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Reading-related Cognitive Deficits in Spanish Developmental Dyslexia

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Abstract

Spanish-speaking children learn to read words written in a relatively transparent orthography. Variations in orthographic transparency may shape the manifestation of reading difficulties. This study was intended to help clarify the nature of developmental dyslexia in Spanish. Developmentally Dyslexic children (DD) were compared to a chronological age-matched control group (CA). Measures included rapid automated naming, verbal working memory, phonological short-term memory, and phonemic awareness. Results demonstrated that developmental dyslexics show reading-related cognitive deficits in areas such as naming speed, verbal working memory, phonological short-term memory, and phonemic awareness. Our results are consistent with studies conducted in the Spanish language and in other transparent orthographies.

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Keywords: transparent orthography; developmental dyslexia; cognitive profile.

1. Introduction

Developmental dyslexia (DD) is defined as an unexpected reading difficulty that is substantially below, expected given the person's chronological age, measured intelligence, and age-appropriate education (Association, 2000; Organisation, 1996). The International Dyslexia Association defines dyslexia as a specific learning disability

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that is neurobiological in origin, characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities, typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge (Lyon, Shaywitz, & Shaywitz, 2003). Developmental dyslexia is a highly heritable disorder with a prevalence of at least 5% in school-aged children (Scerri & Schulte-Korne, 2010).

The manifestation of dyslexia has been well established for English readers, but cross-linguistic studies has revealed that the manifestation of dyslexia varies depending on the type of orthographic transparency of language that children are learning (Defior, 2004; Joshi & Aaron, 2006; Katzir, Shaul, Breznitz, & Wolf, 2004; Miles, 2000). The orthographic transparency refers to the consistency or phonemic system between the grapheme-phoneme (G-P) correspondences (Joshi & Aaron, 2006). Spanish, Greek, Finnish and most Indian languages have a very close G-P correspondence, and are described as having transparent orthographies (Seymour, Aro, & Erskine, 2003). It is known that transparent languages are easier to learn for children than non-phonemic spelling systems (Seymour et al., 2003; Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003). Our research is concerned about Spanish language, which has 24 graphemes corresponding to unique sounds, and there are very few exceptions (e.g. “c”, “g” and “h”), and is described as one of the most transparent languages in the continuum (Seymour et al., 2003). In general, studies carried out with English readers are not totally applicable to other languages, and the processes described as the core underlying dyslexia are not consistent in cross-linguistic researches (Jimenez et al., 2008; Ziegler et al., 2003).

In dyslexia, the main difficulties in reading occur at word level, especially when the task involves recognition of words in isolation. One of the fundamental findings of research into dyslexia is that poor word reading are strongly related to a phonological processing deficit (Herrmann, Matyas, & Pratt, 2006; Jimenez, Rodriguez, & Ramirez, 2009; Melby-Lervag, Lyster, & Hulme, 2012; Soriano & Miranda, 2010). One of the processes underlying the phonological processing is the phonological awareness, defined as the ability to access and manipulate the phonemic level of speech, and it is reported that children with dyslexia have a poor performing in tasks with phonological awareness involved. A task for phonological awareness involves identification and manipulation of phonemes in words, for example, repeating words without the first sound. This deficit is remarkable in opaque orthographies, such as English, but recent findings in transparent orthographies, especially Spanish, has shown that phonological awareness has deficits too, but no more significant than fluency. Brizzolara et al. (2006) concluded that phonological deficits might not represent the main cognitive marker of developmental dyslexia. Indeed, phonological dyslexia is less common in Spanish than in English (Jimenez Gonzalez & Hernandez Valle, 2000).

