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ESTUDIOS

Phonological processing skills in bilingual (Catalan and Spanish) students with and without dyslexia

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Abstract: To examine literacy learning in bilingual contexts, this study assessed phonological processing skills in a sample of bilingual students, both with and without dyslexia. It also aimed to determine whether the stage of literacy acquisition affects phonological skills in bilingual children with and without dyslexia. The participants were 113 Catalan/Spanish bilinguals, aged 8 to 14 years, attending middle and upper primary school, as well as early secondary school. This transversal study assessed accuracy in the following phonological processing skills: phonological awareness (using phonemic awareness tests), phonological decoding (through a pseudo-word reading task), and phonological memory (using a pseudo-word repetition task). Overall, the results showed differences between students with and without dyslexia across all tasks, but no differences were found between the two languages studied. Results by educational stage revealed that differences in the phonemic awareness task diminished with age, while differences in pseudo-word reading persisted. Additionally, differences were observed among middle and secondary school participants without dyslexia, with better accuracy in the phonemic awareness task in Spanish. The results are discussed in relation to previous studies and the transparency and opacity of the languages involved.
Keywords: phonological processing skills; dyslexia; childhood; bilingualism.

ESP Habilidades de procesamiento fonológico en estudiantes bilingües catalán-español con y sin dislexia

Resumen: Este estudio evaluó las habilidades de procesamiento fonológico en una muestra de alumnos bilingües, con y sin dislexia, con el objetivo de examinar el aprendizaje de la lectoescritura en contextos bilingües. También se pretendía determinar si la etapa de adquisición de la lectoescritura afecta a las habilidades fonológicas en niños bilingües con y sin dislexia. Los participantes fueron 113 bilingües catalán/español, con edades comprendidas entre los 8 y los 14 años, que asistían a la escuela primaria media y superior, así como a los primeros cursos de secundaria. Este estudio transversal evaluó la precisión en las siguientes habilidades de procesamiento fonológico: conciencia fonológica (mediante pruebas de conciencia fonémica), decodificación fonológica (mediante una tarea de lectura de pseudopalabras) y memoria fonológica (mediante una tarea de repetición de pseudopalabras). En general, los resultados mostraron diferencias entre los alumnos con y sin dislexia en todas las tareas, pero no se encontraron diferencias entre las dos lenguas estudiadas. Los resultados por etapa educativa revelaron que las diferencias en la tarea de conciencia fonémica disminuían con la edad, mientras que persistían las diferencias en la lectura de pseudopalabras. Además, se observaron diferencias entre los participantes de secundaria y bachillerato sin dislexia, con mejor precisión en la tarea de conciencia fonémica en español. Los resultados se discuten en relación con estudios previos y con la transparencia y opacidad de las lenguas implicadas.
Palabras clave: Bilingüismo; Dislexia; Habilidades de procesamiento fonológico; Infancia.

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Introduction

Dyslexia is a specific written language learning difficulty of neurobiological origin due primarily to a deficit in the phonological component. This difficulty arises unexpectedly, given the individual's intellectual capacity, motivation, and access to appropriate instruction. Additionally, dyslexia is often accompanied by socio-emotional challenges that tend to intensify over time (Shaywitz et al., 2008; Melby-Lervag et al., 2012). According to the DSM-5 (APA, 2014), dyslexia falls under the category of Specific Learning Disorder, alongside difficulties in mathematics, with an estimated prevalence ranging from 5% to 15%. Despite discrepancies between data, due to different language characteristics and diagnostic criteria, it is widely recognized that dyslexia is a common occurrence in classrooms, presenting a significant challenge for educators (Nijakowska, 2016; 2019).

Frith (1999, 2002) proposes a framework to integrate the different causal theories of dyslexia with three interconnected levels: biological, cognitive and behavioural. In addition, a fourth component corresponds to the environment, encompassing factors such as socio-cultural context and the orthographic system in which reading is learned. Focusing specifically on the cognitive level, which is the focus of this study, difficulties are primarily found in phonological processing, particularly in grapheme-phoneme conversion. This specific skill relies particularly on phonemic awareness, a key component of phonological processing (Carrillo, 2012; Frith, 1999). At the behavioural level, these difficulties manifest in tasks related to phonological awareness, naming, verbal fluency, phonological memory, pseudo-word repetition and reading speed (Cuetos et al., 2012; Serrano, 2005). As a result, literacy acquisition is delayed. On one hand, reading is characterized by difficulties in decoding words, slow and effortful reading, and frequent errors such as omissions, substitutions, and problems with reading fluency; while on the other hand, writing is marked by spelling errors and poor writing.

At least half of the world's children are believed to grow up exposed to more than one language (Grosjean, 2010). Many of them, as well as those raised in monolingual environments, will learn to read and write in more than one language, whether as their native language(s) or as foreign languages (Saiegh-Haddad & Geva, 2010). Understanding bilingual language learning in greater detail has important implications for the harmonious development of children and for gaining insight into the experiences of children with atypical language learning.

Next, we will briefly address the two main aspects on which this study focuses in relation to literacy learning: the role of phonological processing skills and bilingualism.

Phonological processing skills

Phonological processing has been defined as the set of mental operations involved in using phonological information to represent, store, and retrieve spoken and written language (Passenger et al., 2000; Wagner et al., 1994; Wagner & Torgesen, 1987). Wagner and Torgesen (1987) identify the following three components of phonological processing: a) phonological awareness, b) phonological decoding in lexical access and c) phonological memory.

