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Reading difficulties in Spanish adults with dyslexia

Paz Suárez-Coalla · Fernando Cuetos

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Abstract Recent studies show that dyslexia persists into adulthood, even in highly educated and well-read people. The main characteristic that adults with dyslexia present is a low speed when reading. In Spanish, a shallow orthographic system, no studies about adults with dyslexia are available; and it is possible that the consistency of the orthographic system favours the reading fluency. The aim of this study was to get an insight of the reading characteristics of Spanish adults with dyslexia and also to infer the reading strategies that they are using. For that purpose, a group of 30 dyslexics (*M* age=32 years old) and an age-matched group of 30 adults without reading disabilities completed several phonological and reading tasks: phonological awareness tasks, rapid automatic naming, lexical decision, word and pseudoword reading, letter detection and text reading. The results showed that highly educated Spanish dyslexics performed significantly worse than the control group in the majority of the tasks. Specifically, they showed difficulties reading long pseudowords, indicating problems in automating the grapheme–phoneme rules, but they also seem to present difficulties reading words, which indicate problems with the lexical route. It seems that the Spanish dyslexic adults, as in deep orthographies, continue having difficulties in phonological awareness tasks, rapid naming and reading.

Keywords Dyslexic adults · Reading strategies · Spanish language · Transparent orthographies

Introduction

It is well documented that children with dyslexia make more errors reading words and have longer latencies than children with normal development (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Korne, 2003). Specifically, they have difficulties reading long low-frequency words and long pseudowords (Davies, Cuetos, & González-Seijas, 2007; Grainger, Bouttevin, Truc, Bastien, & Ziegler, 2003; Rack, Snowling, & Olson, 1992; Zoccolotti et al., 2005), indicating that they are less skilled in the use of the sub-lexical route, according to the dual-route cascaded model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). This is perhaps due to problems with learning and automating the alphabetic code (Schneider & Chein, 2003). Thus, as a consequence, they also show more difficulties than typical readers when reading words (Manis, 1985; Reitsma, 1983; Suárez-Coalla, Ramos, Álvarez-Cañizo, & Cuetos, 2014).

P. Suárez-Coalla (✉) · F. Cuetos
Department of Psychology, Universidad de Oviedo, Pza Feijoo s/n, 33003 Oviedo, Asturias, Spain
e-mail: suarezpaz@uniovi.es

Slowed reading could be the result of the following: difficulties in achieving orthographic representations, slower activation of phonological representations or sluggishness in grapheme to phoneme conversion through the sub-lexical route.

But, what happens to these children when they become adults? Do people with dyslexia, at some point in their lives, overcome these reading difficulties and match people with normal development with regard to reading? The majority of studies seem to indicate that dyslexia persists into adulthood, even in adults with higher education and reading experience (Bruck, 1990; Snowling, Muter, & Carroll, 2007; Undheim, 2009). Additionally, the hallmark appears to be reading slowness (Bruck, 1990, 1992; Hatcher, Snowling, & Griffiths, 2002; Nergård-Nilssen & Hulme, 2014; Parrila, Georgiou, & Corkett, 2007; Shaywitz et al., 1999; see Swanson & Hsieh, 2009 for a review). In particular, people with dyslexia were found to have poor fluency when reading pseudowords, suggesting difficulty with the alphabetic code, i.e. to recover the sound of graphemes, similar to children with dyslexia (Hanley, 1997; Parrila et al., 2007; Pennington, Van Orden, Smith, Green, & Haith, 1990; Snowling et al., 2007). However, speed problems with real words have also been reported (Bruck, 1990; Nergård-Nilssen & Hulme, 2014). Thus, one possibility is that adults with dyslexia continue to have a deficit in word recognition and parallel processing of graphemes (Ben-Dror, Pollatsek, & Scarpati, 1991; Booth, Perfetti, McWhinney, & Hunt, 2000; Hanley, 1997; Shany & Breznitz, 2011; Taroyan & Nicolson, 2009). Moreover, they do not appear to benefit from context because they are also slower at reading texts (Szenkovits & Ramus, 2005; Tops, Callens, Lammertyn, Van Hees, & Brysbaert, 2012).

In addition, people with dyslexia also demonstrate poor performance in phonological tasks and rapid naming (Bogdanowicz, Lockiewicz, Bogdanowicz, & Pachalska, 2014; Hatcher et al., 2002; Swanson & Hsieh, 2009), as repeatedly shown in the literature on developmental dyslexia (Snowling, Bishop, & Stothard, 2000; Stanovich & Siegel, 1994; Swan & Goswami, 1997), supporting the existence of impairment in the phonological processing of words.

Many of these studies concerning dyslexia in adults were carried out in English; however, it is widely recognised that reading difficulties depend on the orthographic depth. Otherwise, orthographic inconsistency has a negative impact on dyslexic symptoms (Caravolas, Lervag, Defior, Seidlova Malkova, & Hulme, 2013; Landerl et al., 2013; Seymour, Aro, & Erskine, 2003; Ziegler et al., 2010). Regular orthographies enable successful decoding, resulting in a high percentage of reading accuracy, while speed problems remain in people with dyslexia. As a consequence, language differences can prevent the generalisation of results, and thus, it is necessary to conduct studies in different orthographic systems. Callens, Tops, & Brysbaert (2012) stated that 'there is a need for scientific evidence about the cognitive profile of students with dyslexia in higher education, particularly for non-English speaking countries' (p. 1). As a result, recently, the interest in adults with dyslexia has increased considerably.

