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Spanish developmental dyslexia: Prevalence, cognitive profile, and home literacy experiences

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ABSTRACT

This study was designed to examine the prevalence, cognitive profile, and home literacy experiences in subtypes of Spanish developmental dyslexia. The subtyping procedure used comparison with chronological-age-matched and reading-level controls on reaction times and accuracy responses to high-frequency words and pseudowords. Using regression-based procedures, 8 phonological dyslexics and 16 surface dyslexics were identified from a sample of 35 dyslexic fourth graders by comparing them with chronological-age-matched controls on reaction times to 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, with the group of parents with children matched in reading age, in comparison with the group of parents with children with surface dyslexia, reporting more literacy home experiences.

Introduction

Developmental or congenital dyslexia has been characterized by the developmental inability to read despite adequate opportunities, intellectual ability, and motivation (Hynd & Hynd, 1984). Research conducted with an English-language focus has described dyslexic children with differing degrees of deficiency in reading pseudowords and irregular words, leading to the conclusion that there

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are developmental analogues of the acquired forms of dyslexia (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang, & Petersen, 1996; Stanovich, Siegel, & Gottardo, 1997).

These cases of developmental dyslexia were interpreted within the functional cognitive architecture assumed by the dual-route theory, which contemplates a phonological dyslexia profile characterized by impaired phonological skills and fairly well-preserved orthographic skills and a surface dyslexia profile characterized by impaired orthographic skills and fairly well-preserved phonological skills. In addition to the dual-route model, other connectionist models may explain individual differences in dyslexia, including the dual-route cascaded (DRC) model of visual word recognition and reading aloud (Coltheart, Curtis, Atkins, & Haller, 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the parallel distributed processing (PDP) model (Seidenberg & McClelland, 1989), and the connectionist dual process (CDP) model (Zorzi, Houghton, & Butterworth, 1998). These computational models of normal and disordered reading aloud differ in their architectural, representational, and processing assumptions. There is, however, general agreement that there are at least two procedures involved in the translation of orthography to phonology: one restricted to whole-word information and the other including or specializing in subword information (Woollams, Lambon Ralph, Plaut, & Patterson, 2007).

Nevertheless, the dual-route model has been one of the common paradigms in subtyping studies (Ho, Chan, Chung, Lee, & Tsang, 2007). Research to determine the extent to which the dual-route models are functional in Spanish (e.g., de Vega & Carreiras, 1989; de Vega, Carreiras, Gutiérrez, & Alonso-Quecuty, 1990; Defior, Justicia, & Martos, 1996; García-Albea, Sánchez-Casas, & del Viso, 1982; Valle-Arroyo, 1996) indicate that there is no difference between the processes involved in reading acquisition in Spanish, a language with a transparent orthography, and the processes implicated in reading acquisition in English, a language with an opaque orthography. In addition, other research studies on phonological dyslexia in transparent orthographies have found that results of individual cases of phonological dyslexia where there is a dissociation of reading words versus nonwords are similar to results found in opaque orthographies (e.g., Cuetos, Valle-Arroyo, & Suárez, 1996; Iribarren, Jarema, & Lecours, 1999). Consequently, if reading mechanisms are the same for different alphabetic writing systems, then the pattern of results found in the subtyping work in English should also be expected in Spanish.

Wydell and Butterworth (1999) proposed the hypothesis of granularity and transparency to predict the incidence of phonological dyslexia in different languages. According to this hypothesis, any orthography can be described on two dimensions: the transparency of print-to-sound translation and the size of the smallest orthographic unit that represents sound (i.e., granularity). They also suggested that orthographies with fine granularity and opaque print-to-sound translation would have a high incidence of phonological dyslexia. In contrast, orthographies with fine granularity and transparent print-to-sound translation would have a low incidence of phonological dyslexia (e.g., Serbo-Croatian, Spanish, Finnish). In summary, phonological dyslexia would be just as common across languages, but phonological dyslexics would be harder to detect in languages with regular orthographies (Frith, 1999).

Spanish has a transparent and fine-grained orthography. The Spanish orthography has 24 graphemes (5 vowels and 19 consonants), each of which represents a unique sound. Therefore, the process of translating print to sound is never ambiguous because each letter of the alphabet has a unique pronunciation except the letters *c*, *g*, and *r*. For example, *c* is pronounced as /k/ when followed by the vowel *a*, *o*, or *u* and as /th/ or /s/ (depending on the region) when followed by the vowel *e* or *i*; the letter *g* is pronounced as /g/ when followed by the vowel *a*, *o*, or *u* and as /h/ when followed by the vowel *e* or *i*; and *r* is pronounced as /rr/ when it appears at the beginning of a word or is preceded by the letter *l*, *n*, or *s* and as /r/ when it appears in the middle of a word or at the end of a word. Moreover, phonological errors can result from a misapplication of accent rules (e.g., melón as mélon). Some Spanish words must have an acute accent (′) on the last, second to the last, or third to the last vowel.

Research generally supports the hypothesis of a higher incidence rate of phonological dyslexia in English in comparison with surface dyslexia (e.g., Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997), but contradictory results were found when we reviewed Spanish studies (Calvo, 1999; Jiménez & Ramírez, 2002; Martínez, 1995; Serrano, 2005). English studies use similar criteria (e.g., similar types of stimuli for matching and identification, similar accuracy measures for irregular words and pseudowords, similar assessment tasks to test the validity of subgrouping) to diagnose phonological dyslexia versus surface dyslexia. However, one reason for the discrepancy in the frequency of phonological dyslexia and surface dyslexia diagnoses between Spanish studies has to do with methodological differences such as different types of stimuli for matching and identification, variability in the studied range of ages, and the tasks used to validate classification into subtypes.

Another debatable issue in the field has been whether the reading and reading-related processing skills of dyslexic children are in all respects identical to those of younger average readers (Ho, Chan, Lee, Tsang, & Luan, 2004). English studies that used both chronological-age-matched and reading-level controls found that the performance of surface dyslexic children was very similar to that of younger normal readers, suggesting a general delay in word recognition, whereas phonological dyslexic children had a specific deficit in phonological processing (Manis et al., 1996; Stanovich et al., 1997). In addition, surface dyslexia has sometimes been characterized as a mild phonological impairment coupled with inadequate reading experience (Stanovich et al., 1997).

Some preliminary research has suggested that home literacy environments (e.g., print exposure) are differentially related to phonological and orthographic processing skills (Cunningham & Stanovich, 1990; Olson, Wise, Conners, Rack, & Fulker, 1989). For example, Olson and colleagues (1989) pointed to differences in the degree of print exposure as one potential environmental determinant of the orthographic processing ability that determines reading skills. However, none of the reviewed studies across languages analyzed the influence of home literacy experiences (e.g., print exposure) on the subtypes of reading disability defined by regression-based procedures.

