (2002) and replicated later by Jiménez, Rodríguez, and Ramírez (2009). It employed the same procedure used by Castles and Coltheart (1993) for identifying dyslexic subtypes based on pseudoword and irregular word reading. Given that Spanish does not have any irregular words, we compared the reaction times (RTs) of students reading high frequency words and pseudowords between the group of dyslexic children and the group of children similar in chronological-age, and reading-level (RL).

Some difficulties have been encountered in research using traditional research designs. So, for example, when reading-disabled subjects are matched in age with normal readers, differences between the groups on non-reading measures have been presumed to reflect deficits causally related to the reading failure of the reading-disabled group (Backman, Mamem, & Ferguson, 1984). When two groups that have different reading levels are compared, any differences found between them could be interpreted as a product rather than as a cause of such differences (Bryant & Goswami, 1986). However, if the children are at the same reading level, any differences between them cannot be attributed to one group being more successful readers than the other group. However, as has been suggested by Bryant and Goswami (1986) the studies that analyze correlates of reading disability should involve a combination of reading level and chronological age matched groups. In the three-group design, there are two control groups in addition to the target group, one for reading level and one for chronological age. Thus, the paradigm allows not only comparison of children of different chronological ages with the same reading level as in the two-group approach, but also comparison within chronological age across reading levels. The addition of the third group, i.e., chronological age controls, allows examination of differing performance levels across two chronological age levels in normal children, as well as relative performance within chronological age and reading level-matched groups (Backman et al, 1984). As several authors have pointed out (Backman et al, 1984; Bryant & Goswami, 1986) positive results (a difference between reading disabled children and normal controls) in experiments that use a reading level match allows us to conclude that the measure under consideration is probably causally related to the reading disabilities. As has been suggested by Manis et al. (1996), "the developmental forms result in patterns that are not observed in normal readers at any age or level of reading acquisition – a *deviant* developmental pattern. Another possibility is that a subgroup might lag in a broad spectrum of reading skills and hence resemble younger normal readers – a *developmental delay* pattern" (p. 162).

Therefore, we conducted further exploration of the validity and reliability of the subgroup assignments by examining the performance on phonological awareness tasks. We predicted that if the subgrouping was valid, phonological dyslexics (Ph-Dys) should perform relatively poorly on the phonological awareness tasks compared to younger normal readers, supporting a specific deficit in phonological processing, whereas there should not be differences on the phonological awareness tasks between surface dyslexics (S-Dys) and younger normal readers.

2.1 Method

Participants. In the initial sample, teachers selected children who they believed were normally achieving readers or were reading-disabled. We assessed these children with different subtests of the Standardized Literacy Skills Test T.A.L.E. (Test de Análisis de Lectoescritura; Toro & Cervera, 1980). The study employed a reading-level-match design including three groups: (1) The reading-disabled sample consisted of 89 third-grade children who achieved a performance below the grade 3 norms (i.e., two years) on each of the subtests of TALE individually; (2) A control group of 37 normal readers matched in age with the reading-disabled group; (3) A control group of 39 younger children at the same reading level as the reading-disabled group. Both reading disabled and younger normal readers were matched on each of the subtests of TALE individually (i.e., letter, syllable, and word

reading) based on grade 1 norms. Normal readers matched in age achieved a performance according to grade 3 norms.

Measures. We used three different phonological awareness tests (i.e., odd-word-out task, phoneme segmentation and phoneme reversal). The *Odd-word-out task* was designed to test the awareness of intrasyllabic units and was based on a similar measure by Bowey and Francis (1991). The difference between the Bowey and Francis measure and ours was that we used pictures. In the *Phoneme segmentation test*, children counted the phonemes of words presented orally. Children were aloud to use aids such as rods to count the phonemes they heard in words. In the *Phoneme reversal test* the children counted the phonemes of words by reversing the order of segments in each word.

Procedure. We used the same regression-based procedure introduced by Castles and Coltheart (1993) and used the same-aged normal readers' performance to identify subtypes of dyslexics. We used RTs to high frequency words and pseudowords, controlling for the number of letters. That is, the RT for each stimulus (word and pseudoword) was divided by the number of letters. We hypothesized that children who have greater RTs for familiar word reading compared to RTs for pseudoword reading would have difficulties using a lexical procedure to read words. On the other hand, children who would show longer latencies for pseudoword reading as compared to familiar word reading would have more difficulties in using a phonological route. To conduct this experiment, the program UNICEN was designed and used together with a device that detected the sounds within the broad band of the human voice but was not affected by the fairly high percentage of background noise. High-frequency words used in the experiment were selected on the basis of ratings generated from a normative study conducted by Guzmán and Jiménez (2001), who employed a sample of 3,000 words obtained from different texts of children's literature. Word familiarity was measured using these authors' procedure of frequency estimation, which involved the separation of the 3,000 words into different sets. Each set was printed and then different groups of 30 children rated each word on a 5-point scale, ranging from *least frequent* (1) to *most frequent* (5). The estimated frequency was calculated for each word by averaging the rating across all 30 judges. On the basis of these ratings, high-frequency words were selected. Pseudowords were extracted from research by de Vega, Carreiras, Gutiérrez, and Alonso-Quecuty (1990). The order of presentation of words and pseudowords was counterbalanced. Items were presented in random order within each set. In total, there were 32 words and 48 pseudowords.