Therefore, recent studies, conducted in several languages with an orthographic system more transparent than English (e.g. Polish, Dutch, Swedish, Finnish, Norwegian, Italian, Hebrew), have attempted to describe the reading and cognitive characteristics of adults with a history of reading difficulties. The principal characteristic reported was the reading slowness, especially for pseudowords. In Polish, Reid et al., (2006) found that 15 undergraduate students showed inferior word, pseudoword and text reading rate than controls; similar results were reported in a study with 24 Italian students with dyslexia (Re, Tressoldi, Cornoldi, & Lucangeli, 2011). Re et al. (2011), using a new Battery for the Assessment of Reading and Writing in Adulthood (BRWA), confirmed the powerful discriminatory power of reading speed, because students with early dyslexia diagnosis were dramatically slower than the control group decoding texts, words and non-words, despite having good understanding. In Swedish (Wolff, 2009) and Norwegian (Nergård-Nilssen & Hulme, 2014), it has also been reported that problems with pseudoword decoding were the principle characteristic of adults with dyslexia.

On the other hand, two recent studies in Dutch with a large number of participants were published (Callens et al., 2012; Tops et al., 2012). Callens et al. (2012) examined the possibility of generalising the findings found in English by Hatcher et al. (2002) to Dutch, a more transparent language. They found that, like English dyslexic adults, Dutch adults with dyslexia scored lower on the phonological tasks, reversal test and spoonerisms as well as rapid naming of letters, digits and colours. Curiously, Dutch adults with dyslexia made more mistakes in word than in pseudoword reading, but perhaps due to the orthographic inconsistency in some words. However, the principal deficiency, as in English, was a greater slowness in reading. Based on these results, they concluded that the profile of Dutch adults with dyslexia was very similar to those found in the English language.

Finally, several studies with Hebrew-speaking adults with dyslexia were carried out with interesting findings (Beidas, Khateb, & Breznitz, 2013; Breznitz & Misra, 2003; Meyler & Breznitz, 2003). Meyler and Breznitz (2003) posited that phonological and orthographic representations are essential for reading, and they explored the ability of adults with dyslexia to process these representations. The results of this study suggested that high-functioning adult readers with dyslexia could show impairment in processing the phonological and orthographic representations of words. According to previous studies, they found that reading accuracy was not a good discriminator of dyslexia among adults, as word recognition improves in adulthood, but reading speed remains slower in this population (as reported before). But, more interestingly, adults with dyslexia demonstrated slow processing speed for phonological, orthographic and cross-modal representations of words. These results support the idea that adults with dyslexia present impairment in both phonological and orthographic representations of words. In addition, Breznitz and Misra (2003) considered that there is an asynchrony in speed of processing (SOP) between orthographic and phonological modalities, which probably contributes to a word recognition deficit. Thus, in accordance with previous studies, it is possible that adults with dyslexia reach a normal and accurate orthographic identification (whole-word), but activation of the orthographic systems is not automatic; in other words, they do not achieve normal word recognition speed and fail to integrate phonological and orthographic codes despite years of practice (Meyler & Breznitz, 2003; Miller-Shaul, 2005; Shany & Breznitz, 2011).

In the Spanish language, a shallow orthographic system, some studies have reported that children with dyslexia have problems achieving an acceptable level of reading speed, with reading strongly affected by length of stimuli, but with a considerable level of reading accuracy (Davies et al., 2007; Suárez-Coalla & Cuetos, 2012). This suggests that Spanish children with dyslexia use a sub-lexical strategy to read; however, problems in storing orthographic representations of words after repeated readings were also described in children with dyslexia (Suárez-Coalla et al., 2014). Therefore, we were interested in identifying the key features of dyslexia among Spanish adults.

In the absence of available data regarding adults with dyslexia, in this study, we tried to examine this subject. A group of adults reporting persistent problems with reading and a high level of education (in this case, we can assume that reading difficulties are not caused by low exposure to reading) was compared with a group of typical readers in different tasks. The aim was to explore their reading characteristics and to examine if these were similar to previous studies concerning dyslexia. In particular, we were interested in knowing if reading slowness persists in Spanish adults with dyslexia, as described in other languages, including the reading characteristics and strategies used by them, and if the phonological problems continue to be present in adulthood.

Method

Participants

Thirty adults with dyslexia (ten males; *M* age=32.23, SD=11.83) and 30 controls (ten males, *M* age=32.67, SD=12.77) matched by age, gender, socio-economic status and education level (all of them had post-secondary education or a university degree; *M* for dyslexics=15.63 years of academic education, SD=2.28; and *M* for controls=15.43 years of academic education, SD=2.20) were tested (Table 1). Differences between groups were not significant for age (t (58)=−0.136; p= 0.892) or for years of academic education (t (58)=0.345; p= 0.731). None of the participants had a history of brain injuries or neurological problems, and all were native speakers of Spanish, with normal hearing and normal or corrected-to-normal vision.

Fifteen adults were diagnosed with dyslexia during childhood; however, in the remaining cases, in order to consider a person as dyslexic, a detailed questionnaire was performed before inclusion in the dyslexic group. The questionnaire (following Giménez, Luque, López-Zamora, & Fernández-Navas, 2015; Leinonen, Müller, Leppänen, Aro, Ahonen, & Lyytinen, 2001) dealt with demographic information, history of reading and writing difficulties during childhood and adulthood, any relatives with the same problem and assistance with language therapy. All of them reported difficulties in completing exams within the same time period as their peers; they also described a lot of spelling mistakes, difficulties in finishing homework because of reading and writing speed and frequent extra tasks to help overcome their problems (it should be noted that for years in Spain, little was known about dyslexia, and many people were undiagnosed, so specific therapy was not common practice). Many of them had relatives who exhibited the same problems and who were diagnosed with dyslexia. On the contrary, people who reported minor difficulties in learning to read during the early years of school were excluded from the study. It should be specified that 20 people (of the initial sample of 50) were excluded from the study for not meeting the criteria for inclusion (no early diagnosis of dyslexia and no persistent reading difficulties).

