# LINGUISTIC AND NON-LINGUISTIC PROSODIC SKILLS IN SPANISH CHILDREN WITH DEVELOPMENTAL DYSLEXIA

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# LINGUISTIC AND NON-LINGUISTIC PROSODIC SKILLS IN SPANISH CHILDREN WITH DEVELOPMENTAL DYSLEXIA


## Abstract

*Background:* The deficit on segmental phonology in developmental dyslexia is well established and according to recent studies this deficit extends to suprasegmental phonology or prosody. However, these studies have focused on word-level prosody. Further research is needed concerning prosodic deficit in dyslexia, especially with a Spanish-speaking population.

*Aims:* The aim of this study was to investigate the role of linguistic (word and phrase-level) and non-linguistic prosodic skills in Spanish children with developmental dyslexia.

*Method and procedure:* 48 Spanish children (8-9 years of age) from ten primary education schools were selected (24 children with developmental dyslexia and 24 chronological age-control children). Non-linguistic rhythm, word and phrase-level prosody, phonological awareness, nonverbal intelligence and reading aloud were assessed.

*Results:* The results obtained show that children with developmental dyslexia scored lower than typically developing readers on non-linguistic rhythm and word and phrase-level prosody tasks. The differences remained statistically significant at the phrase level after controlling for word-level processing (phonological or prosodic), phonological awareness, non-linguistic rhythm and reading skills.

*Conclusions:* Children with developmental dyslexia in Spanish exhibit a core deficit in suprasegmental phonology, at linguistic and non-linguistic levels. The implications of suprasegmental phonology skills for reading acquisition disabilities are discussed.



*Key words:* Developmental dyslexia, prosody, suprasegmental phonology, phrase-level prosody, non-linguistic skills.

What this paper adds?

This study investigates the role of suprasegmental phonology not only in words but also in phrases in Spanish children with developmental dyslexia. In addition, we analyse the influence of linguistic content, considering prosody at linguistic and non-linguistic levels. The results corroborate the existence of prosodic deficits in children with dyslexia. Specifically, the findings show that children with developmental dyslexia present a core deficit in prosodic processing at linguistic and non-linguistic levels. Interestingly, the results suggest that children with developmental dyslexia experience a deficit for phrase-level prosodic processing, regardless of word-level processing (phonological or prosodic), non-linguistic rhythm and reading skills that could affect reading comprehension.

## 1. Introduction

Reading is a complex psycholinguistic skill that requires interaction between visual, orthographic, phonological and semantic systems. Moreover, in alphabetic languages, reading acquisition requires an awareness of phonological sublexical units (Ziegler & Goswami, 2005). Therefore, speech processing skills are crucial for reading acquisition in these languages. A large body of research has established the critical importance of phonological skills to reading development (Melby-Lervåg, Lyster, & Hulme, 2012; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg 2001; Snowling, 2000). In fact, phonological awareness, the ability to recognise and manipulate the sounds of the words, is one of the most important predictors of early reading development in alphabetic orthographic systems (Caravolas et al., 2012), and poor phonological awareness is a defining feature of reading disability (Lyon, Shaywitz, & Shaywitz, 2003).

Developmental dyslexia is a specific learning disability, characterised by difficulties with accurate and/or fluent word recognition, and by poor spelling and decoding abilities, in spite of having average intelligence, adequate education and remedial attention (Vellutino, Fletcher, Snowling, & Scanlon, 2004). These difficulties are thought to result from a phonological deficit that is unexpected, given other cognitive abilities and effective classroom instruction (Lyon et al., 2003). The deficit in segmental phonology awareness, which refers to being aware of the single sound segments of spoken language in dyslexia, is well established (Anthony & Lonigan, 2004; Castles & Coltheart, 1993; Muter, Hulme, Snowling, & Taylor, 1998; Ramus, 2014; Ramus & Szenkovits, 2008; Ziegler & Goswami, 2005). However, phonological deficits extend to the processing of suprasegmental phonology which refers to the acoustic, physical properties of the speech stream, including intensity, fundamental frequency and duration of the signal (Shriberg & Kent, 2003) that are perceived as stress, time and intonation at the word or sentence level. This type of phonology has been the object of less research, but recent evidence shows that it is also related to literacy acquisition (Wang & Arciuli, 2015). The present study investigates this relation in children with dyslexia.