This study had several purposes. First, we wanted to investigate whether the classification of developmental dyslexia into subtypes is the same in Spanish as in English. Our theoretical framework was based on the dual-route model, and we used the same methodological procedures as the English studies (e.g., Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997). Second, we wanted to examine the incidence rates of surface and phonological dyslexia in Spanish. According to the hypothesis of granularity and transparency (Wydell & Butterworth, 1999), the incidence rate of phonological dyslexia in Spanish should be low. Findings with English-speaking children generally support the hypothesis that phonological dyslexia reflects some persistent deficits, whereas surface dyslexia resembles a form of developmental delay. The third purpose of this study was to examine whether reading and reading-related processing skills of dyslexic children in a consistent orthography are in all respects identical to those of younger average readers (e.g., naming speed, phonological awareness, speech perception, orthographical processing). This would provide further evidence that children diagnosed with surface dyslexia may have mild phonological and orthographical processing problems. The latter problem may be due, in part, to inadequate exposure to print (Stanovich et al., 1997). Therefore, a fourth purpose of our study was to determine whether the frequency with which parents provide direct support to their children when they are learning to read has an effect on their orthographic processing abilities (Olson et al., 1989; Sénéchal, LeFevre, Thomas, & Daley, 1998). For this purpose, we analyzed the home literacy experiences and sociocultural characteristics associated with the subtypes of dyslexia. To our knowledge, this is the first study in a transparent orthography that has analyzed the influence of home literacy experiences in dyslexic subtypes.

Method

Participants

The initial group of participants came from local schools. Teachers nominated normally achieving readers (NR) and children who were reading disabled (RD). We studied only those children who were either NR or RD according to their performance in the different subtests of the Spanish standardized reading skills test PROLEC (Cuetos, Rodríguez, & Ruano, 1996). The children were classified into three groups: the reading-disabled group (i.e., the dyslexic group) that was made up of 35 fourth graders (RD, 22 boys and 13 girls, mean age = 117.60 months, *SD* = 6.16), the first control group that consisted of 47 normal readers matched in age with the reading-disabled group (CA group, 23 boys and 24 girls, mean age = 117.04 months, *SD* = 5.45), and a second control group that was made up of 40 younger children of the same reading level as the reading-disabled group (RL group, 20 boys and 20 girls, mean age = 91.70 months, *SD* = 3.73). We also selected four samples of families as a function of the reading profile shown by their children: a group of parents (15 fathers and 16 mothers) with children with a profile of surface dyslexia, a second group of parents (6 fathers and 6 mothers) with children with a profile of phonological dyslexia, a third group of parents (38 fathers and 41 mothers) with children matched in age with children with reading disabilities (group of parents with children matched in age with children with reading disabilities), and a fourth group of parents (33 fathers and 35 mothers) with children matched in reading age in comparison with children with reading disabilities. These participants were the parents of the children in the study.

We operationalized developmental dyslexia or specific reading disabilities based on the following criteria: (a) low performance on the Spanish standardized reading test PROLEC (i.e., below the 25th percentile in pseudoword reading), (b) poor academic performance in reading using a teacher's rating report and average achievement in other academic areas (e.g., arithmetic), and (c) a score higher than 80 on an intelligence test (Cattell & Cattell, 1950/1989) to exclude students with intellectual deficits (Siegel & Ryan, 1989). However, the discrepancy between reading achievement and IQ test scores has been challenged (Jiménez & Rodrigo, 1994; Siegel, 1992; Stuebing et al., 2002); therefore, it has not been included in our definition of reading disability. Results of analyses of variance (ANOVAs) and post hoc comparisons using the Bonferroni method of multiple comparisons showed that the dyslexia group performed significantly lower than the CA control group and similarly to the RL control group on word reading, ($p < .001$). Consequently, both reading-disabled and younger normal readers were matched on word reading using the Spanish standardized reading test PROLEC. There were no significant differences in the distribution of the participants as a function of gender, $\chi^2(2) = 1.81$, $p = .40$, or IQ, Welch $F(2,75.73) = 2.59$, $p = .08$, $\eta^2 = .04$. However, there were significant differences in verbal working memory (VWM), $F(2,119) = 7.59$, $p < .001$, $\eta^2 = .11$, and age, Welch $F(2,72.9) = 433.30$, $p < .001$, $\eta^2 = .11$. Planned contrasts revealed that the RD group performed significantly lower than the CA control group, $t(80) = 3.77$, $p < .01$, and the RL control group, $t(73) = 2.89$, $p < .05$. The CA and RD groups were matched in age, $t(80) = 0.65$, $p = 1.00$, and both groups were older than the RL group, $t(85) = 22.70$, $p < .001$, and $t(73) = 21.80$, $p < .001$, respectively. The means and standard deviations in IQ, VWM, and reading measures by group are presented in Table 1.

Children in the study had learned to read by phonic instruction, and grapheme–phoneme correspondences were taught explicitly in first grade. This method moves children gradually from simple to complex correspondences and is the most common approach to reading instruction in Spanish schools. Excluded from the study were children who had sensory problems, acquired neurological problems, or other problems traditionally used as exclusionary criteria for learning disabilities.

Materials

Standardized reading skills test PROLEC

This test (Cuetos et al., 1996) includes several reading subtests. We administered only the word reading and pseudoword reading subtests. These subtests require the correct identification of 30

Table 1
Means and standard deviations in word reading, pseudoword reading, verbal working memory, and IQ by group.

		Group			
		RL ($n = 40$)	CA ($n = 47$)	RD ($n = 35$)	Group comparison
Word reading	Mean	28.80	29.90	28.20	RD = RL
	SD	1.92	0.28	1.52	RD < CA
Pseudoword reading	Mean	29.25	29.70	24.74	RD < RL
	SD	0.63	0.55	2.33	RD < CA
Verbal working memory	Mean	3.15	3.28	2.66	RD < RL
	SD	0.70	0.77	0.73	RD < CA
IQ	Mean	108.28	116.00	111.54	RD = RL
	SD	11.76	19.58	15.50	RD = CA

Note. RL, reading-level-matched controls; CA, chronological-age-matched controls; RD, reading-disabled group.

ordinary words and 30 pseudowords with different linguistic structures (CCV, CVV, CVC, CCVC, CVVC, and VC, where C = consonant and V = vowel). Both subtests measure the accuracy of the responses. The authors reported an alpha coefficient of .92 and used as validity criteria the teachers' ratings of reading ability. Teachers were asked to rate reading ability on a 10-point scale ranging from *low ability* (1) to *high ability* (10). All correlations between reading measures and teacher ratings were statistically significant ($p < .001$).

Culture Fair (or Free) Intelligence Test (Scale 1 and 2, Form A)

This test (Cattell & Cattell, 1950/1989) allows a measurement of the general mental capacity without interference from cultural bias. The authors used the "two halves" method to calculate reliability and reported a correlation coefficient of .86. They used as validity criteria scores on the Test de Aptitudes Mentales Primarias (TEA-1) (Seisdedos, De la Cruz, Cordero, & González, 1991). A correlation coefficient of .68 was found between the *g* factor measure and results on the TEA-1 test that measured verbal, reasoning, and numerical aptitudes.