The participants in this study (both dyslexics and controls) were volunteers (some university students), collaborating with the Psychology Department of Oviedo in research about reading and dyslexia. To recruit volunteers, information about this research was distributed through the local newspapers and through the diary of the University of Oviedo (DUO).

With the aim of confirming the diagnosis of dyslexia and validating the allocation to the experimental and control group, different tests were utilised: test of general ability (WAIS-R, 1981) and test of reading processes (Ramos & Cuetos, 2005). The reading battery included some tasks to evaluate lexical, syntactic and semantic processes. For lexical and sub-lexical processes, two tasks were used: reading aloud a list of 40 words, varying in length, frequency

Table 1 Distribution of participants by group, age and gender

Group	Gender	Age 18–25	26–40	41–55	Total
Dyslexics	Male	6	2	3	11
	Female	6	8	5	19
Controls	Male	6	2	3	11
	Female	6	8	5	19
Total		24	20	16	60

and syllabic structure, and a list of 40 pseudowords. Reading accuracy and reading speed for words and pseudowords were collected.

Although no normative criteria exist for Spanish-speaking adults with dyslexia, after applying the tests, we could confirm a reading deficit, as they were below average. All participants from the dyslexic group were 1.5 to 2 SD below average on reading speed of pseudowords. But, considering speed and accuracy (words and pseudowords), we could classify people with dyslexia in the following way: 63.3 % were rate-and-accuracy disabled (they demonstrated problems with speed and accuracy, 1.5 or 2 SD below average), 13.3 % accuracy disabled (they showed problems with accuracy, 1.5 or 2 SD below average; reading speed was about average for the words, but not for pseudowords) and 23.3 % rate disabled (they showed problems with speed, but accuracy was about average).

Furthermore, we confirmed significant differences between dyslexics and controls in reading measures (see Table 2), but we did not find significant differences between participants with and without diagnosis of dyslexia during childhood. Finally, considering the wide age range, it must be highlighted that no correlation was found between age and reading level; thus, age was not the reason for a low reading level.

This study was approved by the Ethics Committee of the Psychology Department of the University of Oviedo. Before starting the experimental tasks, all of the participants received pertinent information about the purpose of the study, types of tasks and their duration. Then, written informed consent was received from the participants.

Experimental tasks: materials and procedure

Different experimental tasks were carried out. First, tasks were aimed at reading-related skills such as phonological awareness and rapid automatic naming. In addition, tasks to explore reading skills included the following: lexical decision task (testing the ability to recognise real words, i.e.

Table 2 Demographic characteristics, reading and IQ scores of the adult participants (means and standard deviations)

	Controls (n=30)	Dyslexics (n=30)	p value
Age	32.67 (12.77)	32.23 (11.83)	n.s.
Education (years)	15.43 (2.2)	15.63 (2.28)	n.s.
Words			
Accuracy (out of 40)	39.87 (0.35)	38.87 (1.16)	<0.001
Speed (s)	23.63 (5.98)	33.88 (9.11)	<0.001
Pseudowords			
Accuracy (out of 40)	38.8 (2.11)	34.87 (2.91)	<0.001
Speed (s)	36.33 (7.80)	59.32 (13.62)	<0.001
Syntactic comprehension (out of 24)	23.1 (0.94)	21.93 (1.99)	<0.05
Punctuation (out of 24)	23.83 (0.46)	22.00 (2.85)	<0.001
Speed of text (s)	101.57 (14.72)	136.30 (26.01)	<0.001
Words by min	194.53 (31.13)	142.00 (27.99)	<0.001
Text comprehension (out of 20)	15.70 (4.14)	13.30 (2.41)	<0.05
IQ			
Verbal	108 (8.5)	113 (5.1)	<0.05
Performance	124 (9.1)	128 (5.9)	n.s.

to process orthographic representations), word and pseudoword reading (examining the influence of frequency, length and lexicality in reading and deducing the reading strategy that they were using), letter detection task (exploring if they used a serial strategy when looking for a letter within a word) and reading aloud a text (examining reading difficulties in context).

Tasks of reading-related skills

– *Phonological awareness tasks*. This task consisted of eight different subtasks.

- *Syllable reversal*. The task included 12 words with five to nine letters and two to four syllables. The stimuli were presented orally by the examiner, and the participants were asked to reverse the syllables and pronounce the resultant stimuli (e.g. Tigre–greti).
- *Phoneme reversal*. The task included 12 monosyllabic words (three letters). The stimuli were presented by the examiner, and the participants had to reverse the phonemes of the word and pronounce the result (e.g. Don–nod).
- *Initial phoneme deletion*. The test consisted of 12 words, four to eight letters and two to three syllables. In this case, the participants had to remove the initial phoneme and repeat the new word, after deleting the sound (e.g. Lazo–azo).
- *Spoonerism (exchange of initial phonemes)*. The task consisted of 12 pairs of words. The examiner pronounced two words (a couple of words), and the participants were asked to identify the initial phoneme of the words and exchange the phonemes. Thus, two new words or pseudowords were obtained (e.g. Perro–viejo: verro–piejo).
- *Oral spelling*. Twelve words were presented orally. The words were 4 to 12 letters and two to five syllables. The task required participants to name the letters of the words (e.g. luna: "l", "u", "n", "a").
- *Number of phonemes in a word* (*phonemes counting*). Twelve words were used, with two to four syllables and four to ten letters. The participants had to count the number of phonemes in a word (e.g. rico: four phonemes).
- *Pseudowords repetition*. This task was used to evaluate phonological memory. The participants had to listen carefully to pseudowords and repeat them as clearly as possible. The pseudowords were 4 to 15 letters and two to five syllables (e.g. mafrinegas).
- *Digits span test* (*verbal short-term memory*). In this test, the participant was required to listen to a series of numbers from the examiner and then repeat them back in the same order. The first series consisted of three numbers, such as '3 9 2'. Each number was said in a monotone voice, 1 s apart. If the participant correctly repeated the numbers, the next series, consisting of four numbers such as '4 7 3 1', was presented and so on. The participant continued until reaching a series of numbers that he or she could not repeat. We also used the digit span test backward where the participant had to repeat the numbers backward, i.e. by starting with the last number and going backward to the first number. In this subtest, we scored the number of repeated digits in stated order, plus the number of digits repeated in reverse order.