Phonological awareness (PA) is defined as any form of conscious knowledge about the phonological properties of language (Morais, 2001). It refers to the ability to reflect on the units that constitute spoken language (sentences, words, syllables or phonemes) and is reflected in tasks of sound analysis or synthesis, such as counting, substituting, and adding sounds in words or syllables (Defior, 1991; Goswami & Bryant, 1992; Stahl & Murray, 1994).

PA is a predictor of individual differences in literacy learning. Deficits in this area are often associated with learning difficulties (Defior & Serrano, 2011) and distinguish efficient readers from inefficient ones (Bruck, 1992). The development of PA starts before literacy and is crucial for understanding of the alphabetic principle (Anthony & Francis, 2005; Bus & Van Ijzendoorn, 1999). According to Treiman (1991), PA develops across three hierarchical levels, each involving increasing cognitive demands. The first level, syllabic awareness, refers to the ability to segment and manipulate the syllables within a word. The second level, intrasyllabic awareness, involves recognizing and manipulating the onset and rime components of syllables. The most advanced level, phonemic awareness, entails the ability to segment and manipulate individual phonemes within words.

Children typically master the syllabic level between the ages of 3 and 4 years, and the intrasyllabic level between the ages of 4 and 5 years (Ziegler & Goswami, 2005). Children find it easier to access and manipulate syllabic and intrasyllabic units before reading (Jiménez, 1998). Those who receive training in these skills before or during literacy learning become better readers and writers (Defior et al. 2008; Ehri et al., 2001; Gillon, 2000). The process of acquiring phonemic awareness may vary depending on the characteristics of the orthographic system. In non-alphabetic languages such as Chinese or Japanese, it tends to be less developed (Clemente, 2001).

As for alphabetic languages, when they are transparent, like Finnish, learning is faster because it depends on a single process (alphabetic), whereas in opaque languages, like English, two processes are required (logographic + alphabetic) (Seymour et al., 2003; Defior & Serrano, 2011). On the other hand, learning languages with an abundance of highly complex syllables such as Icelandic, presents more challenges than those with

an abundance of simple consonant-vowel structures, where children show a high level of syllabic knowledge before the onset of literacy (Seymour et al., 2003).

The orthographic system of the Spanish language, along with its clear syllabic structure, means that intrasyllabic awareness is not as relevant (Defior & Herrera, 2003). Jiménez and Muñetón (2002) suggest that phonemic awareness is easier to acquire and more relevant than intrasyllabic awareness. They note that once children have learned the alphabetic code and acquired phonemic awareness, there is no need to categorise words into their intrasyllabic components. Defior et al. (2008) analyse the predictive power of the different phonemic awareness skills in reading and writing, from the pre-reading stage to the first three years of primary school, and show that phonemic awareness is the best predictor of the level of literacy learning, particularly for writing in a more consistent and meaningful way.

Phonological decoding in lexical access, such as the decoding of a word and meaning retrieval, as well as contextual word recognition, plays pivotal role in the process of reading. According to Wagner and Torgesen (1987) is the second component of phonological processing, defined as the ability to retrieve information from the phonological lexicon of spoken language (Lara et al., 2007; Romero et al., 2011). It allows for the decoding the letters of written words one by one until the sound composition of the word being read is reached (Bowers & Swanson, 1991; Frith et al., 1998) through the phonological pathway, according to Coltheart's (1978) dual-route model. It is an essential mechanism for reading acquisition (Frith et al., 1998).

Children learning transparent languages such as Italian commonly use phonological recoding (Frith et al., 1998). However, for learners of English, with its opaque orthography and a high number of irregular words, phonological decoding is not sufficient for word recognition, and the use of the lexical pathway becomes necessary (Ferroni & Diuk, 2014). Frith et al. (1998) found that English-speaking children show more difficulty in phonological decoding tasks. They suggest that the differences are due to the inconsistency of the English language and the learning methods used. Goswami et al. (1998) compare pseudo-word reading in English, French and Spanish and show that phonological decoding is easier for Spanish speakers.

The third component of phonological processing is phonological memory. According to Baddeley (1993), there are two storage mechanisms, one phonological and the other visual. The phonological would correspond to what he calls the "articulatory loop". This component is specialised in retaining and manipulating verbal information as well as developing the necessary rehearsal to temporarily maintain this information before transferring it to long-term memory (Baddeley et al., 1998). Information can come from both external input and from within the cognitive system itself (Baddeley et al., 1988). It is necessary for new phonological learning and is, therefore, vital for learning to read and write. It plays an important role in the development of phonological decoding, which is necessary in the early stages of reading (Gathercole & Baddeley, 1993). The visual component refers to the mechanism responsible for the temporal storage and processing of visuospatial information present in reading. Pseudo-word repetition is a task that has been frequently used to assess this component and has been shown to discriminate between children with and without dyslexia (Vender et al., 2020). Such as in this task, participants are presented with a series of pseudo-words –non-words that follow the phonological rules of the language but have no inherent meaning– like "esmo," "bledos" "pronda,". They are asked to repeat these pseudo-words exactly as they hear or see them, testing their ability to decode and process phonological information accurately. This task isolates the phonological processing ability, and children with dyslexia often show difficulties with it due to challenges in phonological decoding and working memory.

Orthographic and Phonological Interaction in Bilingual Literacy

Traditionally, orthographic systems have been classified based on two criteria: consistency (transparency-opaqueness) and depth (shallowness-depth). On the one hand, they can be transparent-shallow, such as Finnish or Spanish, and on the other hand, opaque-deep, such as English. Consistency refers to phoneme-grapheme and grapheme-phoneme correspondence, while depth refers to the linguistic units represented (Alegría & Carrillo, 2014).

