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# Music skills of Spanish-speaking children with developmental language disorder

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ABSTRACT

*Background:* According to temporal sampling theory, deficits in rhythm processing contribute to both language and music difficulties in children with developmental language disorder (DLD). Evidence for this proposition is derived mainly from studies conducted in stress-timed languages, but the results may differ in languages with different rhythm features (e.g., syllable-timed languages).

*Aims:* This research aimed to study a previously unexamined topic, namely, the music skills of children with DLD who speak Spanish (a syllable-timed language), and to analyze the possible relationships between the language and music skills of these children.

*Methods and Procedures:* Two groups of 18 Spanish-speaking children with DLD and 19 typically-developing peers matched for chronological age completed a set of language tests. Their rhythm discrimination, melody discrimination and music memory skills were also assessed.

*Outcomes and Results:* Children with DLD exhibited significantly lower performance than their typically-developing peers on all three music subtests. Music and language skills were significantly related in both groups.

*Conclusions and Implications:* The results suggest that similar music difficulties may be found in children with DLD whether they speak stress-timed or syllable-timed languages. The relationships found between music and language skills may pave the way for the design of possible language intervention programs based on music stimuli.

## What this paper adds

Temporal sampling theory proposes that problems for the auditory discrimination of the acoustic parameters involved in the expression of stress contribute to both the language and music impairments of children with developmental language disorder (DLD). Most of the studies on this topic have been conducted in English, a stress-timed language, but languages differ in rhythm, which may have different perceptual consequences for children with DLD. Thus, in French and Italian, two syllable-timed languages, there have been contradictory results as to whether children with DLD present impairments in music processing.

Our research offers new evidence in this respect by showing, for the first time, that the music skills of children with DLD who speak Spanish—another syllable-timed language—are lower than those of typically-developing children matched for chronological age.

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Prior studies conducted in stress-timed languages found significant relationships between the language and music skills of children with DLD. Our study shows the same relationships. To the best of our knowledge, this is the first time that these relationships have been found in children with DLD who speak a syllable-timed language.

Our findings are consistent with temporal sampling theory and suggest that children with DLD may have similar music difficulties whether they speak stress-timed or syllable-timed languages.

## 1. Introduction

### 1.1. Developmental language disorder and classical explanatory approaches

Children with developmental language disorder (DLD) present with severe and persistent problems in language skills that cannot be accounted for by any known biomedical condition (Bishop et al., 2017). Formerly referred to as specific language impairment, the new term acknowledges that language may not be the only area affected in this disorder (Bishop et al., 2017).

Impairments in morphosyntax have been considered the hallmark of DLD (Leonard, 2014). Therefore, dominant explanatory theories propose a grammatical deficit as the origin of this disorder (e.g., van der Lely & Pinker, 2014). In contrast to this domain-specific view, a different account suggests that low-level auditory processing deficits help explain the disorder (Tallal & Piercy, 1973). Specifically, the perception of rapid spectrotemporal information is claimed to be impaired. While the impairment is not considered to be specific to language, thus potentially affecting the processing of any sound, it is considered to be very relevant for speech and language processing because it affects the fast temporal window of speech acoustic energy in which the brief formant transitions of consonants occur (Tallal, 2004). Nevertheless, studies on this theory have shown contradictory results (Bishop et al., 1999).

### 1.2. DLD as explained by temporal sampling theory and the prosodic-phrasing hypothesis

More recently, a different theory has also highlighted the role of low-level auditory processing in language development by considering different features of the speech signal. Acoustic energy in speech contains rhythmic variations in different nested scales, including both fast and slow temporal windows (Goswami, 2011; Poeppel, 2014). A slow window—at an approximate rate of 500 ms in any language—corresponds to stressed syllables (Goswami, 2011). It therefore refers to suprasegmental or prosodic information and contributes to the rhythm of the speech signal, since the way in which stress is distributed within a language defines its rhythm. In this respect, a distinction between syllable-timed and stress-timed languages has long been proposed, with the two categories being mutually exclusive, because while in the former, the distance between stressed syllables varies, in the latter, the stressed syllables occur at approximately the same rate (Dauer, 1983).

On this basis, temporal sampling theory claims that the discrimination of the acoustic parameters involved in stress plays a key role in the integrated perception of the different temporal windows of the speech signal, especially in the earliest stages of development (Goswami, 2016, 2017). This claim, in turn, is founded on the multi-time resolution model of neural speech encoding, according to which the acoustic information of stressed syllables is used for neural alignment between rhythmic intrinsic neural oscillations and the different temporal windows of the speech signal, thus enabling successful speech perception (Giraud & Poeppel, 2012; Goswami, 2019; Poeppel, 2014). Therefore, stressed syllables not only play an important role in the rhythmic structure of many languages but are also fundamental for typical speech perception and language development (Goswami, 2015, 2016, 2019).