– *Rapid automatic naming task* (*RAN*). RAN is a classic task to assess and evaluate naming speed, because according the double-deficit hypothesis, people with dyslexia have problems recovering the phonological label of stimuli with fluency. This task included the following: RAN—colours, RAN—digits, RAN—letters and RAN—objects.

- *RAN—colours*. In this task the participants had to recover and pronounce, as quickly as possible, the names of six colours (black, green, blue, red, brown and yellow). The colours were arranged semi-randomly in four rows, nine colours per row (36 total colours to name) and were presented on a computer screen. Before starting with the trial, the participants had the opportunity to name the colours in a practice trial, to familiarise themselves with the task and avoid possible problems with colour perception. The examiner scored the number of errors and the time to name the stimuli.

- *RAN—digits*. In this case, digits instead of colours were used (2, 7, 4, 5, 3, 8). The presentation of the stimuli was the same as for colours, i.e. 36 total digits to name, arranged in four rows, and a practice trial was conducted prior to the beginning of the timed naming. Accuracy and speed were scored.
- *RAN—letters*. The RAN—letters consisted of six letters (b, c, i, t, a, g), presented in four rows (nine per row, 36 total letters to name), using a computer. The participants were asked to name the letters as quickly as possible. Accuracy and speed were scored.
- *RAN—objects*. Finally, a set of pictures of objects (car, star, pencil, chair, umbrella, key) was used. Similarly, the pictures were presented on a computer, in four rows with nine pictures each.

Tasks of reading skills

– *Lexical decision task*. In this task, the participants had to recognise and decide if a visually presented letter sequence constituted a real word. A total of 80 stimuli were presented. Forty stimuli were words (20 short and 20 long, half high frequency and half low frequency), and 40 were pseudowords (20 short and 20 long), considered as fillers. For the short stimuli, the mean length was 4.6 (SD=0.66, 4–6 letters) and for the long stimuli was 8.9 (SD=1.1, 7–11 letters). Regarding the frequency values of words, the mean for the high-frequency words was 55.8 (SD=9.8) and for the low-frequency words 2.1 (SD=0.58). The frequency values and length were obtained from the database of Pérez, Alameda and Cuetos (2003). The pseudowords were constructed from a base word by changing one letter. To answer, the participants pressed, as quickly as possible, a key on the computer keyboard (M-key if the letter sequence constituted a real word and Z-key if not). All the stimuli were presented in lowercase (Times New Roman, 20 point font) on the centre of the screen (black on white) using the Superlab Pro (Abboud & Sugar, 1997). Participants were seated 50 cm (approx.) from the screen, and the following directions appeared on the computer: '*This is a lexical decision task. Real and invented words will appear on the screen. If the letter sequence constitutes a real word*, *press M-key and if not*, *press Z-key. Ready*? *Press spacebar to commence*'. Each stimulus remained for 2500 ms on the screen, replaced by an asterisk as a fixation point for 500 ms, followed by a blank screen for another 500 ms. The mistakes and reaction times (RTs) in words were registered. The duration of the task was 5 min (approx.).

– *Word and pseudoword reading*. We selected 60 words and constructed 30 pseudowords for this study. The words were 30 short words (four to five letters; half high frequency, *M*=61, SD=6.1 and half low frequency, *M*=1, SD=0.8) and 30 long words (eight to nine letters; half high frequency, *M*=61, SD=5.7 and half low frequency, *M*=1, SD=0.4). The lexical frequency values for words were taken from the database of Pérez et al. (2003). The pseudowords were constructed from a set of base words by changing one letter. We included 15 short pseudowords (four to five letters) and 15 long pseudowords (eight to nine letters).

The participants were asked to read the stimuli aloud, presented in a random order on a laptop. The stimuli were presented in two blocks: the first block consisted of words and the second one of pseudowords. Stimuli were presented (Arial, 20 point font) and responses recorded, in .WAV files, using DMDX (Foster & Foster, 2003). Participants were seated 50 cm (approx.) from the display screen. Each stimulus remained for 2500 ms on the screen, then replaced by an asterisk as a fixation point for 500 ms, followed by a blank screen for another 500 ms. After the first block, a pause was marked on the screen, and the participants had to press the spacebar to continue. Before conducting the task, the following instructions appeared on the screen: '*You have to read some words and after that some invented words. You must read them aloud*, *as quickly as possible*, *and without making any mistakes. Press spacebar to commence*'. Also, before starting, six practice trials were run in order to familiarise the participants with the reading task. The task lasted approximately 15 min.

The sound spectrograms of the recorded responses were analysed, using the CheckVocal application (Protopapas, 2007) to extract accuracy, RTs and articulation times (ATs). Mistakes (self-corrections, substitutions, regressions) and omitted responses were excluded.

– *Letter detection task*. A total of 96 stimuli were used, 48 words and 48 pseudowords. The mean frequency of the words was 39 (SD=6.2), and the mean length for words and pseudowords was seven to nine letters (M=8, SD=0.78). The task consisted of detecting a letter previously presented (target) within a stimulus (word or pseudoword). Of the 96 stimuli, 48 stimuli contained the target letter to be detected by the participant; in 16 stimuli, the letter was at the beginning, in 16, it was in the middle and in 16 at the end; the 48 remaining stimuli did not contain the target letter.