In the case of oral language acquisition, it has been shown that prosody (rhythm perception) helps children to segment continuous speech into meaningful words (Cutler & Mehler, 1993). Similarly, evidence suggests that suprasegmental phonology may support the development of segmental phonological skills or even support literacy skills (see Goswami et al., 2002; Thomson & Jarmulowicz, 2016; Wood, Wade-Woolley, & Holliman, 2009). In this respect, certain theoretical proposals have been made regarding prosody and reading. One of the first such models was developed by Wood et al. (2009), and later extended by Holliman, Critten, Lawrence, Harrison, Wood, and Huges (2014). In this model, prosody is related to phonological awareness, and then through morphology to literacy acquisition. According to this model, greater sensitivity to speech rhythms is associated with a higher capacity to identify relevant parts of speech in learning to read (e.g., phonemes, rhymes and words). In this respect, Goswami (2002) found that children with dyslexia have difficulty in detecting the amplitude envelope's rise-time at low frequencies, or the slow modulation of the speech amplitude envelope, which is one of the acoustic correlates of rhythm. More recently, Goswami (2011, 2018) proposed the Temporal-Sampling theory, according to which these difficulties hamper the neuronal entrainment of the speech signal at low frequencies. As neural processing is nested "in phase", difficulties at low frequencies would lead to poor integration of high frequencies processing, which is related to phoneme perception. This theory, moreover, predicts that children with dyslexia will have difficulty at processing any low frequency signal, whether linguistic or non-linguistic. In the present study, we examine the question of non-linguistic rhythm perception in children with dyslexia.

Recent studies have reported that children with developmental dyslexia present deficits in suprasegmental phonology (Cuetos, Martínez-García, & Suárez-Coalla, 2018; Goswami, Fosker, Huss, Mean, & Szucs, 2011; Holliman, Wood, & Sheehy, 2012; Jiménez-Fernández, Gutiérrez-Palma, & Defior, 2015). However, most research in this field has been carried out in English, and less has been conducted into languages with a transparent or phonologically-predictable orthography as is the case of Spanish, in which the relationship between speech sounds and written symbols is direct. Moreover, English and Spanish differ in their rhythmic structure (Peppé et al., 2009). English is a stress-timed language and the rhythm is marked by stress in content words. Spanish, by contrast, is a syllable-timed language, where every word is stressed and where rhythm is marked by the syllable. Thus, the implications for the strength of relationships between children's rhythm skills and their reading development could vary between different languages. Further investigation, therefore, is required to corroborate a possible deficit in suprasegmental phonology among a Spanish-speaking population with reading disabilities.

Researchers have highlighted the existence of a deficit in prosodic processing at the word level (ability/skill to perceive the stress, or to detect and manipulate the stressed syllable in a word) in English children with dyslexia (Goswami et al., 2013), with poor readers (Holliman et al., 2012) and also in a Spanish population with this type of learning disability (Cuetos et al., 2018; Jiménez-Fernández et al., 2015).

In a study of Spanish children with dyslexia, Jiménez-Fernández et al. (2015) found that children with dyslexia showed deficits in a stress-awareness task in which they were instructed to detect the syllable which sounded the strongest in trisyllabic words and pseudowords. Recently, Cuetos et al. (2018) analysed suprasegmental prosodic abilities in a study of eleven-year-old children with dyslexia. A word-level task included in this study was that of *syllable stress perception,* where the children listened to three-syllable words and made a same-different judgment about their stress pattern. Another task, involving prosodic perception, was *T-TRIP*, in which the children were asked to listen to the same nonsense syllable (ma) repeated two to six times but with varying stress patterns and rhythms. The children then had to repeat the sequence exactly as they had heard it. The results obtained showed that Spanish children with dyslexia scored lower than the controls on the prosodic tasks and on prosody perception. This relationship between word-level prosody and reading performance has also been found in other studies in Spanish with typically developing readers (Defior, Gutiérrez-Palma, & Cano-Marín, 2011; Gutiérrez-Palma, Defior, Jiménez-Fernández, Serrano, & González-Trujillo, 2016).

Prosody is a term that encompasses a broad range of phenomena, including phrasing, pausing, rate, loudness and stress (Shriberg, 1993). Therefore, it is not a unitary construct (Holliman et al., 2014) and it would be interesting to explore other levels, such as prosodic processing at the phrase level and non-linguistic rhythms, in order to better understand the role of prosody in developmental dyslexia. To date very few studies have been conducted with a Spanish population with dyslexia in this respect.

*Prosodic processing at the phrase level* concerns the suprasegmental features of speech that help the listener recognise syntactic structure, grammatical boundaries and sentence meaning. At this level, prosody is related to the ability to perceive rhythm, intonation and pauses. Oral-language prosodic features are represented in written language by means of stress marks in words in orthographies such as Spanish or Greek and by punctuation marks in sentences. Some examples in Spanish would be: “No. Quiero dormir” *vs.* “No quiero dormir” (No. I want to sleep *vs.* I don’t want to sleep), “¿Vienes conmigo?” *vs.* “Vienes conmigo.” (Are you coming with me? *vs.* You are coming with me) or “No quiero tomar té” *vs.* “No. ¡Quiero tomar té!” (I do not want to drink tea *vs.* No. I want to drink tea![1]). These sentences contain the same words but the meaning changes because the prosodic features are different. As mentioned above, research in a Spanish-speaking population has highlighted the role of word-level prosodic skills. In our study, phrase-level prosody is measured through the use of punctuation marks (see the Method section).