Ziegler and Goswami (2005) propose an alternative approach to the concept of consistency, taking into account the phonological structure, and in particular, the vowel structure of languages. These authors propose the grain size theory, which essentially states that the orthographic system uses phoneme-grapheme and grapheme-phoneme conversion units of the size that best suits its phonological system. Consistent orthographic systems such as Spanish are called "fine-grained" by these authors, because the graphemes represent the phonemes with great precision due to the phonological structure. The relationship between each grapheme and phoneme is simple and predictable. In orthographic systems such as English, which are "coarse-grained", the decoding units must necessarily be larger, and it is necessary to encode phonological units the size of rhymes, syllables, or whole words. As Schmalz et al. (2017) rightly point out; the main problem for learners of a deep orthography is reading unknown words because the sublexical information of deep orthographies is, by definition, incomplete, inconsistent and complex.

As we have already explained, phonological processing skills play a very important role in learning to read and write a language. But what happens if there are two languages involved in learning? Lallier and Carreiras (2018) argue that the impact of bilingualism does not always manifest itself in the same way. It depends greatly on the specific combination of the languages being learned. The sizes of phonological and visual grains used to read and perform reading-related tasks, as proposed by Ziegler and Goswami (2005), are subject to adaptive processes driven by the orthographic properties of each of the languages. In addition, Lallier and Carreiras (2018) argue that a number of factors can also have a significant influence,

such as the phonological distance between the two languages, the stage of development, the language proficiency of bilinguals, and so on.

In bilingual contexts, children learning to read and write must navigate not only the phonological structures of each language but also potentially different orthographic systems. The interaction between phonological and orthographic systems may either support or hinder the transfer of skills from one language to another, depending on the degree of similarity between the languages involved. This dynamic becomes even more critical when considering bilingual children with reading difficulties such as dyslexia. Moreover, these challenges can be further exacerbated by the need to adapt to two systems that may impose contradictory demands.

Understanding how bilingual children manage these cross-linguistic phonological and orthographic demands is crucial for identifying the cognitive challenges they face. This knowledge is essential not only for advancing theoretical models of bilingual literacy development but also for designing educational interventions that are sensitive to the specific needs of bilingual learners with reading difficulties.

There are not many studies with dyslexic and bilingual participants that include Spanish. Lallier et al. (2014) who investigate the impact of orthographic consistency on the learning of reading in children aged 9 to 11 years with dyslexia, bilingual Spanish and French, two languages with different levels of transparency-opacity. These authors consider that assessing reading skills in bilingual children, in addition to avoiding intervariability, allows us to explore to what extent the dysfunction that causes dyslexia affects two languages with different levels of transparency-opacity in a similar way. The results of their study show that in all tasks, including pseudo-word reading, children with dyslexia have more difficulties in the opaque language, French. In a case study, Ijalba and Bustos (2017) examined a Spanish–English bilingual second grader with developmental dyslexia. The child demonstrated significant phonological processing deficits, which impaired reading abilities in both languages. The study emphasizes the role of orthographic transparency, noting that English posed greater challenges than Spanish.

The present study is set in a socially bilingual context, with Catalan and Spanish. The Catalan orthographic system does not have the same degree of inconsistency as French, but it is more inconsistent than Spanish, both in reading and writing. The Catalan vowel system has up to eight sounds, while Spanish has only five. In Catalan, the phonological content of the vowel requires different diacritical marks, in cases where a vowel represents more than one phoneme. Spanish, with its highly transparent orthography, has consistent phoneme-to-grapheme and grapheme-to-phoneme correspondences, with only a few inconsistencies (e.g., *b/v*, *g/j*). Ninety-six percent of the letters correspond to only one phoneme and almost 90% of the phonemes are represented by only one grapheme. In Catalan, these percentages vary significantly, being 76% and 70%, respectively (Llauradó & Dockrell, 2020).

However, Catalan and Spanish, both Romance languages, in contrast to languages such as English, share a rich morphological repertoire, with almost fifty different morphemes to inflect determiners, nouns and adjectives for number and gender, and verbs for aspect, mood, tense, person and number. Llauradó and Dockrell (2020) analyse the differences between Catalan, Spanish and English, and observe that transparent Spanish spelling involves few spelling errors, whereas Catalan and English spelling is more compromised in the early stages of learning to write. However, Catalan morphology helps to reduce the presence of errors in comparison with English. As for the differential characteristics of Spanish and Catalan in relation to the proposal of Ziegler and Goswami (2005), and taking into account the classifications of authors such as Seymour et al. (2003) or Reis et al. (2020), we can consider that Spanish to be fine-grained, while Catalan would be positioned between Spanish (fine-grained) and English (coarse-grained).

The present study

Decoding mechanisms are formed at the beginning of learning to read and write through a process of becoming aware of the phonological structure of speech. Current theory shows that, to a large extent, PA-related difficulties form the background of dyslexia and that it is important to work on this level during the first years of primary and early childhood education.

Taking into account the relevance of phonological skills, interlinguistic differences, the existing Anglocentric bias in the literature, and the need to study literacy learning in bilingual contexts, we set out to examine phonological processing skills in bilingual children with and without dyslexia, based on educational stage and the following tasks: phonemic awareness as a measure of phonological awareness; pseudo-word reading as a measure of phonological decoding; and pseudo-word repetition as a measure of phonological memory.