  The selected stimuli were presented, in random order, in lowercase (Times New Roman, 20 point font) on the computer screen through Superlab Pro (Abboud & Sugar, 1997). The target letter appeared on the screen for 500 ms, and then, one stimulus appeared (word or pseudoword). The participant had to detect the presence of the target letter and press M-key on the computer if the target letter was present or Z-key if it was not. The stimuli remained on the computer screen until the participant responded.

  The participant received instructions on the computer screen, in addition to orally: '*This is a letter detection task. A letter will appear followed by a word or pseudoword. If the letter is included in the word or pseudoword*, *press M-key*, *if it is not included*, *press Z-key. Ready*? *To begin*, *press the spacebar*'. The answers given by the subject (accuracy and RTs) were stored on the computer. The test lasted 7 min.

– *Text reading*. This task consisted of reading aloud a text. To perform this reading, we used a 228-word text, entitled 'Viaje a la luna [Trip to the Moon]' that the subject had to read aloud. The text was presented on a piece of paper (Times New Roman, 12 point font). The reading was recorded by a SONY ICD-UX533 recorder. Audio recordings were processed off-line using Praat software (Boersma & Weenink, 2010). Only the fourth and fifth sentences of the text were used for in-depth analyses of voice parameters. Each utterance (temporal onset and offset of utterances) and silent pause were marked for the sentences. We identified the utterances and silent pauses using visual inspection and listening to the audio track. Following De Luca, Pontillo, Primativo, Spinelli, & Zoccolotti (2013), different measures were considered: total reading time, total pronunciation time (i.e. reading time excluding pauses), total duration of pauses (i.e. duration of all silent pauses), mean duration of pauses, mean duration of utterances, number of pauses, percentage of pronunciation time and percentage of silent pause time. Reading accuracy was also collected, and the following categories of errors were considered: sounding-out behaviour (i.e. progressive approximation towards the correct utterance of the whole word by sounding-out parts of the word; e.g. ['pla' 'planeta'] instead of ['planeta'], 'planet'), word substitutions, word omissions or insertions and non-word production. All the tasks were performed individually at the Basic Psychology Laboratory of the University of Oviedo, Spain.

Results

From the collected data on the performed tasks, different analyses were carried out with SPSS 19 Statistical Package.

Phonological awareness analysis

The number of correct answers was the dependent variable, and an independent samples *t* test was conducted to compare the scores for the two groups. The results showed that adults with dyslexia had lower performance than the control group in all of the phonological awareness tasks, except for one: number of phonemes in a word (see Table 3).

RAN analysis

Only latencies were analysed because a ceiling effect for accuracy existed in both groups. In an *independent samples t* test, significant differences were found between the two groups in all tasks (see Table 3).

Lexical decision (recognition words) analysis

Since several variables were manipulated, mixed factorial analysis of variance was conducted in this task. The group (dyslexics vs. controls) was the between-subjects factor; frequency (high vs. low) and length (short vs. long) were the within-subjects factors. The RTs in word recognition were the dependent variable.

We found a group effect (F (1, 58)=29.776, p<0.001, partial η^2=0.339), as the dyslexic group was slower than controls; frequency effect (F (1, 58)=153.884, p<0.001, partial η^2= 0.726), as RTs were lower in high than in low-frequency words; length effect (F (1, 58)= 68.806, p<0.001, partial η^2=0.543), with higher RTs for long compared to short words; a length × group interaction (F (1, 58)=20.689, p<0.001, partial η^2=0.263), because the length effect was larger in the dyslexic group than the control group; and frequency × group

Table 3 Phonological awareness and rapid automatic naming scores (means and standard deviations) of the participants: controls and dyslexics

	Controls (n=30)	Dyslexics (n=30)	t	p level	Partial η^2
Syllable reversal	11.13 (0.86)	8.33 (2.19)	−6.526	<0.001	0.042
Phoneme reversal	11.93 (0.25)	11.33 (1.35)	−2.397	<0.05	0.009
Initial phoneme deletion	11.80 (0.48)	10.80 (1.54)	−3.392	<0.005	0.016
Spoonerism	10.87 (1.22)	7.13 (2.64)	−7.036	<0.001	0.045
Oral spelling	11.07 (1.34)	8.73 (2.13)	−5.077	<0.001	0.031
No. of phonemes in a word	9.93 (2.13)	8.93 (2.00)	−1.874	n.s.	0.057
Pseudowords repetition	11.63 (0.67)	10.33 (1.45)	−4.469	<0.001	0.025
Digits span test	11.63 (1.83)	10.03 (2.04)	−3.197	<0.005	0.015
RAN—digits speed	11.36 (2.04)	14.56 (2.49)	5.428	<0.001	0.330
RAN—colours speed	20.63 (3.20)	24.28 (4.37)	3.692	<0.001	0.190
RAN—objects speed	22.82 (2.95)	28.31 (7.16)	3.884	<0.001	0.210
RAN—letters speed	10.89 (1.66)	14.83 (2.57)	7.064	<0.001	0.460

interaction (F (1, 58)=21.324, $p<0.001$, partial $\eta^2=0.269$), since the frequency effect was larger in the dyslexic group (see Table 4).

Regarding errors in words, we found a total of 131 errors: 56 (4.6 %) for the control group and 75 (6.25 %) for the dyslexic group, but the difference was not significant (t test=0.618). The control group made 0 % of errors in high-frequency words; therefore, all of the errors were in low-frequency ones. Of the total, 2.46 % of errors were in short stimuli and 2.14 % in long stimuli. The dyslexic group committed 0.5 % of errors in high-frequency words and 5.75 % in low-frequency ones. On the other hand, they committed 3.5 % of errors on short stimuli and 2.75 % in the long ones.

Word and pseudoword reading

As in the previous task, we considered the effect of the variables lexicality (words vs. pseudowords), frequency (high vs. low) and length (short vs. long). The RTs and the ATs were the dependent variables.