Both word and phrase-level prosodic processing are closely related to comprehension, since differences in suprasegmental features can alter the meaning of a sentence. In the case of phrase-level prosodic skills, several studies have investigated the role of prosodic skills in reading comprehension. Thus, Whalley and Hansen (2006) used a reiterative speech task to assess phrase-level processing in fourth-grade English speakers (mean age 9.3 years). In this task, called “DEEdee”, the prosodic pattern of a real phrase was replaced by the single meaningless syllable “dee” (Nakatani & Schaffer, 1978). The children were asked to match the real spoken phrase (a film or book title) with the correct “DEEdee phrase” (matched in terms of its intonation and prosodic patterns). The results showed a significant positive correlation between the performance in the DEEdee task and a reading comprehension test, even after controlling for word reading accuracy, phonological awareness and general rhythmic sensitivity. In a similar study, Goswami, Gerson and Astruc (2010) analysed phrase-level prosodic processing through the DEEdee task in children with dyslexia. The children with dyslexia were significantly impaired in the DEEdee task compared with chronological age-matched controls and with reading age-matched controls. These authors concluded that phonological and phrase-level prosodic processing made independent contributions to reading ability. Moreover, studies with English children have concluded that children with developmental dyslexia present deficits in phrase-level suprasegmental skills (e.g., Goswami et al., 2013).

Other studies have focused, instead, on the role of prosodic reading in dyslexia. Thus, Alves, Reis and Pinheiro (2014) compared temporal and prosodic parameters in

[1] Due to differences between English and Spanish, the translation of the examples alters the importance of punctuation marks.

nine-year-old Brazilian children with dyslexia, and a control group. The prosodic reading abilities of the two groups revealed unusual characteristics of the dyslexic group with respect to temporal processing (for example: reduced speed of reading articulation and alterations in the number and duration of pauses) and prosodic parameters (the children with dyslexia demonstrated limited melodic variation and had difficulty producing typical stress patterns). Spectrographic studies have also been conducted, to analyse reading prosody in a language with a transparent orthography such as Spanish for subjects with developmental dyslexia. Suárez-Coalla, Álvarez-Cañizo, Martínez, García and Cuetos (2016) analysed the prosodic reading abilities of children and adults with dyslexia. This study found that the subjects with dyslexia read more slowly and made less appropriate and longer pauses than typically developing readers. The participants with dyslexia also had a rather flat pitch contour. In sum, these spectrographic studies show that, as in English (e.g., Binder, Tighe, Jiang, Kaftanski, Qi, & Ardoin, 2013; Schwanenflugel et al., 2004) and Brazilian Portuguese (Alves et al., 2014), Spanish poor readers show inappropriate reading prosody.

Apart from linguistic prosodic skills, another prosody skill that has been examined among populations with dyslexia is that of *non-linguistic rhythm* (NL-R). It has been shown in a typical English-speaking population that NL-R sensitivity is related to reading acquisition (e.g., David, Wade-Woolley, Kirby, & Smithrim, 2007; Holliman, Wood, & Sheehy, 2010). It seems that difficulties in beat perception and production are particularly important for learning to decode, a reading subskill that depends on intact phonological skills (Lundetræ & Thomson, 2018). Measures of NL-R can be used as predictors of poor reading abilities, as demonstrated by Lundetræ and Thomson (2018) in a study of six-year-old Norwegian children. These authors reported that the performance of a productive rhythm task at school entry served as a predictor of poor abilities in word reading and spelling at the end of grade 1. A growing body of research supports the hypothesis of a link between NL-R sensitivity and emerging literacy skills in pre-school children (e.g., Dellatolas, Watier, Le Normand, Lubart, & Chevrie Muller, 2009; Lundetræ & Thomson, 2018; Moritz, Yampolsky, Papadelis, Thomson, & Wolf, 2013).

The link between NL-R and reading abilities has also been corroborated by studies of typically developing Spanish children (Calet, Gutiérrez-Palma, Simpson, González-Trujillo, & Defior, 2015; González-Trujillo, Defior, & Gutiérrez-Palma, 2014). González-Trujillo et al. (2014) assessed NL-R skills in third graders aged eight and nine years, using the Reproduction of Rhythmic Structures Scale (Stamback, 1984). NL-R predicted unique variance in reading fluency and correct stress assignment, regardless of intelligence and working memory. These authors observed that the ability to detect rhythm helps to identify syllables – an important sublexical unit for reading in Spanish (Carreiras & Perea, 2004). In addition, a longitudinal study with Spanish children reported that NL-R skills were among the best predictors (Calet et al., 2015).