In the context of our research, the participants are Catalan and Spanish speakers. In Catalonia, Catalan is both an official and a native language, alongside Spanish. However, it is not always the habitual language of use for the entire population. Although both languages coexist, Spanish tends to dominate in many social and media contexts. In the educational system, Catalan has been the main vehicular language since the 1980s, thanks to the "language immersion model." This approach means that most subjects are taught in Catalan, even for students whose home language is Spanish. The objective is to ensure that all students, regardless of their linguistic background, complete compulsory education with proficiency in both Catalan and Spanish.

Despite broad support for this language policy, recent data indicate a decrease in the use of Catalan as a habitual language in Catalonia (Gencat, 2024), particularly in secondary and upper secondary education. In general, young people understand Catalan, but they tend to use it less frequently in informal social settings, especially on social media. According to Siguan and Mackey (1986), all students are social bilinguals

because they use both Catalan and Spanish as their habitual means of communication. These languages are typologically similar, as both are Romance languages. However, in terms of the writing system, Spanish is a transparent language, while Catalan can be considered a semi-transparent language. Given this situation, our study also aims to examine phonological processing skills as a function of the orthographic depth of the languages under study. According to previous results (Lallier et al., 2014), more difficulties should be observed in Catalan, as it is the more opaque language.

Our main objective is to study phonological processing skills in bilingual students with and without dyslexia, focusing on Catalan and Spanish. Specifically, we aim to:

- Study the differences in phonological processing between students with dyslexia and those without dyslexia.
- Investigate the impact of the orthographic depth of Catalan and Spanish on phonological processing skills, hypothesizing that greater difficulties will be observed in Catalan due to its more opaque orthography.
- Examine whether the educational stage of literacy acquisition has any effect on phonological skills in bilingual children with and without dyslexia.

Method

Participants

The study sample included 113 participants aged between 8 and 14 years. In terms of gender distribution, 60 were girls (53.1 %) and 53 were boys (46.9 %). At the time of the study, they were in 3rd, 4th, 5th, 6th year of Primary Education, 1st and 2nd year of Secondary Education and were attending public and private schools.

Table 1. Main characteristics of the sample

Group		No Dyslexia (ND) n=56	Dyslexia (D) n=57	Contrast test
Middle primary n = 48	**n**	20	28	
	Sex, girls/boys	11/9	16/12	
	Age[a] (months)	113,9 (7,9)	113,6 (7,3)	Z= -0,084 *p* = ,933
	NVIQ[b]	106,1(11,7)	100,1(11,7)	Z= -1,643 *p* = ,100
Upper primary n = 33	**n**	18	16	
	Sex, girls/boys	10/8	10/6	
	Age[a] (months)	138,6 (6,6)	137,4 (7,2)	Z= - 0,485 *p* = ,628
	NVIQ[b]	103,1(9,6)	98,2 (9,7)	Z= -0,062 *p* = ,064
Secondary n = 31	**n**	18	13	
	Sex, girls/boys	8/10	5/8	
	Age[a] (months)	162,8 (6,2)	162,2 (7,9)	Z= - 0,461 *p* = ,645
	NVIQ[b]	98,4 (11,6)	91,9 (5,8)	Z= -1,243 *p* = ,226

Notes: [a]Mean(SD). [b]NVIQ(SD): mean non-verbal intelligence (standard deviation in parentheses).

They were grouped into three groups: group 1, made up of children in 3rd and 4th year of primary school (from 8 years and 5 months to 10 years and 5 months); group 2, children in 5th and 6th year of primary school (from 10 years and 8 months to 12 years and 5 months); and group 3: 1st and 2nd year of ESO/Compulsory Secondary Education, children (from 12 years and 7 months to 14 years and 2 months). Each educational stage group consisted of a group of participants with a diagnosis of dyslexia (hereafter referred to as group D) and a group of participants without a diagnosis of dyslexia (hereafter referred to as group ND). All participants in group D had a prior diagnosis of dyslexia, issued or validated by the psychopedagogical counselling and guidance team of the autonomous community (hereafter EAP) and did not have dyslexia-associated comorbidity of attention deficit hyperactivity disorder with or without hyperactivity, or developmental language disorder. Participants with a non-verbal intelligence quotient index (hereafter, NVIQ) below 80 were not included in the study sample. To assess group comparability in intellectual ability, the BAS II-school (Sipos, 2013) was used to measure non-verbal IQ. Specifically, the matrix and numerical reasoning subtests were administered.

Table 1 shows the main characteristics of the participants according to educational stage group.

Table 1 also shows the study groups with the results obtained for age and NVIQ. In the comparative analysis of the results obtained for age in months, no significant differences were found in any of the groups ($p > .05$). As for the variable NVIQ, the comparison between children with and without dyslexia in

the three groups also shows that there are no statistically significant differences, as shown in the contrast column between groups.

The participants in the study are Catalan and Spanish speakers. Both Catalan and Spanish have a strong social presence and a specific treatment in the curriculum (Huguet-Canalís, 2009). Therefore, all participants are social bilinguals, using Catalan and Spanish as a means of communication. Of the 113 participants, 78 have Catalan as their mother tongue, 22 have Spanish as their mother tongue and 13 come from bilingual families (Catalan and Spanish).

Materials

Phonological Processing Skills (PPS)

As we have introduced, with the aim of assessing the PPS in Catalan and Spanish, we have considered the three main components that different research has shown to have a direct influence on the acquisition of reading and writing: phonological awareness (syllabic, intrasyllabic and phonemic awareness), phonological decoding and phonological memory (Jiménez, 2012).