RT analysis

We found effects for the following: group (F (1, 58)=48.174, $p<0.001$, partial $\eta^2=0.454$), as RTs were higher in the dyslexic group than in the control group; lexicality (F (1, 58)=106.701, $p<0.001$, partial $\eta^2=0.764$), because the RTs depended on the lexicality; length (F (1, 58)= 259.479, $p<0.001$, partial $\eta^2=0.817$), as the RTs were slower in the short stimuli than in the long ones; length × group interaction (F (1, 58)=20.414, $p<0.001$, partial $\eta^2=0.260$), as the length effect was larger among the dyslexic group (see Fig. 1); and lexicality × length interaction (F (1, 58)=68.326, $p<0.001$, partial $\eta^2=0.541$), with a larger length effect in pseudowords than words.

Analysing only the words, we also found the following: a group effect (F (1, 58)=49.853, $p<0.001$, partial $\eta^2=0.462$), as the dyslexic group was slower than controls when reading words; a frequency effect (F (1, 58)=104.155, $p<0.001$, partial $\eta^2=0.642$), with higher RTs for low-frequency than high-frequency words; a length effect (F (1, 58)=102.460, $p<0.001$, partial $\eta^2=0.639$), with higher RTs in long words; a frequency × group interaction (F (1, 58)=22.664, $p<0.001$, partial $\eta^2=0.281$), with higher differences between frequencies in the dyslexic group than in the control group (see Fig. 2); a length × group interaction (F (1, 58)= 33.220, $p<0.001$, partial $\eta^2=0.364$), as the difference between long and short stimuli was higher in the dyslexic group than in the control group; a frequency × length interaction (F (1, 58)=50.067, $p<0.001$, partial $\eta^2=0.463$), with a lower length effect in high-frequency stimuli; and a frequency × length × group interaction (F (1, 58)=16.485, $p<0.001$, partial $\eta^2=0.221$) (see Table 5 for a summary of results).

Table 4 Lexical decision scores (means and standard deviations) of the adult participants, considering frequency (high vs low) and length (short vs long)

	HF words		LF words	
Group	Short	Long	Short	Long
Dyslexics	804 (174)	1083 (359)	1059 (296)	1353 (412)
Controls	652 (104)	744 (166)	780 (134)	856 (165)

HF high frequency, *LF* low frequency

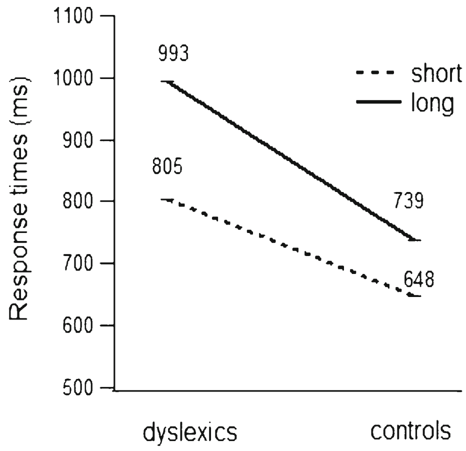

Fig. 1 Length by group interaction in RT of reading-aloud task

AT analysis

Regarding ATs, we found the following effects: group (F (1, 58)=10.334, p< 0.005, partial η^2=0.151), as ATs were higher in the dyslexic group than in the control group; lexicality (F (1, 58)=106.533, p<0.001, partial η^2=0.647), because the ATs depended on the lexicality; and length (F (1, 58)=1916.37, p<0.001, partial η^2=0.971), as the ATs were lower in the short stimuli than in the long ones. We also found a lexicality × group interaction (F (1, 58)=8.472, p< 0.005, partial η^2=0.127), with higher differences between words and pseudowords in the dyslexic group, than in the control group; a length × group interaction (F (1, 58)=21.203, p<0.001, partial η^2=0.268), as the difference between long and short stimuli was higher in the dyslexic group than in the control group; a lexicality × length interaction (F (1, 58)=72.886, p<0.001, partial η^2=0.557), with a lower length effect in high-frequency stimuli; and a lexicality × length × group interaction (F (1, 58)=8.107, p< 0.05, partial η^2=0.123), as the effect of lexicality and length was greater in the dyslexic group (see Table 5).

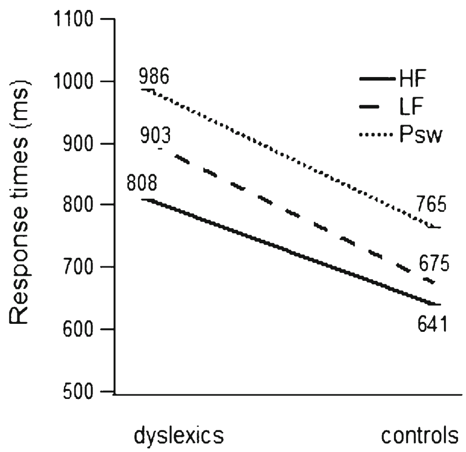

Fig. 2 Lexicality and frequency by group interaction in RTs of reading-aloud task

Table 5 Reading and articulation times (means and standard deviations) of the participants, considering lexicality (words vs pseudowords), frequency (high vs low) and length (short vs long)

Group	Reading times						Articulation times					
	HF words		LF words		Pseudowords		HF words		LF words		Pseudowords	
	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long	Short	Long
Dyslexics	758 (103)	857 (136)	800 (124)	1005 (186)	856 (135)	1115 (208)	430 (60)	672 (75)	446 (57)	707 (77)	462 (62)	834 (133)
Controls	627 (76)	654 (86)	647 (79)	703 (115)	670 (85)	860 (148)	402 (64)	621 (90)	418 (67)	643 (89)	427 (71)	710 (94)

HF high frequency, *LF* low frequency

Finally, when words were analysed separately, we found the following: a group effect (F (1, 58)=5.370, p<0.05, partial η^2=0.085), as the ATs were lower in the control than in the dyslexic group; a frequency effect (F (1, 58)=65.668, p< 0.001, partial η^2=0.531), because the ATs were shorter for high than low-frequency words; a length effect (F (1, 58)=4285.057, p< 0.001, partial η^2=0.987), with higher ATs for long words than short ones; a length × group interaction (F (1, 58)=16.230, p< 0.001, partial η^2=0.219), because the length effect was greater in the dyslexic group; and a frequency × length interaction (F (1, 58)=10.892, p= 0.002, partial η^2=0.158), where the length effect was larger for low than high-frequency words.