Parent Interview Response

The Parent Interview Response was given to the children's parents after they agreed to participate in this study. The parents of children identified with different dyslexic profiles filled out the questionnaires (see Appendix A). The literature indicates that parental background, such as income and education, affects children's literacy skills (Hart & Risley, 1995). Also, the literature amply demonstrates that parents' literacy activities with children, such as reading with them or helping them with homework, affect children's literacy outcomes (Feitelson & Goldstein, 1986; Goldenberg, Reese, & Gallimore, 1992; Sénéchal et al., 1998). We developed the Parent Questionnaire precisely to include these parental factors in our study of dyslexic subtypes and home literacy experiences. The Cronbach's alpha for the Parent Interview Response was .78.

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 to repeat all of the missing words from the set. There were three trials at each level or set size (two, three, four, or five words). For each level or set size, the score was 1 when the child performed the task successfully and 0 score when the child failed to complete the task. Task administration was stopped when the child failed all of the trials at one level.

Test of Phonemic Awareness

We administered the Prueba de Conciencia Fonémica (PCF) (Test of Phonemic Awareness) that is included in the multimedia battery SICOLE-R (Jiménez et al., 2007). The Phonemic Awareness module evaluates the participant's ability to manipulate the sounds or phonemes of spoken words and consisted of four tasks. An average score was calculated by adding the correct responses in the four tasks and dividing that sum by the number of tasks. In the *isolation* task, the child listened to a word (e.g., *lana* [wool]) and needed to say its first sound, /l/, and then use the computer mouse to point to the picture that began with the same sound (in this example, *luna* [moon]). This task consisted of 15 items and had a Cronbach's alpha of .75. In the *segmentation* task, the child listened to a word (e.g., *rana* [frog]) and then needed to say its constituent sounds phoneme by phoneme (e.g., /r/ /a/ /n/ /a/). Pronouncing the sounds or saying the names of letters constituted a correct response. This task consisted of 15 items and had a Cronbach's alpha of .80. In the *deletion* task, the child listened to a word (e.g., *blusa* [blouse]) and then needed to delete its first sound. The way of responding was to use the mouse to select the correct word from three available options (in this case, *lusa* from /lusa/, /tusa/, and /musa/). This task consisted of 15 items and had a Cronbach's alpha of .83. In the *blending* task, the child listened to a sequence of phonemes (e.g., /m/ /e/ /s/ /a/) and needed to say the whole word (e.g., *mesa* [table]). Three pictures were presented on the computer screen (e.g., table, donkey, and bed), and the child needed to select the correct word with the mouse. This task consisted of 15 items and had a Cronbach's alpha of .86.

Naming task

The two reading disability subtypes were defined by their performance on a set of experimental words and pseudowords used by Jiménez and Ramírez (2002). The *naming* task consisted of reading aloud each of the verbal stimuli that appeared one by one on a computer screen. The child needed to read the item as quickly as possible. The sound was recorded by the voice key, which stopped the computer's chronometer. The participant was presented with a block of words followed by pseudowords or vice versa so that he or she would not use a specific strategy. A reliability analysis was used on the different blocks of stimuli for the sample of reading-disabled children. In both the words and pseudowords, the reliability was .97. 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 (Escribano, 1991).

The naming task started with a few practice items. During this phase, the latency time was not registered. Then the first stimulus appeared, setting in motion the chronometer, which stopped as soon as the participant emitted any vocal sound. After registering the latency time, the second item appeared on the screen. The sequencing in the administration of the stimuli was as follows: blank screen on the computer (200 ms), fixation point in the center of the screen (400 ms), and stimulus word or pseudoword. In total, the time between items was 2000 ms. This task was conducted in a single session. 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. 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), and a sample of 3000 words obtained from different texts of children's literature was used to select the words for this task. Word familiarity was measured using these authors' procedure of frequency estimation, which involved the separation of the 3000 words into different sets. For each set, different groups of 30 children were asked to rate 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 and colleagues (1990).

Naming speed task

The *naming speed* task is also included in the multimedia battery SICOLE-R and was adapted from Denckla and Rudel's (1976) rapid automatized naming task. The participant was required to name, as rapidly as possible, two series of graphological signs (i.e., letters and numbers) and two series of non-graphological signs (i.e., colors and common objects). Stimuli consisted in five basic colors, five common objects; five letters, and five one-digit numbers that were repeated 10 times on the card and distributed in 5 rows and 10 columns. The time for each task was taken as the dependent variable.

Homophone comprehension task

In the *homophone selection* task, the participant was presented with a picture, two homophone words,[1] and a spoken question (e.g., "What is an animal?"). The child needed to choose one of the written words. The correct response was the word that matched the picture and the question. There are 12 items on the homophone selection task, and the reliability coefficient was .76.

Speech perception test

The perceptive processing of speech was evaluated by the speech perception test (SPT) that is included in the multimedia battery SICOLE-R. The aim of the SPT is to evaluate the listener's ability to discriminate consonant contrasts in the context of syllables and word pairs. The stimuli–pair recordings were produced by a phonetically trained Spanish female speaker. The test includes 21 identical pairs, 22 pairs that are alike in all respects except in the place of articulation of the initial consonant, 8 pairs that differ only in the manner of articulation of the initial consonant, 6 pairs that are alike in all

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[1] Homophones are words that are spelled differently but have the same pronunciation.

respects except voicing, and 16 pairs that differ in two phonetic features. The interstimulus interval (ISI) is 1 s, and the intertrial interval is 5 s. On this test, the child needs to decide whether the two stimuli are the same or different and to push the left or right button mouse button, respectively. The accuracy responses were registered. The SPT has three tasks. In the *phonological word discrimination* task, the child listened to two words that had sound proximity and different meanings (e.g., /toro/–/loro/ [bull–parrot]). A total of 29 pairs of words presented. In the *syllabic phonological discrimination CV* task, a total of 26 pairs of syllables were presented (e.g., /pa/–/ba/). The *syllabic phonological discrimination CCV* task consisted of 18 items (e.g., /pra/–/tra/). The SPT displays strong reliability for accuracy (Cronbach's alpha = .91). To control for guessing rates, a derived score was calculated by subtracting the proportion of incorrect responses from the proportion of correct responses. This derived score was used in all accuracy analyses (range = 0–1).

Procedure

The procedure used in English studies for identifying dyslexic subtypes is based on pseudoword and irregular word reading (e.g., Castles & Coltheart, 1993; Manis et al., 1996; Stanovich et al., 1997). However, there are no irregular words in a transparent orthography such as Spanish because pronunciations can always be derived and obtained by the strict application of grapheme–phoneme correspondences rules. Other studies conducted in a transparent language such as German (Wimmer, 1996) suggest that dyslexics differ from normal readers not in pseudoword reading accuracy but rather in speed of processing. On the contrary, in opaque orthographies, a reading accuracy measure is sufficient to distinguish subtypes of dyslexic children. In an examination of other methods, Ruíz, Ansaldo, and Lecours (1994) recorded the reaction times (RTs) of both words and pseudowords and found in a patient (identified as "DC") that RTs were significantly higher than those of control participants, mainly for words. It was on this basis, and following Coltheart's (1978) assertion that lexical reading is faster and more efficient than nonlexical reading, that Ruiz and colleagues (1994) maintained that RTs can be used as another way of detecting surface dyslexia in Spanish speakers.