By the other hand, naming speed or Rapid Automated Naming (RAN) is another issue involving dyslexia. Is defined as the ability to name quickly a highly familiar visual stimuli, such as digits, letter, objects and colors presented one by one (Wolf & Bowers, 2000). The RAN task measures reading speed or fluency, and tasks for assess phonological awareness takes a measure of reading accuracy. Although RAN is moderately correlated with phonological awareness, RAN contributes explaining with unique variance the reading achievement. RAN is a robust predictor of reading skills and is independent of a range of other important predictors, such as phonological awareness and IQ in both consistent and inconsistent orthographies (Georgiou, Parrila, & Liao, 2008). It is supported that reading speed is the core of dyslexia in more transparent orthographies, and moreover, is a great predictor of reading differences better than phonological awareness (Guzmán et al., 2004; Meisinger, Bloom, & Hynd, 2010; Serrano & Defior, 2008).

There are other important cognitive processes involved in DD, and it is important the research about this processes to make account about the neuropsychological profile of dyslexia in order to understand reading disabilities. Other cognitive processes that are currently being investigated are phonological short-term memory (STM) and working memory (WM) (Smith-Spark & Fisk, 2007; Swanson, Xinhua, & Jerman, 2009). STM is required to recall the phonemes and digit frequencies, and WM is demanded for simultaneous processes and storage of digits within sequences and final words from unrelated sentences, and is controlled by high demands of attentional processes that imply the executive system to manage them. Both processes are involved indirectly in phonological process and naming speed. In this way, a child with dyslexia shows deficits in both processes (Swanson et al., 2009).

Thus, the aim of this study was to explore the differences between dyslexic group and control group in a range of different measures of reading-related cognitive deficits such as phonological processing, rapid automated naming, and memory types described previously.

2. Method

2.1. Participants

A total of 80 volunteers participated in the following experiment. All the children were students from different schools in Valencia (Spain) and were of lower-middle socioeconomic status, but had no cultural or environmental disadvantages. All of the subjects were Caucasian and spoke Spanish as their primary language. They received credits for their participation. They ranged in age from 9 to 14 years (mean age= 11 years 2 months, SD= 1 year 4 months). Of the entire sample, 52 were boys and 28 girls. These children were classified into two groups: (a) the developmentally dyslexic group, which was made up of 40 students (mean age= 11 years 1 month, SD= 1 year 3 months; 28 male and 12 female); (b) the control group, which consisted of 40 normal readers (mean age= 11 years 2 months, SD= 1 year 5 months; 24 male, 16 female).

The presence of developmental dyslexia was determined by using an adaptation of the multifaceted approach developed by Pereira-Laird, Deane, and Bunnell (1999). The requirements followed in the assessment were: (a) poor academic performance in reading using a teacher's rating report, and average achievement in other academic areas (e.g. arithmetic); (b) scores of 80 or higher on an intelligence test (Cattell & Cattell, 1950/1989), in order to exclude students with intellectual deficits; (c) no evidence or history of neurological damage, environmental disadvantage, emotional disturbance, hearing and vision abnormalities, or any other major handicapping condition, in accordance with the conventional exclusion criteria for the learning disabilities (LD) field; (d) the achievement criteria in reading adopted in this study have been commonly used in the LD literature. Specifically, developmental dyslexia was determined by using a score corresponding to the 25th percentile or less on the word-reading and/or pseudoword reading skills subsets from the Standardized Reading Skills Battery (PROLEC-R, Cuetos, Rodríguez, Ruano & Arribas, 2002).

Table 1. Descriptive data for dyslexic and control groups

		Dyslexic (N=40)	Control (N=40)	F(1,78)	p	η²
Age	M	11,17	11.22	0.024	0.878	.00
	SD	1.38	1.53			
IQ	M	101.2	106.28	2.485	0.119	.03
	SD	18.31	8.98			
Word reading skill	M	56.7	124.28	105.157	.000	.57
	SD	21.95	35.42			
Pseudoword reading Skill	M	40.85	91.54	131.981	.000	.62
	SD	14.56	23.8			
Sex	Male	28	24			
	Female	12	16			

Analysis of variance (ANOVAs) results showed no significant differences between the two groups in age, $F_{(1,78)} = .024$, $p < .878$, $\eta^2 = .00$, or IQ, $F_{(1,78)} = 2.485$, $p < .119$, $\eta^2 = .03$. Obviously, there were significant differences between the groups in word reading skill [(accuracy / speed) x 100], $F_{(1,78)} = 105.157$, $p < .000$,

$\eta^2 = .57$, and in pseudoword reading skill [(accuracy/speed) x 100], $F_{(1,78)} = 131.981$, $p < .000$, $\eta^2 = .62$. The means and standard deviations of these measures are presented by group in Table 1.