Based on this view, the prosodic-phrasing hypothesis proposes that auditory difficulties in the processing of the acoustic correlates of stress produce subtle atypicalities in speech perception, leading to problems in language understanding, with cascading effects on all the components of language (Cumming, Wilson, & Goswami, 2015; Goswami et al., 2016). More specifically, under this hypothesis, difficulties in processing rhythmic phrasing help account for the syntactic impairment observed in DLD (Richards & Goswami, 2019). There is growing evidence supporting this hypothesis. Syllable stress is expressed through acoustic correlates such as pitch, duration, and amplitude rise time (i.e., time needed to reach the peak of intensity) (Greenberg et al., 2003; Quilis, 1981), and children with DLD have been found to present discrimination problems for these parameters (Beattie & Manis, 2013; Corriveau et al., 2007; Cumming, Wilson, & Goswami, 2015; Mengler et al., 2005; Richards & Goswami, 2015, 2019). Auditory discrimination problems correlate with the performance of children with DLD on prosodic stress and phrasing tasks (Cumming, Wilson, & Goswami, 2015; Richards & Goswami, 2015, 2019). In turn, the difficulties that such children face in prosodic stress tasks significantly relate to their impairments in vocabulary and grammar (Cumming, Wilson, & Goswami, 2015; Cumming, Wilson, Leong, et al., 2015).

### 1.3. Relationships between language and music in typically-developing children

The auditory processes related to linguistic rhythm, as highlighted in temporal sampling theory, are not specific to language, despite being especially relevant to this domain (Martínez-Castilla, 2021). Another domain to which the same processes are relevant is music. Thus, the aforementioned acoustic parameters related to stress are also fundamental for neural processing and the perception of musical rhythm (Brandt et al., 2012; Cumming, Wilson, Leong, et al., 2015; Doelling et al., 2019).

Considering that the same low-level auditory processes are relevant to the domains of both language and music, it may be hypothesized that language processing and music processing are related. In fact, there is evidence in this regard in typically-developing (TD) individuals. In TD children, music skills are significantly related to speech perception and grammar (Gordon et al., 2015; Lee et al., 2020; Swaminathan & Schellenberg, 2020). When comparing different music skills, such as rhythm and melody discrimination, the evidence seems to be clearer regarding the relationships between language and musical rhythm (Swaminathan & Schellenberg, 2020), although melody discrimination has also been found to be related to grammar (Politimou et al., 2019).

### *1.4. Music and language skills in children with DLD who speak a stress-timed language*

Considering the aforementioned perspective of domain relevance and the extant evidence in TD children, impairments in music processing in children with DLD are to be expected based on temporal sampling theory and the prosodic-phrasing hypothesis (Cumming, Wilson, Leong, et al., 2015). Relationships between such impairments and language difficulties are also expected for children with DLD (Cumming, Wilson, Leong, et al., 2015). Studies in children with DLD who speak stress-timed languages (e.g., English or German) have provided evidence in this respect. Thus, compared with TD children of the same chronological age (CA), English- and German-speaking children with DLD have been found to present impaired rhythmic skills in beat synchronization (Corriveau & Goswami, 2009; Cumming, Wilson, Leong, et al., 2015), beat perception (Cumming, Wilson, Leong, et al., 2015) and rhythm discrimination (Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015). The same result has been found for melody discrimination (Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015) and music memory (Sallat & Jentschke, 2015).

As expected from the prosodic-phrasing hypothesis, in children with DLD who are native speakers of stress-timed languages, musical rhythm discrimination is significantly related to vocabulary and grammar skills (Cumming, Wilson, Leong et al., 2015; Sallat & Jentschke, 2015). Melody discrimination and music memory also relate to these areas of language in children with DLD (Sallat & Jentschke, 2015).

### *1.5. Studies in children with DLD who speak syllable-timed languages*

As previously mentioned, languages differ in rhythm (Dauer, 1983). As a function of these differences, the perceptual consequences derived from the prosodic-phrasing hypothesis may differ (Goswami, 2019). Considering the rhythmic differences between stress-timed and syllable-timed languages, it would be relevant to conduct studies on children with DLD who speak either of these types of languages. However, studies based on temporal sampling theory have mainly been conducted in English, a stress-timed language (e.g., Cumming, Wilson, & Goswami, 2015; Cumming, Wilson, Leong, et al., 2015; Richards & Goswami, 2015, 2019).