The most common procedure used to carry out the analysis of latency time is the voice key, but we used a more reliable method. The program Cool Edit Pro (Version 2) gives the spectral view and the waveform view of all words and pseudowords that were read by all participants. We extracted the sound that was recorded by the computer while the participant performed the naming task, and latency times and processing times were measured using this program, multitrack digital audio recorder, editor, and mixer for Windows XP. The latency time of each stimulus was registered from the moment the word or pseudoword appeared on the screen until the participant pronounced the first reading sound. The processing time was calculated by adding the time involved in reading the stimuli and the latency time. The wave display offers two ways to represent audio data: waveform view and spectral view. Waveform view displays audio data drawn as a series of positive and negative peaks. Spikes in the y axis indicate increased amplitude (measured in decibels), and the x axis (horizontal) represents time (measured in milliseconds). With this information, we were able to define the starting point and the ending of the pronunciation. Spectral view displays a waveform by its frequency components, where the x axis is frequency (measured in hertz) and the y axis is time (measured in milliseconds).

We used the regression-based procedure developed by Castles and Coltheart (1993). The dependent variable was the latency time and processing time for high-frequency words and pseudowords, controlling for the number of letters. That is, the latency time and processing time for each stimulus (word or pseudoword) was divided by the number of letters.

Results

Table 2 shows the means and standard deviations for the 40 reading-level controls, 47 normal readers matched in age, and 35 dyslexics in the naming task. The comparison between reading-disabled children and the normal readers matched in age and younger normal readers was compromised somewhat by the fact that the reading-disabled group had a lower VWM mean than the control

Table 2
Group means, standard deviations, and *t* values in word naming latency times (in ms/letter), pseudoword naming latency times (in ms/letter), word naming accuracy, pseudoword naming accuracy, word naming processing time, and pseudoword naming processing time by group.

	Group	*n*	Mean	*SD*	*t* Value	
					RL	CA
Word naming latency time	RL	39	.12	.03		
	CA	45	.10	.03	−1.29	
	RD	35	.20	.12	4.42***	5.82***
Pseudoword naming latency time	RL	39	.19	.04		
	CA	46	.16	.04	−1.90	
	RD	35	.25	.08	4.44***	6.45***
Word naming accuracy	RL	40	.97	.02		
	CA	47	.97	.03	0.21	
	RD	35	.90	.14	−3.62**	−3.96**
Pseudoword naming accuracy	RL	40	.87	.09		
	CA	47	.89	.07	1.14	
	RD	35	.72	.16	−5.58***	−6.88***
Word naming processing time	RL	40	.22	.05		
	CA	47	.19	.05	−1.47	
	RD	35	.30	.15	3.64**	5.20***
Pseudoword naming processing time	RL	38	.33	.05		
	CA	45	.28	.05	−4.05***	
	RD	34	.39	.07	3.62**	7.69***

Note. RL, reading-level-matched controls; CA, chronological-age-matched controls; RD, reading-disabled group.
** $p < .01$.
*** $p < .001$.

groups. To control for this difference, we wanted to carry out an analysis of covariance (ANCOVA) taking VWM as the covariate. However, our hierarchical regression analysis testing the homogeneity of regression assumption showed that this assumption was not met by the data. Therefore, we report analyses of variance (ANOVAs) rather than ANCOVAs below. An ANOVA for one factor (reading disabled vs. normal readers matched in age vs. younger normal readers) was conducted, and the latency time, processing time, and accuracy scores were calculated for word and pseudoword naming.

There were significant differences among all groups in word naming accuracy, Welch $F(2,65.72) = 4.17$, $p < .05$, $\eta^2 = .13$, pseudoword naming accuracy, Welch $F(2,67.74) = 16.74$, $p < .001$, $\eta^2 = .30$, word naming latency times, Welch $F(2,64.45) = 12.07$, $p < .001$, $\eta^2 = .24$, pseudoword naming latency times, Welch $F(2,69.24) = 15.55$, $p < .001$, $\eta^2 = .27$, word naming processing time, Welch $F(2,66.14) = 9.76$, $p < .001$, $\eta^2 = .19$, and pseudoword naming processing time, Welch $F(2,68.95) = 27.04$, $p < .001$, $\eta^2 = .34$. Planned contrasts revealed that the dyslexic group performed more poorly than the CA and RL control groups in word naming accuracy, pseudoword naming accuracy, word naming latency time, pseudoword naming latency time, word naming processing time, and pseudoword naming processing time. Finally, the RL group performed less well than the CA group in pseudoword naming processing time. These findings demonstrate that dyslexic children show a deficit in lexical access because they are slower than the RL control group in the word and pseudoword naming tasks. The finding of a dyslexic deficit in an age-matched peer group was consistent with that reported in other studies conducted in a consistent orthography, namely, Spanish (Jiménez, 1997; Jiménez & Hernández-Valle, 2000; Jiménez & Ramírez, 2002).

Identification of dyslexic subgroups using the regression method

In the current study, the same regression-based procedure introduced by Castles and Coltheart (1993) was employed using the same-age normal readers' performance criterion to identify subtypes of dyslexics. This analysis provided an estimate of how much the dyslexics' performance differed from that of same-age normal readers (Manis et al., 1996).

Latency times

In the current study, a statistically reliable linear relationship was obtained between pseudoword naming latency time and word naming latency time for the age-matched groups, $F(1,42) = 24.90$, $p < .001$, with 37% of the variance in one task accounted for by variation in the other task. For word naming latency time, the slope of the regression line was .45 and the intercept was .028. For pseudoword naming latency time, the slope was .82 and the intercept was .08. The residual variances provided estimates of the range of normal variation around the regression lines and were taken to determine the cutoff scores. Standard deviations of the residuals were .025 for familiar words and .033 for pseudowords. The soft subtype cutoff scores were defined by running a regression line with 90% confidence intervals through the Word Naming Latency Time × Pseudoword Naming Latency Time plot for the age-matched and reading-level-matched control groups. This regression line and confidence intervals were then superimposed on the scatterplot of the performance of the dyslexic sample. A surface dyslexic classification was made when a plot met two conditions: (a) an outlier resulted when word naming latency times were plotted against pseudoword naming latency times and (b) the point fell within the normal range when pseudoword naming latency times were plotted against word naming latency times. Phonological dyslexics were defined conversely. This procedure is consistent with Castles and Coltheart (1993), Calvo (1999), Jiménez and Ramírez (2002), Martínez (1995), Serrano (2005), and Stanovich and colleagues (1997), who also sed a 90% confidence interval. However, Manis and colleagues (1996) employed the 95% confidence interval. Recently, Genard and colleagues (1998) compared the effects of three different cutoff criteria on the relative proportions of children classified as dyslexic fitting either the surface or phonological profile. They showed that the relative proportions of dyslexics fitting either the phonological or surface profile did not change as a function of the cutoff criterion adopted (i.e., 1.00 or 1.96 standard deviation).