With regard to phonological awareness, we assessed the last level, phonemic awareness. In these tasks we measured accuracy and not processing speed. Accuracy was measured by the number of errors. Each of them is presented below in the order in which they were administered:

Phonemic awareness (PhonA) in Catalan and Spanish. In Spanish, the "Phonemic Awareness Test" by Jiménez (1998) was administered. It consists of four tasks: synthesising, isolating, segmenting and omitting. Each task consists of three groups of five words with different syllabic structure (CVC, CVCV, CCVC or CCVCV). An adaptation of the four tasks was made in Catalan. The length of the word (1, 2, 3 syllables), the frequency of the syllable structure to be omitted, the position of the phoneme to be manipulated (initial, middle, final) and the lack of visual support were taken into account. In the administration, correction and scoring, the recommendations of the task were followed. Reliability, measured by Chronbach's alpha index, was 0.863 in the Catalan language test and 0.846 in the Spanish language test.

Phonological decoding. A task of reading pseudo-words in Catalan and Spanish was used. Two lists of 10 words each were selected from Aguado et al. (2006) pseudo-word repetition test. For the selection of the Catalan words, the phonotactic structure of the Catalan language was taken into account (ex. 'riol', 'burrefo'; 'augicumal'). The number of syllables, syllable structure and frequency were also taken into account. Each list consists of five words with frequent syllables and five words with infrequent syllables. First, the participant was provided with the list of Catalan pseudo-words, all on a sheet of paper, double-spaced and in lower case, and was asked to read them aloud. The same procedure was then carried out with the list in Spanish. Each incorrect answer scored one point.

Phonological memory. A pseudo-word repetition task was used to assess phonological memory (PM). Ten words (five with frequent syllables and five with infrequent syllables) were selected from Aguado et al. (2006, p.12-15) word list. These words were different from those used in the pseudoword reading task. A list of ten pseudo-words in Catalan was created**.** These words were different from those used in the pseudoword reading task (ex. 'pronda', quieslo', 'mafrínegues'). The participant verbalised the word once and was expected to reproduce it verbally. Each incorrect answer scored one point. This task was administered in only one of the languages, as its aim is to assess phonological memory, which is not influenced by the language used in bilingual populations (see Vender et al., 2020).

Procedure

The administration of the tasks was carried out in a quiet space in public and private primary schools, as well as in secondary schools by the first author of this study. The tasks were administered in an individual session in which the QINV was assessed first and then the six phonological processing skills tasks in the following order: phonemic awareness task (Catalan and Spanish), pseudo-word reading (Catalan and Spanish), and pseudo-word repetition (Catalan).

To carry out the study, the ethical principles of data protection, privacy and informed consent, established by the European Commission (2013), were taken into consideration. For the selection of participants, we contacted the (Omitted for anonymity reasons) education inspectorate, EAPs, school management, and members of the Catalan Dyslexia Association. Based on informative letters, participation and permission was requested from the families through an informed consent form explaining the purpose of the study, its development, the collection and processing of data and the preservation of confidentiality to the families who expressed their interest. The recommendations of the European Commission (2010) on the possible vulnerability of participants that are not competent to give consent were also taken into account. The participants were informed about the study according to their capacities and maturity.

In the data analysis, the non-parametric Mann Whitney U-test was used for the comparison between the groups of children with dyslexia and those without dyslexia. The use of this statistic is due to the fact that normality analyses using the Kolmogorov-Smirnov and Shapiro-Wilk tests lead us to assume a non-normal distribution for all the variables analysed, mainly in the analyses comparing educational stage groups. For the comparison of the tasks across languages, direct scores were converted to Z-scores and the Wilcoxon test for paired data was used.

Results

The overall results for the phonemic awareness (hereafter PhonA) and pseudo-word reading tasks for Catalan and Spanish, as well as the results for pseudo-word repetition, are shown in Table 2. The comparison between groups shows statistically significant differences in all tasks between the group of children with dyslexia and the group of children without dyslexia. The mean number of errors in each task is higher in the group of dyslexic participants.

Table 2. Scores on phonological processing tasks and comparison between groups

	(ND) n=56		(D) n=57		Contrast test
	M	(SD)	M	(SD)	
Pseudo-word repetition	0.3	(0.6)	0.8	(1.3)	t = 2.659; p = .005
Catalan					
PhonA Total	0.8	(1.4)	3.4	(6.5)	t = 2.918; p = .002
Pseudo-word reading	1.6	(1.6)	3.6	(1.8)	t = 6.403; p < .001
Spanish					
PhonA Total	0.7	(1.4)	3.9	(6.3)	t = 3.717; p < .001
Pseudo-word reading	1.2	(1.3)	3.7	(2.3)	t = 7.009; p < .001

Notes. Scores correspond to the mean number of errors. ND: No Dyslexia; D: Dyslexia; PhonA: Phonemic Awareness.

Firstly, it is important to highlight that in terms of the comparison of the tasks between languages, no significant differences are observed between the data obtained in the total PhonA in Catalan versus total PhonA in Spanish for both groups (ND: Z = -0.065; p = .948; D: Z = -1.273; p = .203). Similarly, in pseudo-word reading, we also observed that there were no significant differences in the number of errors in this task between Spanish and Catalan for both groups (ND: Z = -0.090; p = .928; D: Z = - 0.226; p = .821).