Regarding errors, participants in the control group only produced 33 errors (1.2 %) while the dyslexic group produced 64 (2.37 %), so the difference was significant (t test <0.001). In the control group, 0.4 % were produced in words (0.1 % in high frequency and 0.3 % in low frequency) and 0.8 % in pseudowords. Moreover, 0.07 % of the mistakes were in the short stimuli and 1.13 % in the long ones. In contrast, the dyslexic group made 0.89 % of errors in words (0.48 % high frequency, 0.41 % low frequency) and 1.48 % in pseudowords. Moreover, 0.41 % were in short stimuli and 1.96 % in long ones.

Letter detection task

In this task, detection time, i.e. the time a person needed to detect the target letter, was the dependent variable. The independent variables were the group (dyslexics vs. controls), lexicality (words vs. pseudowords) and position (initial, medium and final).

A principal effect of lexicality was found (F (1, 58)=22.492, p<0.001, partial η^2=0.279), as it was easier to find the target when the stimuli was a word instead of a pseudoword; we also found a position × group interaction (F (1, 58)=10.577, p< 0.005, partial η^2=0.154), because dyslexics took more time detecting the letter the farther it was from the beginning of the stimuli, while controls appeared to show a similar time, regardless of the position occupied by the letter to detect (see Fig. 3), and lexicality × position interaction (F (1, 58)=9.722, p< 0.005, partial η^2=0.144), because the effect of position was higher in pseudowords than in words.

Text reading

A t test for independent samples was carried out for group comparisons. Total reading aloud time was significantly shorter for control than dyslexic group. We also found significant differences in total pronunciation time, number of pauses and errors (see Table 6). On the other hand, people with dyslexia spent 81.48 % of time in pronunciation and 18.52 % in pauses, while controls employed 84.50 % of their time in pronunciation and 15.50 % in pauses.

Table 6 Text reading scores of the adult participants (means and standard deviations)

	Controls (n=30)	Dyslexics (S=30)	p level	Ratio
Total reading time	11371 (1600)	14137 (3091)	<0.001	1.24
Total pronunciation time	9555 (1118)	11394 (2093)	<0.001	1.19
Number of pauses	4.79 (1.50)	7.19 (3.15)	<0.001	1.5
Error	0.11 (.42)	0.89 (1.12)	<0.001	8.09

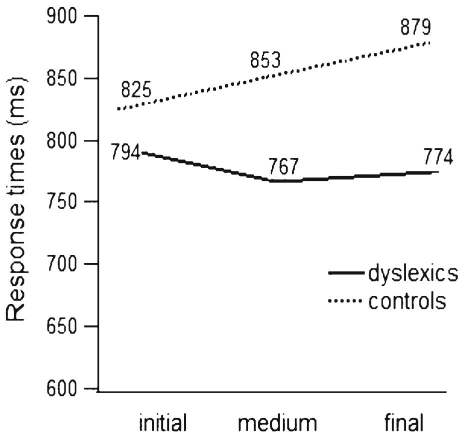

Fig. 3 Position (initial, medium and final) by group interaction in letter detection task

Discussion

The aim of the current research was to examine the reading characteristics of Spanish adults with dyslexia (all of them with post-secondary education or with a university degree, i.e. with considerable reading exposure). No studies have yet examined this population in Spanish, and it seems necessary to conduct studies in different orthographic systems in order to generalise results. Namely, we were interested in providing data about reading rate, reading strategies and phonological problems in Spanish adults with dyslexia. To deal with these aims, adults with dyslexia and typical readers were compared on different reading and reading-related tasks: phonological awareness, RAN, words and pseudowords naming, lexical decision task, letter detection and text reading. The results showed that the dyslexic group performed significantly worse (speed and accuracy) than controls on a large number of tasks.

Starting with the phonological tasks, adults with dyslexia had worse performance than controls on all the tasks except in phoneme counting (counting the number of phonemes in the words). Differences were highly significant in syllable reversal, spoonerism and oral spelling tasks. These results were consistent with those found in many other languages such as English (Bruck, 1992; Downey, Snyder, & Hill, 2000; Griffiths & Frith, 2002; Pennington et al., 1990), French (Dufor, Serniclaes, Sprenger-Charolles, & Demonet, 2007; Szenkovits & Ramus, 2005), Dutch (Callens et al., 2012; Tops et al., 2012) and Polish (Reid, Szczerbinski, Iskierka-Kasperek, & Hansen, 2006). It seems that adults with dyslexia, even after many years of education, continue to be affected by phonological skills. The prominent and persistent problems with phonological awareness have been corroborated with neuroimaging and event-related studies (Breier et al., 2003; Kovelman et al., 2011), and this persistence is consistent with the phonological deficit theory, considering that people with dyslexia have specific difficulties manipulating speech sounds and learning the letter–sound mapping (Snowling, 2000); although, in this field, there is some controversy, as these phonological problems have been considered a symptom, rather than a cause of dyslexia by several authors.