Fig. 1 illustrates the data from the sample of 35 fourth graders classified as dyslexic and plots word naming latency time against pseudoword naming latency time. The regression line and confidence intervals from the 47 age-matched controls are also shown. All four groups that are defined by conjoining these results with the converse plot (pseudoword naming latency time vs. word naming latency time) are indicated in Fig. 2. Here 45.7% were classified as surface dyslexic and 22.8% were classified as phonological dyslexic.

Processing time

To test whether we could find similar results using processing times, we repeated the same analysis. The dependent variable was the processing time to high-frequency words and pseudowords, controlling for the number of letters. That is, the processing time for each stimulus (word or pseudoword) was divided by the number of letters.

A statistically reliable linear relationship was obtained between pseudoword naming processing time and word naming processing time for the age-matched groups, $F(1,43) = 42.20$, $p < .001$, with 49% of the variance in one task accounted for by variation in the other task. For word naming processing time, the slope of the regression line was .59 and the intercept was .016. For pseudoword naming processing time, the slope was .83 and the intercept was .13. The residual variances provided estimates of the range of normal variation around the regression lines and were taken to determine the cutoff scores. Standard deviations of the residuals were .031 for familiar words and .037 for pseudowords. Here 34% were classified as surface dyslexic, 23% were classified as phonological dyslexic, and one child was classified as having a mixed profile. These percentages are similar to the results obtained with latency times.

Accuracy responses

We repeated the same analysis using accuracy scores as the dependent variable. A statistically reliable linear relationship was obtained between pseudoword naming accuracy and word naming accuracy for the age-matched groups, $F(1,43) = 11.80$, $p < .01$, with 19% of the variance in one task accounted for by variation in the other task. For word naming accuracy, the slope of the regression line

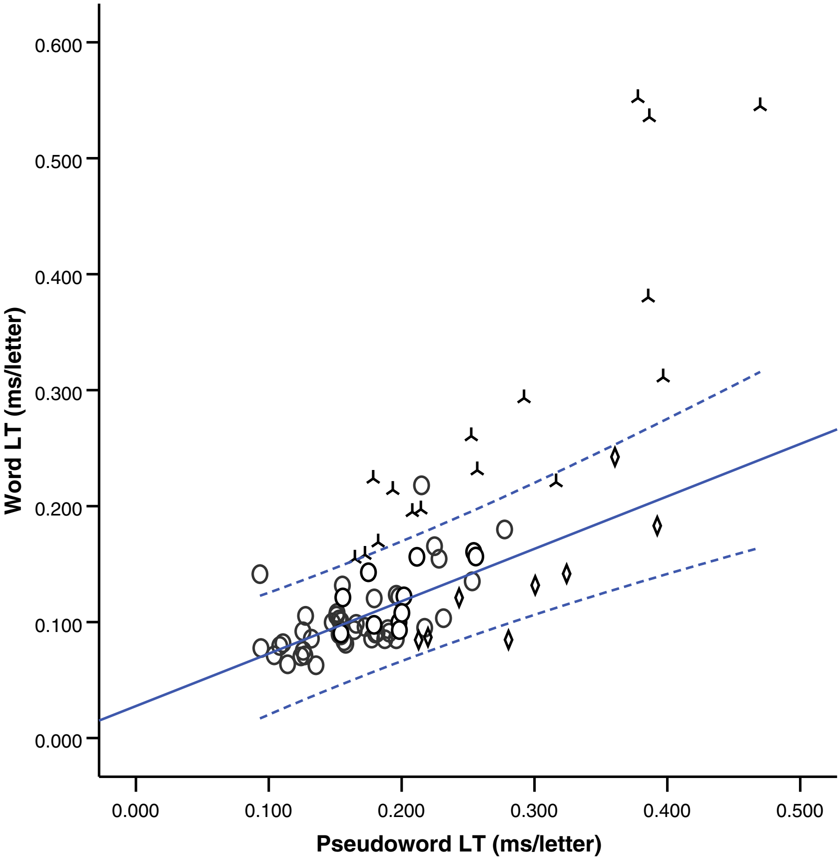

Fig. 1. Familiar word naming latency times (LTs) plotted against pseudoword naming LTs for reading-disabled children. The regression line and confidence intervals were derived from the data of the chronological-age-matched controls. ⅄, surface dyslexics; ○, chronological-age-matched controls; ◇, phonological dyslexics; □, reading-disabled children.

was .19 and the intercept was .81. For pseudoword naming accuracy, the slope was 1.01 and the intercept was –.183. The residual variances provided estimates of the range of normal variation around the regression lines and were taken to determine the cutoff scores. Standard deviations of the residuals were .028 for familiar words and .068 for pseudowords. Here 3% were classified as surface dyslexic, 3% were classified as phonological dyslexic, and the other 94% were classified within the confidence interval, that is, without difficulties. This means that accuracy scores are not appropriate for classifying dyslexic subtypes in a consistent orthography.

Before we analyzed the differences among all groups that were extracted from the regression analyses, we tested whether the groups were equivalent in VWM and IQ. There were significant differences in the distribution of the participants as a function of VWM, $F(3,107) = 4.97$, $p < .01$, but not IQ, Welch $F(3,25.11) = 1.96$, $p = .14$. Planned contrasts revealed that there were differences between PD and both control groups (CA and RL), $t(54) = -3.28$, $p < .01$, and $t(46) = 6.42$, $p < .001$, respectively. For this reason, we examined the influence of VWM and IQ and the goodness of their use for this type of analysis. In the case of VWM, it was not possible to control this variable because it was not fulfilling the criteria of the ANCOVA. Table 3 shows the means and standard deviations for the 40 reading-level controls, 47 normal readers matched in age, 8 phonological dyslexics, and 16 surface dyslexics in the naming task.

Analyzing latency times and processing times, there were significant differences among groups in word naming latency time, Welch $F(3,23.57) = 10.85$, $p < .001$, $\eta^2 = .51$, pseudoword naming latency time, Welch $F(3,24.22) = 13.26$, $p < .001$, $\eta^2 = .37$, word naming processing time, Welch