Table 3. Phonological processing skills in Catalan and Spanish according to groups

	Group 1 Middle Primary			Group 2 Upper Primary			Group 3 Secondary		
	ND n=20 M(SD)	D n=28 M(SD)	Contrasts	ND n=18 M(SD)	D n=16 M(SD)	Contrasts	ND n=18 M(SD)	D n=13 M(SD)	Contrasts
RepPseud	0.4(0.7)	1.0(1.5)	Z = -1.593; p = .111	0.2(0.5)	0.6(1.0)	Z = -1.298 p = .194	0.2(0.4)	0.6(1.4)	Z = - 0.611 p = .541
CATALAN									
PhonA	1.3(1.5)	5.7(8.5)	Z = -1.917; p = .055	0.9(1.6)	1.4(1.6)	Z = -.952 p = 0.341	0.2(0.7)	0.8(1.4)	Z = -1.076 p = 0.282
ReadPseud	2.3(1.5)	4.0(2.0)	Z = -3.023; p = .002	1.9(1.8)	3.4(1.6)	Z = -2.465 p = .014	0.6(0.6)	3.1(1.4)	Z = -4.513 p < .001
SPANISH									
PhonA	0.9(1.4)	6.6(8.0)	Z = -3.968; p < .001	0.9(1.8)	1.8(1.7)	Z = -2.045; p = 0.041	0.2(0.4)	0.5(1.4)	Z = -0.098; p = .922
ReadPseud	1.7(1.8)	4.5(2.5)	Z = -4.392; p < .001	1.2(1.0)	3.1(1.5)	Z = -3.486; p < .001	0.7(0.7)	2.7(2.1)	Z = -3.073; p = .002

Note. Scores correspond to the mean number of errors. ND: No Dyslexia; D: Dyslexia; PhonA: Phonemic Awareness. ReadPseud: Pseudo-word reading; RepPseud: Pseudo-word repetition; n. s. no significant.

As for the comparison with respect to educational stage groups, the results obtained are shown in Table 3. As can be seen in this table, for the Catalan language, pseudo-word reading is the only task in which participants show differences according to age group. It is interesting to note that the comparison in phonemic awareness in group 1 is close to significance.

Also in Spanish, pseudo-word reading is the only task in which participants show differences in all age groups. The comparison in relation to phonemic awareness is significant in group 1 and in group 2.

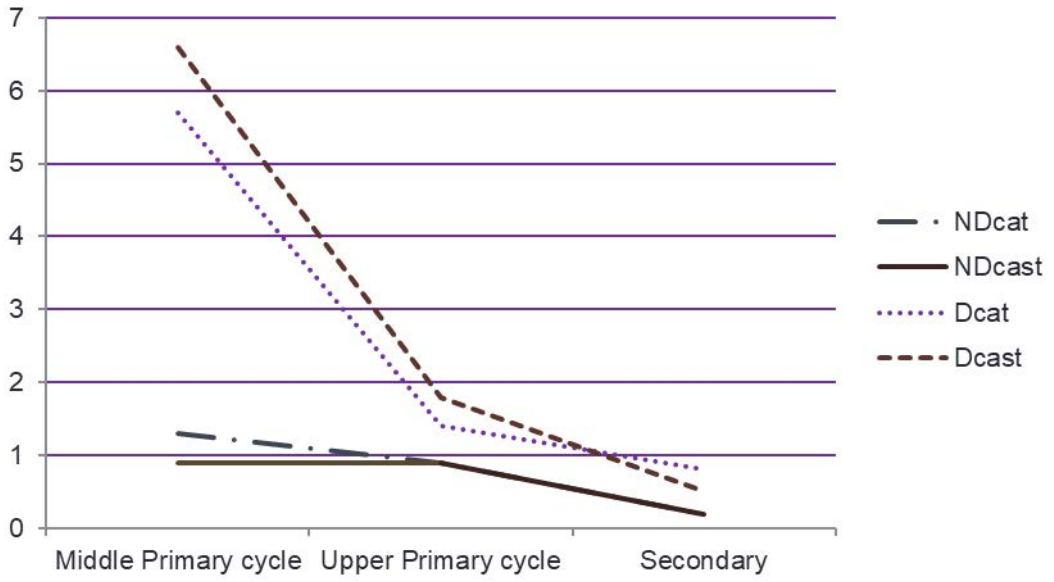
As for pseudo-word repetition, no significant differences are observed between the study groups (Neither in Catalan nor in Spanish).

In order to jointly illustrate the results obtained in both languages for the two variables that show significant differences (phonemic awareness and Pseudo-words reading), Figures 1 and 2 show the data by group and for both languages.

Figure 1 graphically illustrates the results in relation to phonemic awareness as a function of group, so that the decrease in the number of errors with educational stage can be observed in both languages studied. As

the figure shows, younger participants with dyslexia start with a higher number of errors than participants without dyslexia; however, from upper primary school onwards (10-11 years) the errors in this task in both languages are similar to those of participants without dyslexia.