Results. We carried out two different analyses: (1) a comparison of dyslexic subgroups to the CA control group, and (2) a comparison of dyslexic subgroups to the RL control group. The first analysis allows us to know how the performance of the dyslexic children differs from normal readers of the same age (Manis, et al., 1996). The soft subtypes were defined by running a regression line with 90% confidence intervals through the Word RTs x Pseudoword RTs plot for the CA and RL control children. This regression line and confidence intervals were then superimposed on the scatterplot of the performance of the dyslexic sample. A surface dyslexic is a child who is an outlier when word RTs are plotted against pseudowords RTs, but is within the normal range when pseudowords RTs are plotted against words RTs. Ph-Dys are defined conversely.

If we compare our results with the English and French studies, the percentage of dyslexic subtypes were quite different. Table 1 shows the proportion of Ph-Dys and S-Dys identified in our study and the proportion in other studies. Castles and Coltheart (1993) found 55% Ph-Dys, Manis, et al. (1996) found 33.3% Ph-Dys, and Stanovich, et al. (1997b) found 25% Ph-Dys in their samples. In our study, we found 18% Ph-Dys and 53% of S-Dys, a greater proportion of S-Dys in comparison to Castles and Coltheart (30%), Manis, et al. (29%) and Stanovich, et al. (22%). Similarly, Genard, et al. (1998) found 56% of S-Dys, and only 4% of Ph-Dys. In general, controlling for CA, there were more Ph-Dys than S-Dys. Similarly, compared to RL controls, there were more Ph-Dys readers than S-Dys; however, the S-Dys profile almost disappeared.

On the other hand, in the Chinese orthography, Ho (2001) found that the incidence of S-Dys and Ph_Dys differs. In general more Chinese dyslexic children have a surface dyslexia (26%) than Ph-Dys (13%), ascertaining our assumption that phonological dyslexia appears to be less common in Chinese than in English.

Studies	PD*	SD.*	D.D*.	ND.*	Variables
Castles & Coltheart. (1993)	55%	30%	6%	9%	Accuracy
Manis et al. (1996)	33%	29%	10%	28%	Accuracy
Stanovich et al. (1997)	25%	22%	28%	25%	Accuracy
Genard et al. (1998)	4%	56%	3%	37%	Accuracy
Sprenger et al. (2000)	52%	32%	3%	13%	Reaction Times
Jiménez & Ramírez. (2002)	18%	53%	3%	26%	Reaction Times/number of letters

*(PD:phonological dyslexics, SD:surface dyslexics, DD: double deficits ND: non-deficit)

Table 1. Classification of dyslexics based on regression method on CA control group

The second analysis focused on whether the performance of dyslexics resembled the performance of younger children learning to read at a normal rate (Manis, et al., 1996). RTs of the dyslexics were plotted so as to identify phonological dyslexics (children with high pseudoword RTs relative to word RTs). The Pseudoword RTs were plotted against the Word RTs. The regression line and confidence intervals are based on the data from the 39 RL controls. Overall, nineteen of the 48 surface dyslexics identified in the regression analysis for the CA group fell below the confidence limit for the RL control group. In contrast, the same 20 phonological dyslexics were identical to those identified from the CA regression lines.

With regard to the validity of subtypes, three separate analyses of variance (ANOVAs) for one factor (younger normal readers vs. phonological dyslexics vs. surface dyslexics) were conducted using the number of correct responses on each of the three phonological awareness tests as dependent variables. Bonferroni's correction was used to determine the acceptable alpha level for rejecting the null hypothesis.The ANOVA on the odd-word-out task was significant [$F(2, 104) = 9.48$; $p < .001$]. A multiple comparison test indicated that younger normal readers scored significantly higher than the phonological dyslexics ($t = 4.50$;

$p < .001$) and surface dyslexics ($t = 2.19$; $p < .05$). The ANOVA on the phoneme segmentation task revealed significant differences [$F (2, 105) = 3.26$; $p < .05$], and the test indicated that the younger normal readers performed significantly better than the phonological dyslexics ($t = 2.56$; $p < .01$) and surface dyslexics ($t = 3.80$; $p < .001$). The ANOVA on the phoneme reversal revealed similar results [$F (2, 105) = 5.95$; $p < .05$] indicating again that younger normal readers scored significantly higher than surface dyslexics ($t = 3, 84$; $p < .001$) and phonological dyslexics ($t = 3.72$; $p < .001$).