In various studies of English-speaking populations, the participants with dyslexia scored lower on the NL-R tasks (e.g., Overy, 2000; Overy, Nicolson, Fawcett, & Clarke, 2003). Overy (2000) compared children with reading difficulties and children with no such difficulties in different NL-R tasks, and found that the former scored significantly lower in the rhythm copying task, which required children to copy a short rhythm after hearing it. In this line, too, Overy et al. (2003) assessed children with dyslexia (mean age 9.0 years) and controls (mean age 8.9 years) in three rhythm skills: rhythm copy, rhythm discrimination and song rhythm. The dyslexic group displayed significant deficits in NL-R tasks in comparison with the control group. To our knowledge, no previous studies have examined the performance of this prosodic skill by a Spanish population with dyslexia.

In sum, there is increasing empirical evidence that persons with dyslexia present a deficit in suprasegmental processing; nevertheless, the majority of the studies considered in our literature review refer to the prosodic skills of English speakers. Of the few studies to be conducted with a Spanish-speaking population with dyslexia, none have specifically analysed whether children with dyslexia also show deficits in prosodic processing at the phrase level or in NL-R. Therefore, in order to enhance our understanding of deficits in prosody in children with dyslexia in Spanish, the present study considers these questions, taking into account that they might be influenced by the orthographic transparency of the writing system. Hence, we examine whether Spanish children with developmental dyslexia show a prosodic processing deficit not only at the word level, but at the phrase level and at the non-linguistic level. Specifically, these research questions are addressed:

1. Are there significant group differences between children with dyslexia and chronological-age matched typical developers in NL-R sensitivity?

2. Are there significant group differences between children with dyslexia and the chronological-age matched controls in terms of linguistic prosodic skills (at the word and phrase levels)?

3. If so, do phrase-level suprasegmental skill differences remain after controlling for PA, word-level prosodic processing and NL-R skills? Do phrase-level suprasegmental skill differences remain after controlling for reading skills?

## 2. Method

### *2.1. Participants*

The study group was composed of 48 Spanish children (8-9 years of age) from ten primary education schools. The sample included 24 children with developmental dyslexia (11 girls; age *M* =100.4 months, SD = 4.5) and 24 typically developing readers (11 girls; age *M* = 100.7 months, SD = 4.6).

The participants for this study were selected in two steps. In the first, 61 children were indicated by their teachers as possibly presenting dyslexia. In the second step, these children were assessed to determine whether they met the inclusion criteria. The criteria used to make a diagnosis of developmental dyslexia were non-verbal IQ (NVIQ) of 90 and an average percentile below the 25th on four measures (accuracy and speed; word and pseudoword). Of the 61 participants identified by the teachers with reading difficulties, 24 satisfied the criteria for inclusion in the dyslexic group.

For the chronological control group, in the first step of the process, the teachers identified 36 ‘average’ children from the same classes as those of the children with dyslexia. In the second step, 24 were selected in accordance with the criterion of NVIQ of 90 or more and average scores for reading words and pseudowords equal to or greater than percentile 60 (see Table 1).

All participants were native Spanish speakers and had normal hearing and vision and no reported neurological or psychiatric disorder. All were of average socio-economic status and in the school year that corresponded to their chronological age. The parents were informed about the study and gave their consent for their children´s participation.

### *2.2. Materials and design*

This study includes standardised tests of cognitive ability and reading performance, together with tasks specifically designed for this research.

#### *2.2.1. General cognitive ability*

Non-verbal intelligence was estimated using the Raven Coloured Progressive Matrices (Raven, 1995), which assesses logical visual processing in the absence of linguistic content.

### *2.2.2. Reading*

In order to assess reading difficulties, measures of both accuracy and fluency (speed) must be obtained. The evaluation of speed (and not only accuracy) is particularly relevant in Spanish due to the transparency of this language (high consistency in grapheme-phoneme conversion), which means that measures of reading speed may be more sensitive to reading difficulties. For this purpose, word and pseudoword reading subtests from the LEE Battery (Lectura y Escritura en Español [Reading and Writing in Spanish]) were employed (Defior et al., 2006). Each test provides two measures, accuracy and speed (four measures in total).

#### *2.2.2.1. Word reading*

The participants were asked to read a list of 42 words of medium frequency varying in length and in orthographic complexity. A maximum of 2 points could be awarded for each item: one point for correct decoding and one point for fluent reading (e.g., absence of repetitions or syllabic reading). The participants' reading speed (the time spent reading all the items) was also measured.