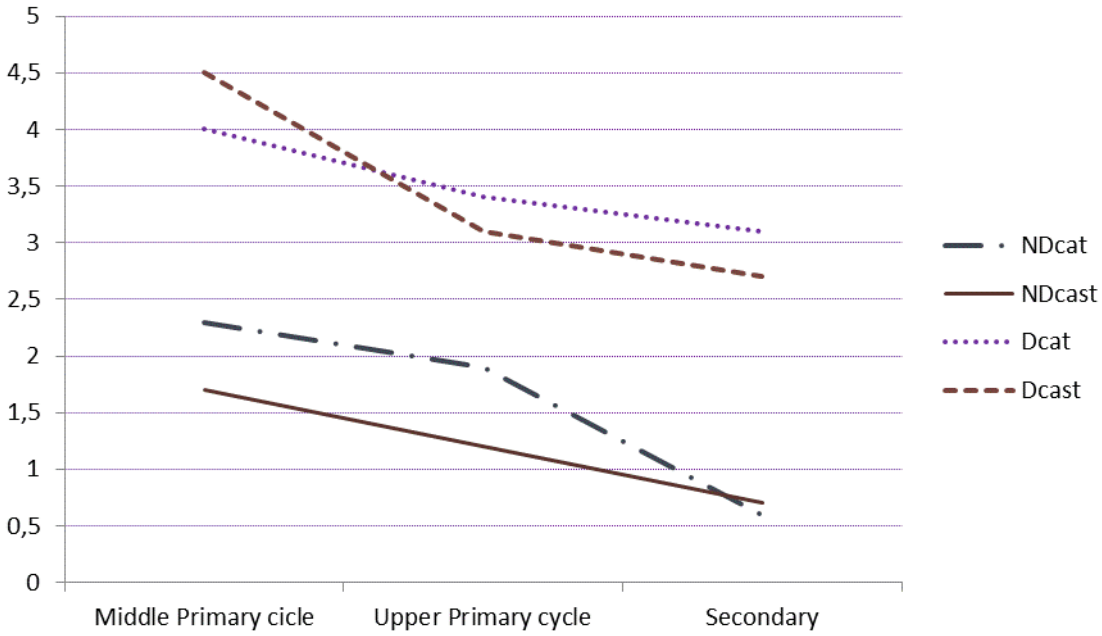
Figure 1. Phonemic awareness errors as a function of educational stage group and language group.



Note. ND: No Dyslexia; D: Dyslexia; cat: Catalan; cast: Spanish. This figure is based on means, not in Z scores.

As for the comparison of the phonemic awareness task between the two languages, after the transformation to Z scores, no significant differences are observed between the data obtained in the total PhonA in Catalan versus total PhonA in Spanish in the group of dyslexic children ($p > .05$ for all educational stage groups). However, significant differences are observed in the group of children without dyslexia in middle Primary group ($Z = -2.935$; $p = .003$) as well as in the secondary school group ($Z = -2.421$; $p = .015$). In both cases, they make more errors in Catalan. No significant differences are shown in the upper Primary group ($Z = -0.198$; $p = .843$).

Figure 2. Errors in pseudo-word reading as a function of educational stage group and language.



Note. ND: No Dyslexia; D: Dyslexia; cat: Catalan; cast: Spanish. This figure is based on means, not in Z scores.

As for the pseudo-word reading task, Figure 2 shows the errors as a function of educational stage group and language. Here we see that errors decrease similarly as a function of stage, both in participants with dyslexia and in participants without dyslexia. However, in contrast to the phonemic awareness task, it is

shown that the differences between the two groups of participants are maintained regardless of stage in the two languages studied.

In pseudo-word reading, after transformation to Z-scores, no significant differences are shown in the number of errors in this task between Spanish and Catalan ($p > .05$ for all stage groups).

Discussion

Overall, significant differences are observed in all tasks (total phonemic awareness, pseudo-word reading, and pseudo-word repetition) between the group of participants with dyslexia and the group of participants without dyslexia, similarly in both languages of the study. However, when the data are analyzed by educational stage group, the differences in pseudo-word repetition are no longer apparent, and differences in phonemic awareness are only observed in the younger group for Spanish, with a tendency towards significance in Catalan (see tables 1 and 2), although this is probably due to the lack of statistical power. However, in the pseudo-word reading task, differences between participants with and without dyslexia were found in all stage groups, as well as in both languages.

Regarding phonemic awareness, it is interesting to note that participants with dyslexia in secondary school perform at the same level as participants without dyslexia in middle primary school (Figure 1). Therefore, children with dyslexia in secondary school are similar in this task to children without dyslexia who are 4 or 5 years younger. Similarly, in pseudo-word reading, it is important to note that participants with dyslexia at the secondary school stage made more errors than participants without dyslexia at the middle primary school stage, who are four or five years younger (Figure 2).

The results of our study indicate that participants with dyslexia indeed show accuracy difficulties in phonological processing compared to their peers. These results support the phonological deficit theory and are therefore consistent with research that has found a higher error rate in persons with dyslexia in phonemic awareness tasks (Defior et al., 2005; Hulme et al., 2002; Jiménez et al., 2009). However, these difficulties are mainly concentrated in the youngest participants in the study, so that from upper primary school onwards, difficulties in phonemic awareness tend to disappear. Thus, in both languages, there is a positive evolution in phonemic awareness tasks: while in the non-dyslexic participants, errors practically disappear, the older participants with dyslexia continue to make errors in secondary school. Although the differences are no longer significant, performance on these tasks does not match that of the non-dyslexic group. In this sense, previous studies in Spanish point in the same direction (Rodrigo et al., 2009).

On the other hand, and in relation to the opacity or transparency of languages, although it has been observed that the effect of orthography on reading is stronger in opaque languages (Reis et al., 2020; Ziegler et al., 2010), in our study, which includes one language with transparent orthography and another with medium transparency, we did not observe differences in favour of the Spanish language in terms of accuracy in phonemic awareness tasks in the group of participants with dyslexia. We only observed such differences in the group of participants without dyslexia at the middle primary and secondary school levels. Therefore, it could be considered that students without difficulties do take advantage of the benefits of the transparent orthography of the Spanish language, but this is not the case for students with dyslexia.