2.1.1 Discussion

Studies in English have presented a consistent picture of developmental deviancy and developmental lag that appears to characterize the phonological and surface subtypes (e.g., Manis, et al., 1996; Stanovich et al., 1997b). Phonological dyslexia reflected true developmental deviancy. In contrast, surface dyslexia resembled a form of developmental delay. In the Spanish studies (Jiménez, et al., 2002; Jiménez, et al., 2009) surface and phonological subtypes both represent deviations from normal development. However, the results of the phonological awareness tasks did not validate the division of the dyslexic sample into these two subgroups. Both dyslexic subtypes exhibited significant discrepancies between pseudoword and familiar word reading but they shared the same phonological problems, because both performed more poorly than the younger children in analyzing the phonemic structure of spoken words.

In another study, Jiménez et al. (2009) examined the prevalence, cognitive profile, and home literacy experiences of dyslexic children with different subtypes in Spain. Just like in the other study, we examined the response of three groups (a) a chronological-age-matched group, (b) a reading-level control group, and (c) a dyslexic group. Using regression-based procedures, the author identified 8 phonological and 16 surface dyslexics from a sample of 35 dyslexic 4th-grade children by comparing them to chronological-age-matched controls on RTs for high frequency word and pseudoword reading. However, when the dyslexic subtypes were defined by reference to reading-level controls, 12 phonological dyslexics were defined but only 5 surface dyslexics were identified. Both dyslexic subtypes showed a deficit in phonological awareness, but children with surface dyslexia also showed a deficit in orthographical processing assessed by a homophone comprehension task. This deficit was associated with poor home literacy experiences because the group of parents with children matched in reading age, in comparison to parents with children with surface dyslexia, reported more literacy home experiences.

Sprenger-Charolles, et al. (2000) found that the phonological impairment of the two dyslexic groups was quite severe, since it emerged even relative to younger average readers. Therefore, they suggested that these results are more in line with the hypothesis that a phonological deficit is at the core of developmental dyslexia than with Castles and Coltheart's idea that a "clear double dissociation exists between surface and phonological reading patterns" (1993, p. 174).

Recently, Sprenger-Charrolles, Siegel, Jiménez, and Ziegler (2011) carried out a review of studies conducted in languages varying in the transparency of their orthography. They also concluded that the regression-based method appears to result in less reliable subtypes within and between languages.

In sum, we concluded that in a transparent orthography developmental dyslexics do form a homogeneous population with a unique underlying phonological impairment.

3. Study 2: Computer speech-based remediation for reading disabilities in Spanish dyslexics

An increasing number of researchers have used computers in experiments on the remediation of reading disabilities (e.g., Jones, Torgesen & Sexton, 1987; Olofsson, 1992; Olson & Wise, 1992; Torgesen & Barker, 1995; Van Daal & Reitsma, 1993; Van der Leij, 1994). It has been demonstrated that reading on the computer with speech feedback significantly improved disabled reader's phonological decoding and word recognition. With regard to the best instructional intervention for remediating reading disabilities, Swanson (1999) tested in his study whether certain models of instruction (e.g., direct instruction, strategy instruction, etc.) have broad effects across word-recognition and comprehension measures. He found that effect sizes were higher for word recognition when studies included direct instruction. Moreover, studies of computer-aided remediation for reading-disabled children demonstrated that word recognition skill improved when different forms of orthographic units were manipulated (Olson & Wise, 1992). The study presented here was first published by Jiménez et al. (2003). We had predicted that reading on the computer with speech feedback can provide a helpful remedial tool for children with RD in a transparent orthography.

3.1 Method

Participants. A sample of 73 Spanish children was obtained ranging between 7 years 1 month and 10 years 6 months of age. Using the standard-score discrepancy method, the children with reading difficulties were classified into two groups based on the difference, or lack thereof, between their scores on the IQ test and their standard scores on the Pseudoword subtest of the PROLEC (Cuetos, Rodríguez, & Ruano, 1996). Children were classified as having dyslexia if their pseudoword standard score was more than 15 points lower than their IQ score (N=14), and if their score on an IQ test was >80. Children were considered poor readers if their pseudoword score was less than 15 points lower than their IQ score (N=31), and if their score on an IQ test was >80. The overall sample was classified into three different groups: (1) an experimental group of 14 dyslexics (8 male, 6 female) who received computer-based reading practice; (2) an experimental group of 31 garden variety poor readers (GV) (17 male, 14 female) who also received the same type of practice, and (3) a control group of 28 reading-disabled children (20 male, 8 female) who did not receive computer-assisted practice.