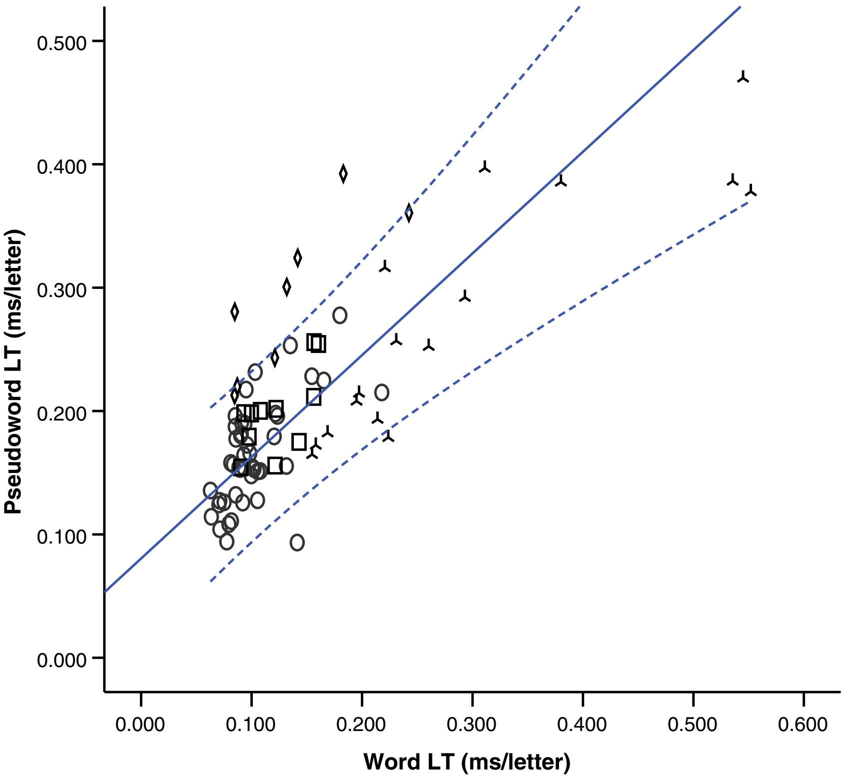

Fig. 2. Pseudoword naming latency times (LTs) plotted against familiar word naming LTs for reading-disabled children. The regression line and confidence intervals were derived from the data of the chronological-age-matched controls. ⅄, surface dyslexics; ○, chronological-age-matched controls; ◇, phonological dyslexics; □, reading-disabled children.

F(3,24.93) = 8.94, $p < .001$, $\eta^2 = .44$, pseudoword naming processing time, Welch *F*(3,23.83) = 17.68, $p < .001$, $\eta^2 = .40$, word naming accuracy, Welch *F*(3,22.83) = 3.27, $p < .05$, $\eta^2 = .22$, and pseudoword naming accuracy, Welch *F*(3,23.55) = 10.87, $p < .001$, $\eta^2 = .37$. Planned contrasts revealed that the SD group differed significantly from the RL, CA, and PD groups in word naming latency time and word naming processing time. This means that the SD group was slower than the other groups. The PD and SD groups differed significantly from the RL and CA groups on pseudoword naming latency time. Also, both the PD and SD groups were slower than the CA and RL control groups on pseudoword naming processing time. In addition, the RL group had a slower pseudoword naming processing time than the CA group. Similar to the results obtained in pseudoword naming latency time, there were no significant differences in pseudoword naming processing time between both dyslexic subtypes ($F < 1$).

With regard to accuracy measures, the SD group obtained lower scores in word naming accuracy than the CA and RL control groups. The PD and SD groups differed significantly from the CA and RL groups on pseudoword naming accuracy.

Comparison of dyslexic subgroups and reading-level-matched control group

This analysis informs whether the performance of this sample of fourth graders classified as dyslexic resembled that of younger children learning to read at a normal rate (Manis et al., 1996). As was the case with the age-matched group, word naming latency time and pseudoword naming latency time showed a strong linear relationship, *F*(1,36) = 18.70, $p < .001$, with 34% of the variance in one task accounted for by variation in the other task. For word naming latency time regressed against pseudoword naming latency time, the slope of the regression line was .76 and the intercept was .09. For

Table 3
Group means, standard deviations, and *t* values in word naming latency times (in ms/letter), pseudoword naming latency times (in ms/letter), word naming accuracy, pseudoword naming accuracy, word naming processing time, and pseudoword naming processing time by group.

	Group	*n*	Mean	*SD*	*t* Value		
					RL	CA	SD
Word naming latency time	RL	39	.12	.03			
	CA	45	.10	.03	−1.54		
	SD	16	.29	.13	8.84***	10.18***	
	PD	8	.13	.05	0.40	1.28	−5.71***
Pseudoword naming latency time	RL	39	.19	.04			
	CA	46	.16	.04	−1.96		
	SD	16	.27	.09	4.84***	6.42***	
	PD	8	.29	.06	4.30**	5.47***	0.54
Word naming accuracy	RL	40	.97	.03			
	CA	47	.98	.03	0.21		
	SD	16	.87	.18	−4.46***	−4.71***	
	PD	8	.89	.11	−2.71	−2.86	0.62
Pseudoword naming accuracy	RL	40	.87	.09			
	CA	47	.90	.08	1.21		
	SD	16	.69	.16	−5.83***	−6.86***	
	PD	8	.70	.17	−4.13**	−4.86***	0.29
Word naming processing time	RL	40	.22	.05			
	CA	47	.19	.05	−1.70		
	SD	16	.40	.17	7.64***	9.07***	
	PD	8	.21	.05	−0.014	0.82	−5.34***
Pseudoword naming processingtime	RL	38	.33	.05			
	CA	45	.28	.05	−4.10**		
	SD	15	.40	.08	3.69**	6.80***	
	PD	8	.42	.07	3.56**	5.96***	0.59

Note. RL, reading-level-matched controls; CA, chronological-age-matched controls; SD, surface dyslexics; PD, phonological dyslexics.
** $p < .01$.
*** $p < .001$.

pseudoword naming latency time regressed against word naming latency time, the slope was .44 and the intercept was .03. Standard deviations of the residuals were .03 for word naming latency time scores and .04 for pseudoword naming latency time.

Fig. 3 illustrates the data from the sample of 35 fourth graders classified as dyslexic and plots word naming latency time against pseudoword naming latency time. The regression line and confidence intervals from the 40 younger average readers are also shown. All four groups that are defined by conjoining these results with the converse plot (pseudoword naming latency time vs. word naming latency time) are indicated in Fig. 4.

Overall, 5 of the 16 plots associated with surface dyslexics and identified in the regression analysis for the age-matched group fell below the confidence limit for the reading-level-matched control group. In contrast, the 8 plots identified as corresponding to phonological dyslexics were identical to those identified from the age-matched group's regression lines, but 4 new children were classified as well. Therefore, a total of 12 dyslexics were classified by this procedure.

Cognitive profile

Table 4 shows means and standard deviations in phonological awareness, naming speed, speech perception, and homophone comprehension for each group.