#### *2.2.2.2. Pseudoword reading*

The participants were asked to read 42 items, composed of combinations of syllables extracted from the word reading task. Both accuracy and reading speed were measured; the scoring criteria were identical to those applied in the word reading subtest.

### *2.2.3. Suprasegmental phonology tasks*

The following tasks were set to measure word-level suprasegmental processing skills, phrase-level suprasegmental processing skills and NL-R:

#### *2.2.3.1. Word stress awareness (WSA)*

This task was composed of 3 practice and 18 test words (see Annex I). All the words in this task were trisyllabic; six were proparoxytones (e.g., lámpara [lamp]), six were paroxytones (e.g., domingo [Sunday]) and six were oxytones (e.g., caracol [snail]). The children listened to the previously recorded words, which were played one by one on a computer, and then had to press the letter on the keyboard that corresponded to the location of the stressed syllable, i.e. the one that sounded the strongest. The response keys were ‘‘v’’, ‘‘b’’, or ‘‘n’’ on a Spanish-language computer keyboard. These keys correspond spatially to the three possible locations of the strongest syllable. Thus, the participants were instructed to press the ‘‘v’’ key when the stress fell on the antepenultimate syllable, the ‘‘b’’ key when the stress fell on the penultimate syllable, and the ‘‘n’’ key when the stress fell on the final syllable. Accuracy (number of correct responses, up to a maximum of 18) was registered. Cronbach’s α reliability coefficient was .87.

*2.2.3.2. Pseudoword stress awareness (PSA)*

This task was equivalent to the Word Stress Awareness task, except that it involved pseudoword stimuli (see Annex II). Pseudowords were used to eliminate the influence of lexical knowledge in detecting the stressed syllable. Six items were proparoxytones (e.g., cátupos), six were paroxytones (e.g., sulipo) and six were oxytones (e.g., zabofá). Cronbach’s α reliability coefficient was .83. All other details of design were the same as for the WSA task.

*2.2.3.3. Phrase-level suprasegmental processing task*

The “Prosodia” subtest from the LEE Battery (Defior et al., 2006) was used for this task. This subtest is composed of one practice and eight test items. Every item contains two sentences, with the same words but different punctuation marks; hence, the meaning depends exclusively on the use of the punctuation marks, i.e. written prosody (for example, “No quiero tomar sopa” *vs.* “No. ¡quiero tomar sopa!” [I don`t want any soup *vs.* No. I want some soup!]). Three possible meanings were presented (for example, 1. Contesto que no y grito que quiero tomar sopa [I say no and I shout that I want some soup]; 2. Digo que no quiero tomar sopa [I say I don’t want any soup]; 3. Digo que quiero tomar sopa [I say I want some soup]: two were correct and one was a foil. The children had to read the sentences and connect the sentences and meanings; each sentence had only one correct meaning. The number of correct responses, with a possible maximum score of 16, was recorded. Cronbach’s α reliability coefficient was .58.

*2.2.3.4. Non-linguistic rhythm task*

The Reproduction of Rhythmic Structures Scale (Stamback, 1984) was used to measure NL-R skills. This is a production task in which children use a pencil to tap sequences of sounds previously reproduced by the computer. These sequences are composed of beats with short or long time intervals between them: 1/4 second or 1 second. The sequence difficulty increases progressively. In our study, the computer first provided two practice trials. The practice items were repeated until the child correctly produced the test items. For each test trial, the children were allowed a second attempt if their first one was incorrect, as recommended for this instrument. One point was awarded for each correct trial. All children attempted a minimum of 12 trials regardless of their performance. After Trial 12, testing was terminated if errors were made on both attempts of four consecutive trials. The maximum score on this task was 21.

#### *2.2.4. Phonemic awareness*

Two phonemic awareness tasks (segmental phonology) were selected, based on their strong link with reading acquisition in Spanish (Jiménez & Venegas, 2004). These tasks were applied individually.

##### *2.2.4.1. Blending Sounds (BS)*

Each child listened to individual sounds (e.g., /l/u/n/a/), recorded on a CD and pronounced by the researcher. Each item was presented at a rate of one per second, and children were asked to join them to form a word (e.g., luna [moon]). Each word was pronounced twice. There were 4 practice items and 14 test items, consisting of three to six phonemes (see Annex III). The participants received feedback only for the practice trials. The task was stopped if the child committed three consecutive errors. The number of correct responses, with a possible maximum score of 14, was recorded. The Cronbach's α reliability coefficient was .84.

##### *2.2.4.2. Counting Sounds (CS)*

The children listened to trisyllabic words, containing from 6 to 9 sounds, and were instructed to count their sounds (e.g., tostada [toast], 7 sounds). The test was composed of 3 practice items and 18 test items (see Annex IV). The number of correct responses, with a maximum score of 18, was recorded. Cronbach's α reliability coefficient was .57.