Measures. We used the Standardized Reading Skills Test PROLEC. This test includes different reading subtests. We only administered the following subtests: (1) word reading, (2) pseudoword reading, and (3) text comprehension. Word and Pseudoword reading subtests required correct identification of ordinary words and pseudowords. Both subtests are based on the accuracy of the responses. The comprehension subtest includes a short story and questions which were given to the children after reading. We used the same phonological awareness tests as in Study 1 (i.e., odd-word-out task, phoneme segmentation and phoneme reversal).

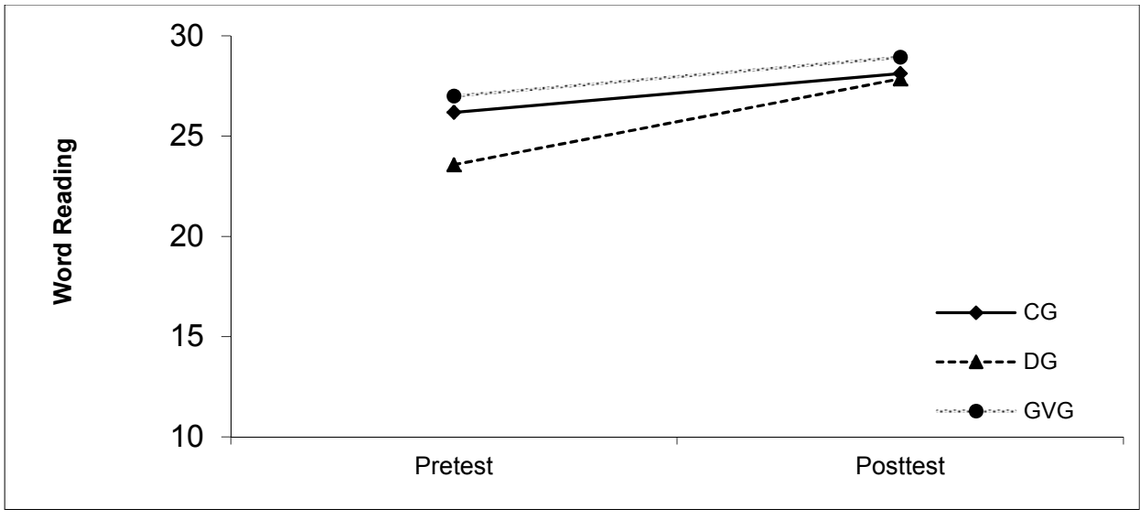
Procedure. All the tests were administered by psychologists in a random order, to avoid any effect of the presentation of the material. Once the computer equipment was installed in the schools, the children were randomly assigned to the experimental and control conditions. We first carried out a general trial session, in which the children were trained in all of the TEDIS (Tratamiento Experimental de la Dislexia = Experimental Treatment of Dyslexia) program requirements. Once the treatment sessions started, the examiners were present just to guarantee the optimal technical functioning of the program. The children came to the computer room for 40 minutes per day during language arts time, to keep equivalent the reading instruction time for experimental subjects and for matched untrained controls in the same class. A core technical component in the TEDIS remedial program is the "talking" computer, which gives support and feedback through digitized speech. The TEDIS program provided feedback segmented into sub-word units (i.e., phonemes, syllables, onset-rime segments) which were sequentially highlighted and spoken by the computer. All children received orthographic and speech feedback that was presented in syllable or sub-syllable units. In each session the words were presented on the center of the screen. These words were pronounced by a professional speech trainer and recorded on tape in a studio.

First of all, the computer segmented the word into sub-word units whereas a woman's voice was pronouncing them. Children were asked to attempt to pronounce each segment before clicking the mouse again to hear the speech support. Then, the subject had two options to choose, clicking with the mouse: (1) to repeat the same task with the same sub-word units, or (2) to pronounce the whole word. When the subject was able to pronounce the word correctly, the subjects had to press the keyboard to obtain the next word. When speech feedback was requested, the sub-word sound was immediately delivered through the headphones. When the subject asked for speech feedback, only the relevant word was presented on the screen. If the subject did not read the word, then he or she was asked to repeat the task again by the examiner. Only when the child had three failures with the same word, would the examiner press the keyboard and the presentation of a new word was shown. Every eight stimuli the program asked a multiple-choice comprehension question. Each child had to indicate with the mouse which of the pictures showed on the screen, was related to the target word. The children were allowed to use the speech-feedback option. Van Daal and Reitsma (1993) examined whether it is best to give feedback on all words or to allow the disabled readers to choose. It was found that reading disabled children in the intervention who were matched age did not learn less when the computer unsolicitedly delivered the spoken form of all words than when they were allowed to choose. In addition, the results of a series of small quasi-experimental studies indicated positive treatment effects, in which the dyslexics who received computer training with speech feedback, improved their performance in reading and spelling, compared to students who only had access to conventional special education (Lundberg, 1995). Fifteen sessions were the total of the TEDIS program. In each session, the reading materials consisted of 40 nouns and were divided as a function of the different linguistic parameters into (a) word length (short vs. long), (b) word frequency (familiar vs. nonfamiliar) and word linguistic structure (consonant-vowel (CV) vs. consonant-consonant-vowel (CCV)). During the computer-based word reading, we collected information about the number of accurately read words, number of speech feedback, and reading time. The reading time of each stimulus was registered given that the word appeared on the screen until the child pronounced it successfully.