If we look at the results of the pseudo-word reading task, we find highly significant differences in accuracy between the groups and in both languages. Moreover, this holds true for all educational stage groups. Although research by Goswami et al. (1998) conducted with 7-year-old children across three languages that differ in spelling depth (English, French, and Spanish) shows that participants make more errors in pseudo-word reading accuracy as the spelling depth increases, this is not the case in our study, as we observed a similar number of errors in both languages. Therefore, in the pseudo-word reading task, we can conclude with some certainty that it allows for discrimination between groups (D and ND) overall and in all stage groups. This type of task has shown good predictive ability for reading difficulties. The discrepancy between our findings and those of Goswami (1998) may be attributed to the linguistic proximity between Catalan and Spanish, which could facilitate cross-linguistic transfer.

Regarding phonological memory, in the pseudo-word repetition task, we can observe better performance by the group of participants without difficulties compared to the group with dyslexia. However, although the group without dyslexia maintains better performance overall, the significant differences disappear when we analyse the results by educational stage. Similar to the phonemic awareness task, the differentiation by educational stage group is only significant in the younger group. This result contrasts with the findings of the study by Vender et al. (2020), in which a pseudo-word repetition task allowed clear discrimination between 10-year-old children with and without dyslexia. It is worth noting that other studies in various languages have shown that phonological memory correlates moderately or weakly with reading ability (de Jong & Van der Leij, 1999; Dufva et al., 2001; Scarborough, 1998). Furthermore, similar to our study, Georgiou et al. (2008) find that phonological memory significantly contributes to predicting word reading skills only in the youngest group of children in the more transparent language.

Moreover, in line with previous results with bilingual samples (Lallier et al., 2014), we observed differences in phonological processing skills based on language. However, the observed differences are not significant, as they are only found in two of the stage groups in the study and in the phonemic awareness task.

Our study does not provide a clear explanation as to why, in the case of these two languages, differences were not observed that have been found in other bilingual populations with dyslexia. However, we can draw on the guidelines of Lallier and Carreiras (2018), who suggest that, in addition to grain size, there are other

factors that can also significantly influence literacy learning in bilingual students, meaning the impact of bilingualism does not always manifest in the same way.

In this regard, one possibility to consider is that the specific combination of languages in our study plays an important role, since the difference in grain size between Catalan and Spanish may be smaller than the difference between French and Spanish (Lallier et al., 2014). As a result, the same differences may not be evident as in the case of Spanish-French bilingualism. Still, we also consider it relevant to take into account the school and social context in which literacy learning takes place. Although the language of literacy learning is initially and primarily Catalan, from the primary school stage onward, literacy learning is provided in both Catalan and Spanish, and the written presence of Spanish is socially predominant. Therefore, literacy learning in both languages occurs simultaneously. We believe this socio-cultural characteristic is also important for interpreting the data obtained in this study. Another factor to consider, as previously noted, is the typological proximity between the two languages in our study, which may facilitate cross-linguistic transfer. Additionally, it is worth considering that bilingual students with difficulties may be using different strategies to compensate for their difficulties than students without dyslexia, and as a result, different outcomes may be observed between the two groups.

This study has pedagogical implications. The findings highlight the importance of sustained and targeted support for bilingual students with dyslexia, particularly in phonological processing tasks. The persistence of difficulties in pseudo-word reading across educational stages suggests that this task remains a reliable indicator for identifying dyslexia beyond early schooling. Educators should consider incorporating structured phonological training throughout primary and secondary education. Moreover, the absence of language-based differences in students with dyslexia underscores the need for consistent intervention strategies across both Catalan and Spanish. The study also emphasizes the value of early identification and continuous monitoring, as some older students with dyslexia perform below younger peers without dyslexia. These insights can inform more inclusive and effective literacy instruction in bilingual educational settings.

As a follow-up to this study, future research should investigate literacy learning in bilingual students with or without dyslexia, with larger samples and different language combinations. In fact, one limitation of this study is the lack of a monolingual pupil sample. Although a comparison with monolingual Spanish pupils would have been possible, we could not include a sample of monolingual Catalan pupils, since the participants are bilingual in both Catalan and Spanish. Furthermore, this study did not include measures of completion time in the assessment tasks, which could have provided valuable insights in differentiating between bilinguals.

Conclusions

In summary, as expected, our study shows that Catalan-Spanish bilingual students with dyslexia have greater difficulties in phonological processing skills than their non-dyslexic bilingual peers. In some tasks, older participants with dyslexia do not reach the level of younger non-dyslexic participants. On the other hand, pseudo-word reading appears to be the task that best differentiates students with dyslexia across the educational stages studied (middle primary school, upper primary school, and secondary school).

Furthermore, as a relevant and specific aspect of our study, these results are observed in both languages, Catalan and Spanish, in children with dyslexia. Interlinguistic differences are only found among bilingual children without dyslexia, with better accuracy in the phonemic awareness task in Spanish.

This study provides empirical data on how bilingualism interacts with dyslexia, particularly in relation to phonological processing. The analysis by educational stage, along with evidence that tasks such as pseudo-word reading remain effective for identifying dyslexia beyond the early years of schooling, represents a significant contribution to the field.

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Ignasi Ivern: Article conceptualization; First draft writing; Methodology; Writing revision draft. Statistics.
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Conflict of interest

There is no conflict of interest to declare.

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