Significant differences were also found between the dyslexic and control groups in RAN, with a major effect size in alphanumeric stimuli: RAN—digits and RAN—letters (smaller but substantial effect sizes were found for RAN—colours and RAN—objects). RAN required proficient retrieval of phonological labels from long-term memory, so it is useful in order to decode written words (Wagner et al., 1997). The impairment in RAN is considered an underlying cause (or symptom) of dyslexia and is repeatedly found in the literature with adults with dyslexia (Bruck, 1992; Bruck & Treiman, 1990; Martin et al., 2010; Parrila et al., 2007; Reid et al., 2006; Swanson & Hsieh, 2009; Szenkovits & Ramus, 2005). In some way, the observed phonological and RAN problems help us to confirm the diagnosis of dyslexia, because these problems are repeatedly described in the literature.

Regarding the reading tasks (reading words, pseudowords and text), important differences were also found between groups, because adults with dyslexia were slower and made more mistakes than controls. This performance, especially slowness in different reading situations and affected by different variables, provides information about reading characteristics of Spanish adults with dyslexia. Similar results were reported in other languages (e.g. Polish, Italian, Hebrew), but in Dutch (contrary to Spanish), people with dyslexia had poorer performance in the reading of words than in the reading of pseudowords, probably because Dutch is a deeper orthographic system than Spanish where consistency favours accuracy. Additionally, as found in other studies in transparent orthographies and in Spanish among children, reading speed was more affected than accuracy in adults with dyslexia. This seems to imply that low reading speed is a characteristic that remains in adulthood and is language independent. Moreover, in our study, we have confirmed that this low speed was also found in the ATs, as previously found in studies with Spanish children with dyslexia (Davies et al., 2007; Davies, Rodríguez-Ferreiro, Suárez, & Cuetos, 2013; Suárez-Coalla & Cuetos, 2012). In this case, the ATs as well as RTs are affected by reader skill, suggesting that phonological coding processes may continue after response onset, so the word's pronunciation may not be fully prepared at response onset.

Moreover, as noted in previous studies, the speed problems in people with dyslexia also arise when reading a text (De Luca et al., 2013; Szenkovits & Ramus, 2005; Tops et al., 2012), as they spend more time reading aloud a text and make more pauses than controls. Therefore, they do not benefit from the context as much as the controls, demonstrating a difficulty in recovering the pronunciation of the graphemes or accessing the phonological representation of words.

But, more importantly, we can postulate the reading strategies used by adults with dyslexia, if we consider three different tasks (reading aloud, word recognition and letter detection) and the psycholinguistic variables under consideration: length, lexicality and lexical frequency. In the reading-aloud task, the statistical analyses showed significant interactions between group and the three mentioned variables. The lexicality by group interaction highlighted that differences between words and pseudowords were larger in the dyslexic group than in the control one. Adults with dyslexia had more difficulties reading pseudowords, which indicated great difficulties using the grapheme–phoneme rules. In addition, the length effect, considered a marker of developmental dyslexia (Zoccolotti et al., 2005), suggests that they are using a sub-lexical route to read, although not a very effective route. This difficulty with long stimuli was probably caused by problems learning and automating the grapheme–phoneme rules. As children with dyslexia (Davies et al., 2007; Ramus, 2001; Zoccolotti et al., 2005), adults with dyslexia probably do not process the letters in parallel but make a serial reading, letter by letter. Considering lexical frequency and the special difficulties with low-frequency words, it could denote the absence of orthographic representations, besides low skills with the grapheme–phoneme rules, but we could also postulate difficulties accessing stored orthographic or phonological representations (Meyler & Breznitz, 2003). As considered by Meyler and Breznitz (2003), adults with dyslexia suffer impairment in processing the phonological and orthographic representations of words. They probably present phonological and orthographic representations of words, but they have problems accessing them. In any case, the characteristics of the Spanish adults with dyslexia were similar to ones found in children with dyslexia (Davies et al., 2007; Suárez-Coalla & Cuetos, 2012) as their main difficulty appeared when reading long low-frequency words and long pseudowords.

In addition, another two tasks provided information about the reading profile of adults with dyslexia: letter detection and lexical decision. Regarding the letter detection task, an important position effect detecting the letter within the word and pseudoword was found. Those with dyslexia had longer latencies when the letter was in a more advanced position, indicating a serial process in reading, as compared to controls. This task was not used in the literature, but it could reinforce the hypothesis that those with dyslexia use a serial strategy when processing the letters of a word, while controls process the letters in parallel.

Otherwise, in the lexical decision task, adults with dyslexia were slower than controls and also showed a high effect of length and frequency, although they were accurate (i.e. they did not have problems in recognising words, but the process was slow). Other studies reported this disadvantage for people with dyslexia in a lexical decision task (Nicolson & Fawcett, 1994; Shaul, Arzouan, & Goldstein, 2012; Taroyan & Nicolson, 2009), suggesting anomalies in the early stages of word processing, i.e. in the recognition of the visual form of the words (VWFA). Therefore, we could propose the presence of difficulties in accessing the orthographic representations.

Taking into account the results of all the tasks performed, it is possible to conclude that adults with dyslexia do not have a single problem. On the one hand, they seem to demonstrate problems using the grapheme to phoneme conversion rules; on the other hand, there are reasons to think that they have difficulty accessing or processing orthographic representations of words.

Thus, our results in Spanish, despite the orthographic transparency, were similar to those found in English (and other orthographic systems as Dutch, Norwegian, Finnish, Swedish, French or Polish, for instance). Spanish adults with dyslexia and high education continued to show a performance below than expected, considering their level of education, with significant differences compared to the control group.

In summary, Spanish people with dyslexia present deficits in phonological awareness and rapid automatic naming (speed). They show special difficulties reading long pseudowords and low-frequency words, suggesting a weak automatisation of grapheme–phoneme correspondence rules; also, they are slower than controls reading and recognising words (in special low-frequency words), so they probably have difficulties in processing phonological and orthographic representations of words.

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