Results

Pretest-posttest measures

A (3x2) Group (dyslexics, GV poor readers, control) x Moment (pretest, posttest) mixed analysis of variance (ANOVA) was performed on the word recognition and phonological awareness tasks. This analysis yielded a main effect of Time [F (1, 67) = 33.47; p<.001, MSE = 185.50, ES = .33]. In addition there was a significant interaction of Group x Moment [F (2, 67) = 4.23; p < .019, MSE = 23.43, ES = .11]. Tests of simple main effect confirmed that there was an improvement on word recognition in dyslexics [F (1, 67) = 23.2; p < .001, MSE = 128.57], and in GV poor readers [F (1, 67) = 10.48; p < .05, MSE = 58.06]. Dyslexics' baseline level was lower than the other groups; however, they reached the same level of performance in post test. Finally, there were no differences between pretest and posttest scores in the control group [F (1, 67) = 2.63; p = .10, MSE = 14.58] (See Figure 1).



Note: CG = Control Group; DG = Dyslexic Group; GVG= GV Poor Readers Group.

Fig. 1. Interaction between Group and Moment on Word Reading

With regard to phonological awareness measures, both the main effects of Group, [F (6,128) = .82, p <. 04, MSE = 146.56, ES = .09], and of Time, [F (3, 64) = .03, p < .001, MSE = 125.47, ES = .96] were significant. Also, a Group x Time interaction was significant [F (6, 128) = 18.39, p < .04, MSE = 4.0, ES = .09]. Subsequent tests of simple main effects confirmed that there were differences in the posttest between GV poor readers, the control group [F (3, 64) = .85, p < .01, MSE = 150.81], and GV poor readers and dyslexics [F (3, 64) = .87, p < .03, MSE = 125.43]. However, there were no differences between dyslexics and the control group at posttest [F (3, 64) =.91, p = .14, MSE = 109.32]. Again, dyslexic's baseline level was lower than the other groups; however, they reached the same level of performance in post test.

Training sessions measures

A (2x2x15) Group (dyslexics, GV poor readers) x Word Frequency (familiar vs. nonfamiliar) x Word Set (1 vs. 15) mixed analysis of variance (ANOVA) was performed on the number of accurately read words, number of speech feedback, and reading time. A Group x Word Frequency x Word Set interaction was significant [F (13, 767) = 2.11; p < .012, MSE = 36.72,

ES = .35]. Subsequent test of simple main effect revealed that reading time was greater for dyslexics than for GV poor readers in nonfamiliar words during computer-based reading [F (13, 767) = 8.36, p < .001, MSE = 742.62]. A (2x2x15) Group (dyslexics, GV poor readers) x Word Length (short vs. long) x Word Set (1 vs. 15) mixed analysis of variance (ANOVA) was performed on the number of accurately read words, number of speech feedback, and reading time. There was a significant Group x Length x Word Set interaction [F (11, 561) = 3.21; p < .001, MSE = .68, ES = .28] when we analyzed the number of accurately read words. Subsequent test of simple main effect revealed that the dyslexic group was more affected by long words during computer-based reading [F (11, 561) = 5.50, p < .001, MSE = 1.17] (see Figure 2).