### *2.3. Procedure*

The children who were selected by their teachers as poor readers were tested individually in a quiet room at their school. The Raven Coloured Progressive Matrices test and word-pseudoword reading tests were applied in an initial session to see whether the children met the aforementioned criteria (word and pseudoword reading tests with percentile <25 and non-verbal intelligence test with percentile ≥ 90). Those who did were then tested in two individual sessions. In the first, the phonemic awareness (blending and counting sounds) and phrase-level prosodic processing tasks were applied, and the second was dedicated to the word-pseudoword stress awareness and NL-R tasks; stimuli presentation and response recording were controlled by E-Prime software, version 1.2. (Schneider, Eschmann, & Zuccolotto, 2002). When a participant with dyslexia was detected, the teacher was asked to find another child in the same class with similar characteristics (such as gender, reading instruction and school record) but with good reading skills. The two groups' non-verbal IQ and reading abilities are summarised in Table 1.

### *2.4. Data analysis*

Descriptive statistics were used to describe the different subgroups within the study participants (see Table 1). Separate ANOVAs were conducted for Phonemic Awareness tasks, NL-R, word-level suprasegmental tasks and the phrase-level suprasegmental task to detect inter-group differences. Finally, analyses of covariance (ANCOVA) tests were run to determine whether differences between the groups in phrase-level suprasegmental phonology skills remained after controlling for PA, NL-R, word-level suprasegmental and reading skills.

## 3. Results

A single-sample t-test comparison of the two groups revealed differences in the four reading measures but not in age or in non-verbal IQ, as required in the entry criteria (see Table 1).

**Table 1**

Descriptive statistics. Percentile means and (standard deviations) by group.

| | Male/ Female | Age (months) | Non-verbal IQ (Raven) | Percentile word reading accuracy | Percentile word reading speed | Percentile pseudoword reading accuracy | Percentile pseudoword reading speed |
|---|---|---|---|---|---|---|---|
| Dyslexia group (N = 24) | 13/11 | 100.4 (4.5) | 99.6 (7.4) | 5.7 (2.3) | 10.2 (11.3) | 6.5 (3.8) | 19 (22.2) |
| Typically developing group (N = 24) | 13/11 | 100.7 (4.6) | 100.3 (7.6) | 81.5 (15.8) | 82.5 (12.3) | 71 (20.8) | 82.9 (10.2) |
| Group comparison | | n.s. | n.s. | $p < .0001$ | $p < .0001$ | $p < .0001$ | $p <.0001$ |

*Note.* In parentheses: standard deviation.

Table 2 shows the mean accuracy score achieved by the DD and TD groups in the phonemic awareness task and in the suprasegmental phonology tasks (NL-R, WSA, PSA and phrase-level suprasegmental tasks). One-way ANOVA confirmed that the dyslexia group (DD) showed a significantly poorer performance than the typically developing group (TD) in the Blending task, $F(1, 46) = 30.91$, $p < .0001$, $\eta^2_p = .40$ and in the Counting Sounds task, $F(1, 46) = 14.93$, $p < .0001$, $\eta^2_p = .25$.

**Table 2**

Accuracy (means and standard deviations) by each group in the phonemic awareness and suprasegmental phonology tasks.

| | Blending (Max. 14) | Counting Sounds (Max. 9) | NL-R | WAS (Max. 18) | PSA (Max. 18) | Phrase-level suprasegmental task (Max. 16) |
|---|---|---|---|---|---|---|
| Dyslexia group (N= 24) | 6.5 (3.1) | 4.5 (1.9) | 27.25 (7.58) | 11.6 (4.2) | 9.9 (3.7) | 9.8 (3.2) |
| Typically developing group (N= 24) | 11.3 (2.9) | 6.4 (1.5) | 33.54 (5.04) | 15.3 (3.7) | 13.6 (3.9) | 13.9 (1.8) |
| *P* | .00 | .00 | .00 | .00 | .00 | .00 |

*Note*. In parentheses: standard deviation; NL-R = Non-linguistic rhythm; WSA= Word stress awareness; PSA= Pseudoword stress awareness.

ANOVA also confirmed that the dyslexia group showed significantly poorer performance than the typically developing group in the non-linguistic prosodic task, $F(1, 46) = 11.47$, $p = .001$, $\eta^2_p = .20$, in the WSA task, $F(1, 46) = 10.07$, $p = .003$, $\eta^2_p = .18$ and in the PSA task, $F(1, 46) = 11.39$, $p = .002$, $\eta^2_p = .20$. As both tasks were significantly correlated ($r = .802$; $p < .001$), a composite score was calculated in order to obtain a single measure of word-level suprasegmental processing.