Phonological awareness

Phonological dyslexics should perform more poorly on the phonological awareness tasks than younger normal readers, and this would support a specific deficit in phonological processing, whereas

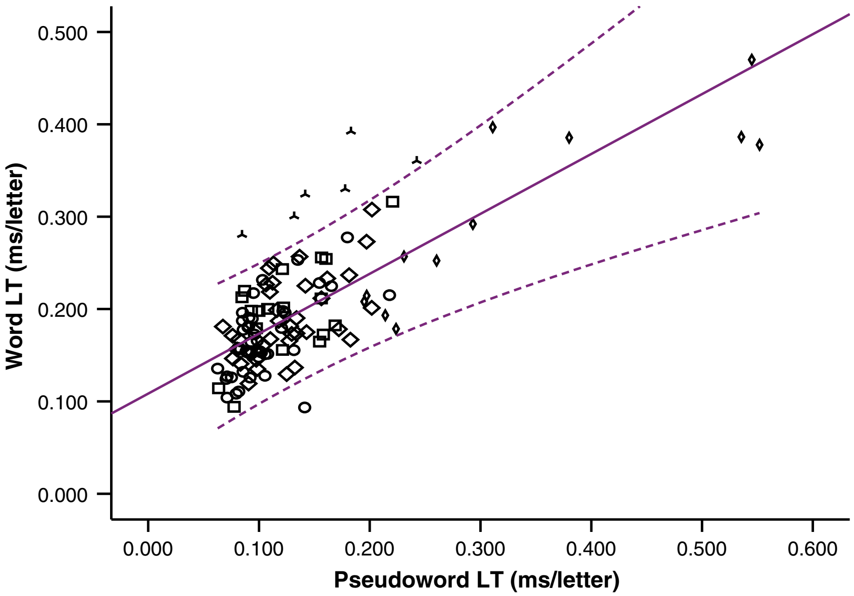

Fig. 3. Familiar word naming latency times (LTs) plotted against pseudoword naming LTs for reading-disabled children. The regression line and confidence intervals were derived from the data of the reading-level controls. ⅄, surface dyslexics; ◇, reading-level-matched controls; ○, chronological-age-matched controls; ◊, phonological dyslexics; □, reading-disabled children.

there should not be differences between surface dyslexics and younger normal readers on the phonological awareness tasks. ANOVAs for one factor (CA vs. RL vs. PD vs. SD) were conducted using the number of correct responses as a dependent variable. The ANOVA on the PCF test was statistically significant, Welch $F(3,22.04) = 14.20$, $p < .001$, $\eta^2 = .46$. A multiple comparisons test indicated that the PD and SD groups scored significantly lower than the RL and CA groups.

Naming speed

The ANOVA on naming speed revealed statistically significant differences, Welch $F(3,24.55) = 18.40$, $p < .001$, $\eta^2 = .34$. Planned contrasts revealed that the CA group was significantly faster than the RL, PD, and SD groups.

Speech perception

The ANOVA on speech perception revealed similar results given that there was a statistically significant difference, Welch $F(3,22.56) = 32.90$, $p < .001$, $\eta^2 = .51$. Planned contrasts revealed that the CA group performed significantly better than the RL, SD, and PD groups.

Homophone comprehension

In this task, the ANOVA revealed a statistically significant difference, Welch $F(3,21.69) = 17.60$, $p < .001$, $\eta^2 = .45$. Planned contrasts revealed that the CA group performed significantly better than the RL, SD, and PD groups. Also, the RL group performed better than the SD group.

Parent Interview Response

Table 5 shows the means and standard deviations for each group of parents in the Parent Help Scale, Parent Education Scale, and Parent Work Scale.

Parent Help Scale. The ANOVA revealed a statistically significant difference, $F(3,97) = 4.75$, $p < .01$, $\eta^2 = .13$. Planned contrasts revealed that there were significant differences between the group of

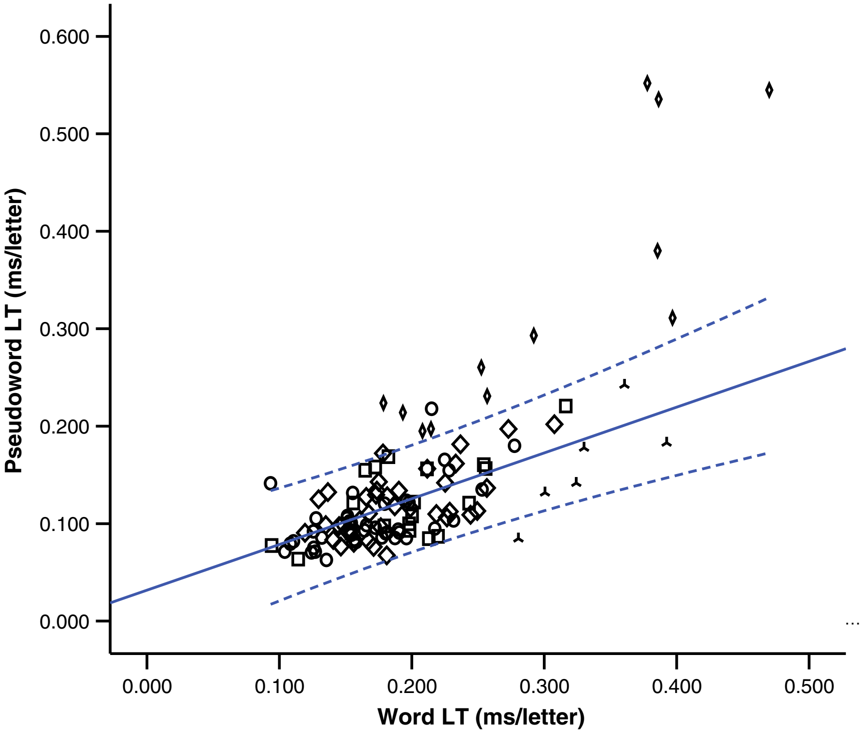

Fig. 4. Pseudoword naming latency times (LTs) plotted against familiar word naming LTs for reading-disabled children. The regression line and confidence intervals were derived from the data of the reading-level controls. ⅄, surface dyslexics; ◇, reading-level-matched controls; ○, chronological-age-matched controls; ◊, phonological dyslexics; □, reading-disabled children.

parents with children matched in reading age in comparison with children with reading disabilities and the group of parents with children with a profile of surface dyslexia, $t(48) = 3.50$, $p < .05$. This means that environmental support for literacy was greater in younger normal readers' parents than in surface dyslexic children's parents.

Parent Education Scale. There were no significant differences between groups in men, $\chi^2(3 = 6.05$, $p = .109$, but there were significant differences in women, $\chi^2(3) = 12.53$, $p < .01$. Mann–Whitney planned contrasts revealed that the differences were between the group of parents with children matched in age with children with reading disabilities and the group of parents with children with a profile of surface dyslexia, $U = 152.50$, $r = -3.01$, $p < .05$, and between the group of parents with children matched in reading age in comparison with children with reading disabilities and the group of parents with children with a profile of surface dyslexia, $U = 156.50$, $r = -2.33$, $p < .05$. This means that surface dyslexic children's mothers had lower academic education than younger normal readers' mothers.

Parent Work Scale. There were no significant differences between groups' parents in parent work, $\chi^2(3) = 3.16$, $p = .95$, or between groups' mothers, $H(3) = 3.54$, $p = .31$.

Discussion

Our findings are in accordance with the hypothesis of granularity and transparency (Wydell & Butterworth, 1999) because the incidence rate of phonological dyslexia found in Spanish studies is lower than that found in English studies. This is coincident with previous studies conducted in

Table 4
Group means, standard deviations, and *t* values in phonological awareness, naming speed, speech perception, and homophone comprehension by group.