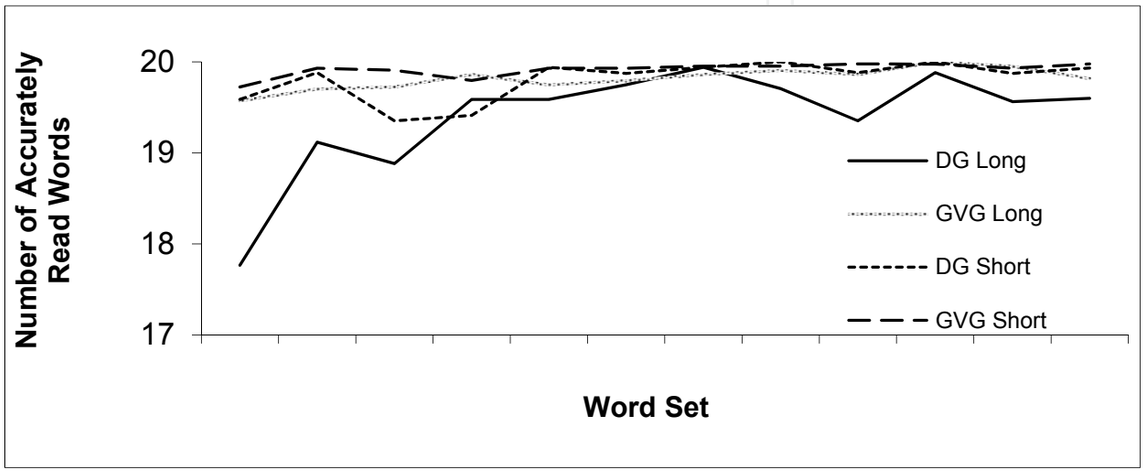


Fig. 2. Interaction between group and word length and word set on the number of accurately read words. DG = long words for dyslexia group; GVC Long = long words for garden-variety poor readers' group; DG Short = short words for dyslexia group; GVG Short = short words for garden-variety poor readers' group.

3.1.1 Discussion

As suggested by Swanson (1999, p. 504) "there have been conceptual shifts regarding what underlies reading problems in children with LD, which in turn raised questions about the best instructional intervention for remediating such problems". Nowadays, there is consensus that many cases of reading disabilities are caused by difficulties in the visual word recognition. The majority of recent research suggests that word identification problems are basically phonological route problems (e.g., Olson, Kliegl, Davidson & Foltz, 1985; Perfetti, 1985; Rack, Snowling & Olson, 1992; Van Den Bos & Spelberg, 1994; Wagner & Torgesen, 1987). As reviewed above, many studies carried out in opaque orthographies using the Reading Level (RL) match design have found empirical evidence in favor of the deficit model in phonological processing, because dyslexics have more difficulty in reading nonwords than normal readers matched in age or in RL (Olson, Wise, Conners, Rack & Fulker, 1989; Stanovich & Siegel, 1994). Moreover, some empirical evidence exists that in languages with a transparent orthography, in which the reading disabled show severe difficulties in the use of the phonological route as they do in the English language (e.g., Jiménez, 1997; Jiménez & Hernández-Valle, 2000; Jiménez & Ramírez, 2002; Jiménez, et al.,

2009), suggesting that a phonemic deficit is curtailing the development of phonological decoding. In addition, the degree of phonological reading deficit is not related to the degree of discrepancy between reading and IQ (for a review see, Stanovich & Siegel, 1994).

The results of this study indicated that computer-assisted practice proved to be as beneficial to the GV poor reader group as for the dyslexic group. We found that reading-disabled children with and without IQ-achievement discrepancy improved their performance on word reading, in comparison to the control group. Nevertheless, dyslexics had more difficulties than GV poor readers during computer-based word reading under conditions that required extensive phonological computation because they were more affected by low frequency words and long words. For another study, Jiménez et al. (2007) assessed the effects of four reading-training procedures for children with reading disabilities (RD) in Spain, with the aim of examining the effects of different spelling-to-sound units in computer speech-based reading. A sample of 82 Spanish children ranging between 7 years 1 month and 10 years 6 months, and whose pseudoword reading performance was below the 25th percentile and IQ >90 were selected. The subjects were randomly assigned to five groups: (1) the Whole-Word training group (WW) (n=16), (2) the Syllable training group (S) (n=16), (3) the Onset-Rime[1] training group (OR) (n=17), (4) the Phoneme training group (P) (n =15), and (5) the untrained control group (n= 18). Children were pre- and post-tested in word recognition, reading comprehension, phonological awareness, and visual and phonological tasks. Results indicated that experimental groups who participated in the phoneme and whole-word condition improved their word recognition compared to the control group. In addition, dyslexics who participated in the phoneme, syllable and onset-rime conditions applied for more number of calls during computer-based word reading under conditions that required extensive phonological computation (low frequency words and long words). However, reading time was greater for long words in the phoneme group during computer-based reading. The authors concluded that reading on the computer with speech feedback can provide a helpful remedial tool for children with RD in a transparent orthography.

Regarding the best instructional intervention for remediating reading disabilities, Swanson (1999) tested in his study whether certain models of instruction (e.g., direct instruction, strategy instruction, etc.) have broad effects across word-recognition and comprehension measures. He found that effect sizes were higher for word recognition when studies included direct instruction. Additionally, an increasing number of researchers have used computers in experiments on the remediation of reading disabilities (e.g., Jones, Torgesen & Sexton, 1987; Olofsson, 1992; Olson & Wise, 1992; Torgesen & Barker, 1995; Van Daal & Reitsma, 1993; Van der Leij, 1994). It has been demonstrated that reading on the computer with speech feedback significantly improved disabled reader's phonological decoding and word recognition. Moreover, studies of computer-aided remediation for reading disabled children demonstrated that word recognition skill improved when different forms of orthographic units were manipulated (Olson & Wise, 1992).