Furthermore, one-way ANOVA revealed significantly poorer performance by the dyslexia group in the phrase-level suprasegmental task, $F(1, 46) = 30.99$, $p = .001$, $\eta^2_p = .40$. These results suggest that the children with dyslexia have a core deficit for prosodic processing, at the linguistic and non-linguistic levels.

As the Counting Sounds and Blending tasks were significantly correlated ($r = .471$; $p = .001$), a composite z-score was calculated in order to obtain a single measure of phonemic awareness, which was used for the analysis of covariance. The results of the ANCOVA showed that after controlling for phonemic awareness, differences between the groups in the phrase-level suprasegmental processing task remained statistically significant, $F (1, 46) = 9.43$, $p < .001$, $\eta^2_p = .17$.

Another ANCOVA confirmed that the differences between the TD and DD groups remained significant for phrase-level suprasegmental processing skills after controlling for NL-R, $F (1, 46) = 19.22$, $p < .001$, $\eta^2_p = .30$. This finding suggests that suprasegmental linguistics differences cannot be explained by the lower NL-R in the dyslexia group.

A third ANCOVA showed that the differences between the TD and DD groups remained significant for phrase-level suprasegmental processing skills after controlling for word-level suprasegmental processing skills, $F(1, 46) = 16.45$, $p < .001$, $\eta^2_p = .27$, which suggests that the children with dyslexia have a deficit for phrase-level prosodic processing, regardless of word-level processing (either phonological or prosodic) and non-linguistic prosodic skills.

The fourth and final ANCOVA showed that differences between the TD and DD groups remained significant for phrase-level suprasegmental processing skills after controlling for word and pseudoword reading, $F(1, 46) = 6.67$, $p < .05$, $\eta^2_p = .13$.

## 4. Discussion

The aim of this study was to examine suprasegmental phonology skills in children with dyslexia, at linguistic and non-linguistic levels. This is a novel aspect; the role of segmental phonology in dyslexia is well established, but that of suprasegmental phonology has been less widely investigated. Recent studies have revealed a deficit in word-level prosodic processing in English children with dyslexia (Goswami et al., 2013; Holliman et al., 2012), and also in Spanish children with dyslexia (Cuetos et al., 2018; Jiménez-Fernández et al., 2015). However, further research is required to determine whether Spanish speakers with reading disabilities present a deficit in suprasegmental phonology, at the phrase level and at the non-linguistic level.

Firstly, our results corroborate that children with dyslexia present a poorer performance in segmental phonology than typically developing readers of the same age. As mentioned before, this is not surprising given the literature supporting these results in different orthographies (e.g., Bradley & Bryant, 1978; Cuetos et al., 2018; Goswami et al., 2013; Jiménez-Fernández et al., 2015; Lyon et al., 2003; Moll et al., 2014; Ramus & Szenkovits, 2008; Ramus, 2014; Serrano & Defior, 2008; Share, 1995; Snowling, 2000).

One of the main findings of our study is that the children with dyslexia presented a core deficit in suprasegmental phonology processing at linguistic and non-linguistic levels. Three prosodic tasks, which have been used in previous research involving Spanish children, were selected to measure word and phrase-level prosodic processing and NL-R. As previous studies had suggested, the results confirmed poorer performance by the dyslexic group in suprasegmental processing at the word level, both for words and for pseudowords (Cuetos et al., 2018; Goswami et al., 2013; Jiménez-Fernández et al., 2015). Regarding suprasegmental processing at the phrase level, when phonemic awareness and word-level suprasegmental tasks were entered as covariates, differences in the phrase-level prosodic tasks remained statistically significant. This finding indicates a possible deficit in phrase-level suprasegmental processing regardless of word-level suprasegmental processing. These differences in suprasegmental processing at the phrase level also persisted when NL-R was introduced as a covariate. It should be taken into account that phrase-level processing has more complexity and difficulty, and so the children are faced with a greater challenge. To solve the task presented in this study, the children had to cope with punctuation marks, intonation, pauses and stress. Our results are in accordance with previous studies in English, which have reported differences between children with dyslexia and control children in phrase-level suprasegmental processing skills (Goswami et al., 2010; Goswami et al., 2013).