	Group	*n*	Mean	*SD*	*t* Value		
					RL	CA	SD
Phonological awareness	RL	33	.80	.10			
	CA	37	.85	.09	1.74		
	SD	13	.55	.18	-6.18^{***}	-7.57^{***}	
	PD	8	.59	.17	-4.25^{**}	-5.36^{***}	0.78
Naming speed	RL	40	39.45	6.75			
	CA	46	30.69	5.53	5.89^{***}		
	SD	16	42.93	9.78	1.71	6.13^{***}	
	PD	8	39.58	7.79	0.05	3.37^{*}	−1.13
Speech perception	RL	33	.78	.10			
	CA	45	.94	.06	6.76^{***}		
	SD	14	.67	.17	−3.44	-8.65^{***}	
	PD	8	.72	.10	−1.35	-5.42^{***}	1.28
Homophone comprehension	RL	34	.80	.13			
	CA	38	.92	.08	3.55^{*}		
	SD	13	.56	.20	-5.49^{***}	-8.18^{***}	
	PD	8	.69	.18	−2.17	-4.35^{*}	2.08

Note. RL, reading-level-matched controls; CA, chronological-age-matched controls; SD, surface dyslexics; PD, phonological dyslexics.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 5
Means and standard deviations in Parent Help Scale by group.

	Mean	*SD*
RLP	1.68	0.60
CAP	1.49	0.54
SDP	1.09	0.46
PDP	1.20	0.46

Note. RLP, reading-level-matched controls' parents; CAP, chronological-age-matched controls' parents; SDP, surface dyslexics' parents; PDP, phonological dyslexics' parents.

orthographies with fine granularity and transparent print-to-sound translation (e.g., in Spanish: Jiménez & Ramírez, 2002; in French: Genard et al., 1998; Ziegler et al., 2008). A comparison of these results with those reported in the English studies indicated that the percentages of dyslexic subtypes in Spanish and English are quite different. In the current study, 45.7% of the respondents were classified as surface dyslexics and 22.8% were classified as phonological dyslexics. These results are coincident with those of Genard and colleagues (1998) (56 vs. 4%), Jiménez and Ramírez (2002) (53 vs. 18%), and Ziegler and colleagues (2008) (29 vs. 19%). However, the opposite pattern was found in English studies by Castles and Coltheart (1993) (30 vs. 55%), Manis and colleagues (1996) (30 vs. 33%), and Stanovich and colleagues (1997) (22 vs. 25%).

Developmental phonological dyslexia is apparently less common in Spanish than in English, and these findings suggest that the specific orthographic characteristics of alphabetic languages could explain the differences found in the studies in English and Spanish. The simplicity of the phonological structure of Spanish and the shallowness of its orthography should foster phonological processing in early reading. In fact, a number of studies carried out in relatively consistent writing systems have reported high accuracy scores for recoding words and nonwords toward the end of first grade (Ziegler & Goswami, 2005). So, for instance, Signorini (1997) reported that word reading strategies from Spanish-speaking children displayed a tendency to use a phonological recoding mechanism in word reading.

With regard to surface dyslexia, our research revealed a greater proportion of surface dyslexics, as compared with phonological dyslexics, than has been observed by English studies. An alternative interpretation of why there are so few cases of developmental surface dyslexia in an opaque orthography when participants are matched on reading age has to do with how participants were matched. McDougall, Borowsky, MacKinnon, and Hymel (2005) argued that we should not be surprised that cases of surface dyslexia are reduced when participants are matched on the basis of real word reading performance. They reported that this matching bias could have influenced Manis and colleagues' (1996) and Stanovich and colleagues' (1997) findings regarding the nature of surface dyslexia. However, in the current study, reading-level control participants were matched to the dyslexics on the basis of their real word reading performance. Also, in the French language, Genard and colleagues (1998) and Ziegler and colleagues (2008) found that there were many more surface dyslexics in their studies than in the studies conducted examining English-speaking children.

On the other hand, we investigated whether the surface and phonological dyslexics could be distinguished in terms of their underlying cognitive deficits. 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; Samuelson, Finnström, Leijon, & Mard, 2000; Stanovich et al., 1997). Phonological dyslexia reflects developmental deviancy, whereas surface dyslexia resembles a form of developmental delay. Stanovich and colleagues (1997) pointed out that "surface dyslexia may arise from a milder form of phonological deficit than that of the phonological dyslexic, but one conjoined with exceptionally inadequate reading experience" (p. 123). In the current study, both dyslexic subtypes showed a deficit in phonological awareness, but children with surface dyslexia also showed a deficit in orthographical processing assessed by the 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 with parents with children with surface dyslexia, reported more literacy home experiences. In fact, differences in the degree of print exposure have been suggested as one potential environmental determinant of the orthographic processing ability that determines reading skills (Olson et al., 1989). In the French language, Sprenger-Charolles, Colé, Lacert, and Serniclaes (2002) found specific deficits in phonemic awareness and phonological short-term memory for both phonological dyslexics and surface dyslexics. More recently, Ziegler and colleagues (2008) found a picture of surface dyslexia different from the one commonly suggested in the literature because surface dyslexics in their study showed small impairments in orthographic access, but the main deficits of surface dyslexics were phonological in nature. Even in the English language, when a process dissociation method of estimating reliance on sight vocabulary and phonetic decoding has been used instead of a regression-based approach, developmental surface dyslexia is not simply a delayed reading deficit (McDougall et al., 2005).

In conclusion, according to the hypothesis of granularity and transparency, we found that the incidence rate of phonological dyslexia in Spanish was low. In addition, we identified two domains in which surface dyslexics significantly differed from phonological dyslexics when both groups were compared with the reading-level-matched control group. Both dyslexic subtypes showed a deficit in phonological awareness, but children with surface dyslexia also showed a deficit in orthographical processing assessed by the homophone comprehension task. Furthermore, this deficit was associated with poor home literacy experiences, with the group of parents with children matched in reading age, in comparison with the group of parents with children with surface dyslexia, reporting more literacy home experiences.

Acknowledgement

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Appendix A. Parent questionnaire

The Parent Help Scale was a composite of the following questions:

How often do you buy newspapers or journals?
How often do you buy books, literature, or stories?
How often do you encourage your children to read at home?
How often do you go with your children to visit the library?
How often do you visit the section of books at the department stores?
How often do you visit expositions, trades, or cultural centers with your children?
How often do you read with your children encyclopedias, books, or information on the Internet?
How often do your children write letters, stories, or personal newspapers?

The Parent Education Scale was a composite of these questions:
What is the grade or year of school the father has completed?
What is the grade or year of school the mother has completed?

No studies
Elementary grade certification
Secondary School diploma
High school
Undergraduate
Master's degree

The Parent Work Scale included the following categories:

Private company
Official of the state or community
Eventual
Self-employed (autonomous)
Unemployed with unemployment benefits
Unemployed without unemployment benefits
Pensioner
Work at home (not rewarded)
Basic help basic (subsidies, coupons, etc.)

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