In the teaching of reading, children can be trained on the print-to-sound translation by using linguistic units of different sizes: a word can be taught as a whole unit, in individual letter-sound units, or in sublexical units of intermediate size (syllable, BOSS, onset-rime).

[1] The syllable in Spanish consists of an 'onset' (initial consonant or cluster) plus a 'rime' (vowel and any following consonants).

However, the spelling-to-sound unit used in training may be a critical factor in determining the effectiveness of remedial instruction for RD. Consequently, various remedial studies carried out in English have tried to determine which is the size of the spelling-to-sound unit more optimal for computer speech-based training of RD (e.g., Lovett, Barron, Forbes, Cuksts, & Steinbach, 1994; Olson & Wise, 1992). For Spanish, the Syllable and Onset-Rime condition did not contribute to improve phonological decoding. This finding is not surprising because this type of units does not seem to be as relevant in a language where a direct correspondence between graphemes and phonemes does exist, and where the syllable boundaries are well defined. Therefore, Jiménez et al (2003) suggested that in a transparent orthography such as Spanish, remedial education may be more successful if it concentrates on the phoneme level more than on onset-rime units, in contrast to what has been suggested by Treiman (1992) in the English language. The improvements in the Phoneme group support the idea that the phonemic level plays an important role in dyslexia in a transparent orthography as Spanish. By forcing attention to individual letters within the word and with the speech feedback at the same time during the training, could provide the basis to improve phonemic segmentation skills, and promoting the grapheme-phoneme correspondences, an ability that is not achieved by the severe RD children. In relation to the Whole Word condition, interestingly, this unit also benefited word recognition ability. A possible explanation for this finding has to do with the fact that the dual route model of reading is functional in Spanish despite its orthographic transparency by which, in principle, all the words could be read by the phonological route. Some empirical data support the functionality of both routes in Spanish children (Defior, Justicia & Martos, 1996; Valle-Arroyo, 1989), suggesting no differences between the processes involved in the reading of Spanish and those implicated in opaque orthographies, such as English. In this sense, it is important to note that children who participated in this study were between 7-10 years old, an age in which we would expect the use of the orthographic routine of reading. The reason for the gains after treatment within this experimental condition may be explained by the fact that children could place their attention on the whole word present on the computer screen with the phonological speech feedback. This connection between the word and its individual sounds may have enhanced the connections between their orthographic and phonological forms.

4. Concluding discussion

Wydell and Butterworth (1999) suggested that the effect of a phonological deficit on reading depends on the transparency of the orthography. Probably the most likely source of these difficulties is a deficit in representing phonological information at earlier developing levels of phonology: the syllable, onset, and rime. Goswami (2002) suggested that syllabic representation is basic to many languages, and that children's ability to recognize syllables and rhymes precedes learning a particular spelling system. This developmental view can readily explain cross-language differences in reading acquisition, and it can also explain cross-language differences in the manifestation of developmental dyslexia (see also Wydell & Butterworth, 1999; Wydell & Kondo, 2003 for a similar conclusion). Some of the processes underpinning language acquisition are disrupted in developmental dyslexia leading to deficits in the development of a phonological representation of words before literacy is acquired. According to this theoretical analysis, dyslexic children in all languages appear to have a phonological deficit at the syllable and rhyme levels prior to acquiring literacy. This

deficit leads to problems in acquiring letter-sound relationships and in restructuring the phonological lexicon to represent phoneme-level information.

Some linguists have suggested that different phonological units exist in the Spanish language (i.e., syllable, onset and rime). Jiménez and Ortiz (1993) designed a study to verify whether or not such linguistic realities are psychological realities as has been found in the English language. The results obtained suggested that children at the pre-reading stage are more sensitive to syllabic units, than to instrasyllabic and phonemic units. Moreover, they demonstrated that good readers did not differ from disabled readers and non readers at the syllabic awareness level, but they had higher levels of instrasyllabic awareness, and phonemic awareness. In languages like Spanish, onset-rime segmentation is equivalent to phonemic segmentation for many words (e.g., for a word like "loro", the onset-rimes are /l/ /O/ /r/ /O/ and so are the phonemes). In fact, Spanish children with reading disabilities do not use correspondences based on higher level units as onsets and rimes in visual word recognition (Jiménez, Alvarez, Estévez & Hernández-Valle, 2000). Goswami (2002) also suggested that dyslexic children learning to read in languages with a simple syllabic structure would probably have less difficulty in the acquisition of grapheme-phoneme recoding strategies. However, in the first study presented here both Spanish dyslexic subtype samples were impaired as a group relative to the CA group on phonological awareness tasks analyzed. Both dyslexic subtypes performed significantly worse than the RL group on the measures of phonological awareness suggesting that a phonemic deficit is curtailing the development of phonological decoding. We replicated the finding of a dyslexic deficit in an RL match that we found for previous studies conducted in a transparent orthography (i.e., Spanish) (Jiménez, 1997; Jiménez & Hernández-Valle, 2000).