The NL-R deficit observed in these Spanish children with dyslexia is comparable with that found in previous studies with English-speaking populations given similar tasks (Overy, 2000; Overy et al., 2003). It seems that rhythm facilitates the segmentation of continuous speech into meaningful words, a crucial aspect in vocabulary acquisition and the development of phonological awareness, meaning that any impairment in rhythm perception would provoke a deficit in reading acquisition (Wood et al., 2009). The task used in the present study to measure non-linguistic prosodic skills has previously been used in longitudinal and correlational studies in Spanish, and the results obtained highlight the relationship between NL-R and reading abilities in typically developing readers (Calet et al., 2015; González-Trujillo et al., 2014). To our knowledge, the present study is the first in which the task has been used with Spanish children presenting developmental dyslexia. The fact that Spanish children with dyslexia scored lower than typical readers on NL-R, like their English-speaking counterparts, strongly suggests that a NL-R deficit is common across languages, independently of their characteristics. As a consequence of this deficit, children with dyslexia would have diminished their ability to segment the speech into meaningful words. Therefore, they would have affected vocabulary and phonological awareness development (Wood et al., 2009).

Further research has suggested that the origin of this NL-R deficit has to do with difficulties for perceiving the rise-time at low-frequencies (Goswami, 2002), which is one rhythm's acoustic correlate. More recently, Goswami in her Temporal-Sample theory (2011, 2018) has linked this rise-time deficit to an impaired integration of speech processing; she proposes that an underlying difficulty in neural rhythmic entrainment, besides poor perception of acoustic rhythm, and poor perception of amplitude envelope rise time are all associated with developmental dyslexia and are one cause of the poor phonological skills of children with this learning disability. Therefore, according to the Temporal-Sample theory, the link from rhythm to reading goes from rise-time perception to phonological development, namely from difficulties for rise-time perception at low frequencies. Thus, this theory would predict that children with dyslexia would have difficulties for any type of low-frequency perception, including NL-R difficulties. The results of the present study support this hypothesis. Accordingly, an interesting area for future research would be to explore non-linguistic prosodic skills, using not only a productive rhythm task but dyslexia would be found whatever the task (productive or perceptive), and cross-linguistically.

Although Spanish is a language with a transparent orthography, we observed a similar deficit profile to what has been reported for English populations, that is, suprasegmental processing bears a direct relation with reading disabilities. Therefore, both levels of phonology – segmental and suprasegmental – are relevant to reading ability, to which each skill makes an independent contribution.

The present findings are novel in several ways. This is the first time that phrase-level prosodic processing (through the use of punctuation marks) and NL-R have been studied in Spanish children with dyslexia. Additionally, we show that the phrase-level deficit is not related to word-level or non-linguistic deficits. These findings may impact on the educational field by showing that assessment and intervention in such cases should take into account both linguistic and non-linguistic prosodic skills in reading acquisition and dyslexia. Moreover, in the case of non-linguistic prosodic skills it might be interesting to consider them in the assessment of reading difficulties. The assessment of this ability prior to the acquisition of decoding skills could provide an early marker of reading difficulties in later life. These findings also suggest that training in non-linguistic prosodic skills could benefit reading acquisition.

A limitation of this study is that the measure of phrase-level suprasegmental phonology involved written stimuli and thus required the children with dyslexia to read. However, word-decoding problems that might affect these children (i.e., using the grapheme-to-phoneme conversion rules) cannot explain the study results, as the children were required to read two sentences with exactly the same words ("No voy a dormir" vs. "No. Voy a dormir"). In fact, when reading skills were entered as covariates, the differences between the outcomes of the phrase-level prosodic tasks remained statistically significant. Therefore, these results show that children with dyslexia have problems in decoding punctuation marks or written prosody, and thus provide evidence that the children's decoding deficit includes suprasegmental phonology at the phrase level. Moreover, phonological awareness (closely related to word-decoding skills) was controlled for in the ANCOVA analyses, and nevertheless significant differences were found in phrase-level prosody. Further research should include oral prosody tasks, but as a first step, we have shown that problems are encountered in decoding phrase-level prosody during a reading task. A valuable second step would be to examine whether similar problems arise in oral phrase-level suprasegmental tasks.

Another limitation was that the internal reliability for the measure of phase-level suprasegmental processing task was only moderate (Cronbach' s $\alpha = .58$). Therefore, to validate our findings, future research should incorporate a more reliable phase-level suprasegmental processing task.

Finally, in future work in this area it would be advisable to include another group of reading age-matched controls, something that was not possible in our study because children at an initial stage of reading (i.e., a reading-matched control group) would not totally understand some prosodic tasks. In an exploratory study, a reading-matched control group was selected, but they achieved only random-level accuracy in the stress-awareness task, possibly because at this initial stage of reading, the children do not yet fully understand the concept of ''syllable'', which is a basic prerequisite for performing the task.

## 5. Conclusions

The findings from this study support the idea that Spanish children with dyslexia exhibit a core deficit in suprasegmental phonology processing skills, both at the linguistic and at the non-linguistic level. These results may have practical implications for special education, suggesting that it might be useful to train children with dyslexia in both linguistic and non-linguistic prosodic skills. Further exploration of suprasegmental skills is needed for children with dyslexia at different stages of learning to read.

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