2.2. Measures

Various reading and reading-related cognitive tests were used to compare the two groups. All the tests were carried out individually in a quiet room, and the same experimenter administered all of them. The presentation order of the tests was randomized.

Culture Fair (or free) Intelligence Test (Scale 2, Form A). This test (Cattell & Cattell, 1950/1989) allows the measurement of general mental capacity without the interference of cultural basis. The authors used the "two halves" method to calculate reliability, and they reported a correlation coefficient of .86. For validity, they used criteria scores on the TEA Test (Seisdedos, De la Cruz, Cordero, & González, 1991). A correlation coefficient of .68 was found between the g factor measure and results on the TEA test, which measured verbal, reasoning, and numerical aptitudes.

Word and Pseudoword Reading Skills. (PROLEC-R, Cuetos, Rodríguez, Ruano & Arribas, 2002). Two combined scores of reading skills were taken, one based on word reading skill and the other on pseudoword reading skill. Word reading test requires the correct identification of 40 words that vary greatly in frequency, length and linguistic structure (CCV, CVV,CVC, CCVC, CVVC and VC, where C= consonant and V=vowel) and pseudoword reading consists of 40 pseudowords, which were constructed by changing or adding one or two letters of each of the 40 words on the reading test. In both cases, the child's score consisted of an accuracy score divided by the reading speed, measured as the time taken to complete the task, and then multiplied by 100. The reading battery has been found to have an internal consistency of Cronbach's alpha =.74, and the teachers' ratings of reading ability were used as validity criteria. Teachers were asked to rate reading ability on a 10-point scale ranging from low (1) to high (10) ability. Correlations between reading measures and teachers' ratings were statistically significant (p < .001).

Verbal working memory. To assess the children's working memory, we administered the task used by Siegel and Ryan (1989). The child heard sentences that had the final word missing. The task was to supply the missing word and then repeat all the missing words from the set. There were three trials at each level or set size (two, three, four or five words). For each trial, the score was 1 point (3 for set) when the child performed the task successfully, and the score was 0 when the child failed to complete the task. Task administration was stopped when the child failed all the trials at one level.

Phonological short-term memory. To assess short-term memory, we used a phonological memory task (Soriano & Miranda, 2010). On this task, the child needed to repeat 20 Latin words not related to the Spanish lexicon (e.g. umbrifer). The rationale for using a Latin-based phonological memory task is that it requires children to repeat phonological strings. Children's repetition abilities are highly associated with the speed of learning the phonological forms of new words. In the construction of this task, we took the precaution that the Latin words were not similar to Spanish morphology. The total number of correctly repeated Latin words was calculated for each child. The Cronbach's alpha was .74.

Phonemic awareness. We administered the Test of Phonemic Awareness (Jiménez, 1995). This test evaluates the participant's ability to manipulate the sounds or phonemes of spoken words, and it consists of four tasks containing 15 items each. On the isolation task, the child listened to a word (e.g. lana [wol]) and had to say its beginning sound, /l/. On the segmentation task, the child listened to a word (e.g. rana [frog]) and then had to say its constituent sounds, phoneme by phoneme (e.g. /r//a//n//a/). Pronouncing the sounds or saying the names of the letters constituted a correct response. On the deletion task, the child listened to a word (e.g. blusa [blouse]) and then had to delete its initial sound and say the remaining sounds (e.g. lusa). On the blending task, the child listened to a sequence of phonemes (e.g. /m//e//s//a/) and had to say the whole word (e.g. mesa [table]). The total score was calculated by adding the correct responses on the four tasks. Each task had a Cronbach's alpha ranging from .75 to .86.