On the other hand, Stanovich et al. (1997b) suggested that surface dyslexia may arise from a milder form of phonological deficit than phonological dyslexia; this type of difficulty could be influenced by the orthographic peculiarities of the language. We suggested that in a transparent orthography the difficulties with the phonological processing emerge more clearly, especially in surface dyslexia. Therefore, we suggest that the existence of dyslexic subtypes could be a consequence of the differences in the orthographic systems.

We would like to conclude this section by pointing out that in studies employing accuracy-based measures of subtypes, the subjects have been selected on the basis of accuracy-based reading scores (Jiménez, 2010). But there is a pool of subjects who might have met rate-based but not accuracy-based criteria for inclusion in a dyslexia study. We do not know what kinds of cognitive and reading profiles rate-disabled children would show, because they are typically not included in subtype studies in English. Until these children are tested, it may be premature to argue that there are differences in the incidence of various subtypes across orthographies. The difference might be due to the accuracy vs. rate criterion of selecting subjects, rather than differences in the orthography, although both could be factors that affect the identification of a reading disability. Consequently, this issue is open to debate and it is exemplified by observations made by Share (2008): 'it remains to be seen to what extent the classic dual-route distinction between phonological and surface dyslexia, a purely accuracy-based dichotomy, relates to accuracy/speed differences, particularly in the case of more conventional (i.e. transparent) orthographies'.

Empirical evidence indicates that computer-assisted practice can improve word recognition for reading disabled children compared to a control group. However, we also found that the performance of dyslexic children during computer-based word reading was also affected by low frequency words and long words.

To conclude, the research findings presented here provide empirical support to the hypothesis based on a phonemic deficit in dyslexia in a transparent orthography. Moreover, the research findings demonstrate that reading by the computer with speech feedback may constitute a helpful remedial tool for children with RD. Consequently, both studies reported here provide empirical evidence about the role of phonological processing in dyslexia in the Spanish language, consistent with other multiple case studies.

The origin of this phonological deficit in developmental dyslexia is also open to debate. Sprenger-Charolles et al. (2006) examined the classical phonological explanation that ascribes dyslexics' reading deficit to a specific cognitive deficiency in phonological processing, primarily in phonemic awareness and in phonological short-term memory. They also examined the current non-phonological explanations that assume that the phonological deficit of dyslexics is secondary to more basic sensori-motor impairment: a deficiency in either rapid auditory processing, or in the visual magnocellular pathway, or in motor skills. The authors show why perceptual explanations of dyslexia should be based on alternative perceptual modes rather than on deficits, and they place the perceptual explanation in the framework of a three-stage model of speech perception. They argue that dyslexics' phonological deficits are secondary to more basic sensori-motor impairments. Overall, they concluded that the non-phonological explanations are rather weak, and they propose a new phonological explanation for dyslexia, based on a specific mode of speech perception. In sum, "allophonic perception offers a new perspective in the study of dyslexia. Therefore, further research is necessary to gain a better understanding of the way dyslexics perceive speech, and especially how they segment the speech stream. While allophonic theory constitutes a first step in this direction, it still has to be articulated with other dimensions of language processing" (p. 172).

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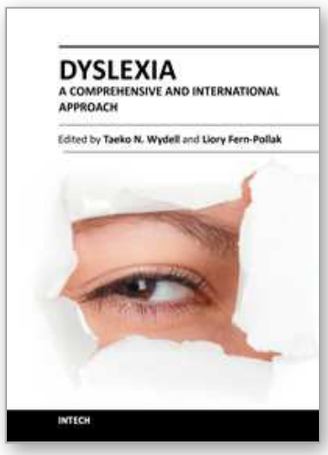

Dyslexia - A Comprehensive and International Approach

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This book brings together dyslexia research from different perspectives and from different parts of the world, with the aim of providing a valuable source of information to medical professionals specializing in paediatrics, audiology, psychiatry and neurology as well as general practitioners, to psychologists who specialise in developmental psychology, clinical psychology or educational psychology, to other professions such as school health professionals and educators, and to those who may be interested in research into developmental dyslexia. It provides a comprehensive overview of Developmental Dyslexia, its clinical presentation, pathophysiology and epidemiology, as well as detailed descriptions of particular aspects of the condition. It covers all aspects of the field from underlying aetiology to currently available, routinely used diagnostic tests and intervention strategies, and addresses important social, cultural and quality of life issues.

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