Rapid Automatized Naming (RAN) – Objects, Colours, Numbers and Letters. These four measures were selected from the RAN/RAS test (Wolf and Denckla, 2005). The task consists of 5 items each arrayed on a page, each repeated in random order 10 times. One page has 50 simple object drawings, 50 colours, 50 numbers, and the other 50 letters. Participants were initially asked to provide the name of each symbol: object, color, number or letter, to assess familiarity with the presented stimuli. Following this, participants were presented with the page containing the matrix of symbols and asked to name each item from left to right as quickly as possible. Total time in seconds was recorded.

3. Results

Results of analysis of variance (ANOVAs) showed significant differences between the groups in verbal working memory, $F_{(1,78)} = 34.030$, $p < .000$, $\eta^2 = .30$; phonological short-term memory, $F_{(1,78)} = 82.696$, $p < .000$, $\eta^2 = .51$; phonemic awareness, $F_{(1,78)} = 60.768$, $p < .000$, $\eta^2 = .43$; and in all the four Rapid Automatized Naming (RAN) measures: RAN-Objects, $F_{(1,78)} = 65.762$, $p < .000$, $\eta^2 = .45$; RAN-Colours, $F_{(1,78)} = 29.278$, $p < .000$, $\eta^2 = .27$; RAN-Numbers, $F_{(1,78)} = 21.053$, $p < .000$, $\eta^2 = .21$; and RAN-Letters, $F_{(1,78)} = 24.050$, $p < .000$, $\eta^2 = .23$. The means and standard deviations by group of these measures are presented in Table 2.

Table 2. Means and standard deviations by group in reading-related cognitive deficits

		Dyslexic (N=40)	Control (N=40)	F(1,78)	p	η²
Verbal working memory	M	4.4	6.77	34.030	.000	0.3
	SD	1.42	2.14			
Phonological Short-term Memory	M	17.75	20	82.696	.000	0.51
	SD	1.56	.00			
Phonemic Awareness	M	39.2	44.85	60.768	.000	0.43
	SD	4.55	0.48			
RAN Objects	M	51.75	35	65.762	.000	0.45
	SD	11.85	5.48			
RAN Colours	M	60.67	37.47	29.278	.000	0.27
	SD	26.42	6.09			
RAN Numbers	M	33.23	22.45	21.053	.000	0.21
	SD	14.56	2.89			
RAN Letters	M	32.45	21.90	24.050	.000	0.23
	SD	12.96	4.11			

4. Discussion

Our purpose was to investigate the existence of reading-related cognitive deficits associated with developmental dyslexia in Spanish. Like as in other studies carried out in the Spanish language (Jiménez González, 1997; Jimenez et al., 2009; Serrano & Defior, 2008), our findings suggest that a phonological deficit exists in dyslexic children who learn to read in a transparent orthography.

Furthermore, our findings support the hypothesis that, in a transparent orthography, naming speed is one of the most reading-related deficits, which is consistent with the results from studies carried out in Italian (Brizzolara et al., 2006) and in Spanish (Guzmán et al., 2004; Jimenez et al., 2009; López-Escribano, 2007).

The developmentally dyslexic group also showed lower verbal working memory and lower phonological short-term memory than the chronological-age control group. This finding suggests that WM and STM deficits can co-occur in Spanish developmental dyslexics, as was also shown in the recent selective meta-analysis carried out by

Swanson et al. (2009). Thus, deficiencies in memory can be due to both phonological and executive processing demands.

In summary, results from this study help to clarify the manifestations of dyslexia in transparent languages like Spanish. Our results show that developmental dyslexia in Spanish seems to be associated with reading-related cognitive deficits that involve verbal working memory, naming speed and impairments in two main phonological skills related to learning to read, phonemic awareness and phonological short-term memory. One major implication of these results is that there may be multiple pathways to developmental dyslexia in the Spanish language. Nevertheless, the findings suggest that measures of these impairments are needed to identify the nature of children's difficulties and effectively determine the appropriate support.

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