In Italian, a syllable-timed language, Caccia and Lorusso (2019) concluded that rhythmic prosodic processing is not impaired in children with DLD, posing a problem only when there is an interaction with syntax. In a different study, the same authors found similar results regarding musical rhythm (Caccia & Lorusso, 2021). Thus, in contrast to what would be expected from temporal sampling theory and the prosodic-phrasing hypothesis, the discrimination of musical rhythmic sequences was not found to be impaired in Italian-speaking children with DLD compared with TD children of the same CA.

Different results have been found in other syllable-timed languages. In Spanish, a rhythmic prosodic impairment has been found in children with DLD not only when prosody interacts with syntax but also in the processing of prosody alone (i.e., without a linguistic function) (Calet et al., 2021). In agreement with this latter result, in the field of music, French-speaking children with DLD have been found to perform significantly worse than CA-matched TD peers on musical rhythm discrimination, melody discrimination and music recognition tasks (Bedoin et al., 2016; Clément et al., 2015).

### *1.6. Scope, aims and hypotheses of the study*

There are few studies on the music skills of children with DLD who speak syllable-timed languages, and their results are contradictory (Bedoin et al., 2016; Caccia & Lorusso, 2021; Clément et al., 2015). Thus, while Italian-speaking children with DLD have been observed to show impaired musical rhythm discrimination only if called on to establish relationships between musical rhythm and language (Caccia & Lorusso, 2021), French-speaking children with the disorder have shown impairments in musical rhythm discrimination even as a standalone task (Bedoin et al., 2016; Clément et al., 2015). Our research aimed to offer new evidence on and clarify this issue by ascertaining whether the music skills of children with DLD who speak Spanish—another syllable-timed language—are impaired. The research also sought to study whether the music skills of Spanish-speaking children with DLD relate to their language ability, a result that has previously been found only in children with DLD who speak stress-timed languages (Corriveau & Goswami, 2009; Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015). To achieve these aims, the musical rhythm discrimination, melodic discrimination and music memory skills of Spanish-speaking children with DLD were compared with those of TD peers matched for CA. The possible relationships between these music skills and the language skills of children with DLD were also studied. Based on temporal sampling theory and the prosodic-phrasing hypothesis (e.g., Cumming, Wilson, & Goswami, 2015; Goswami, 2015, 2016, 2019; Goswami et al., 2016), it was hypothesized that Spanish-speaking children with DLD would show impaired music skills, particularly in rhythm discrimination. Significant relationships between the music and language skills of children with DLD were also expected.

## 2. Method

### *2.1. Participants*

The study group was composed of 37 Spanish-speaking children (5–11 years of age). The sample included 18 children with DLD (17 boys) and 19 CA-matched TD children (6 boys). To select the participants with DLD, the following criteria were used (Aguado et al., 2015):

• A standard nonverbal IQ score equal to or greater than 75, as measured by the Matrices subtest of the Kaufman Brief Intelligence Test (K-BIT, Kaufman & Kaufman, 2000).

• A score of 1.5 SD below average on the Grammatical Structures Comprehension Test (CEG), i.e., a test evaluating receptive grammar in the Spanish language (see below) (Mendoza et al., 2005), and the sentence repetition subtest of the Spanish versions of the Clinical Evaluation of Language Fundamentals-4 (CELF-4) (Semel et al., 2003) or the CELF Preschool-2 (Wiig et al., 2009), depending on participants' CA.

• No additional diagnoses of hearing impairment, dyslexia or any other neurodevelopmental disorder.

• A diagnosis of DLD.

As mentioned, the DLD and TD groups were matched for CA ($p = .77$). There were no significant between-group differences in nonverbal cognitive performance ($p = .14$). Descriptive statistics on the participants are shown in Table 1. To compare between-group performance on the linguistic measurements, *t* tests were conducted. As expected, the children with DLD performed significantly worse than the TD children on the CEG ($t(29.27) = -7.02$, $p < .001$, $r = 0.79$) and the sentence repetition subtest of the CELF ($t(35) = -5.79$, $p < .001$, $r = 0.73$). The participants also completed the Peabody Picture Vocabulary Test-III (PPVT-III, Dunn & Dunn, 2010) and the K-BIT vocabulary expression test (see below), and the children with DLD obtained significantly lower scores than the TD children on both tests ($t(26.28) = -4.41$, $p < .001$, $r = 0.63$; $t(35) = -3.27$, $p = .002$, $r = 0.51$, respectively).

The participants in this study were recruited from schools and private clinics. In schools, a diagnosis of DLD was made by the school counsellors (i.e., professionals specialized on education, and language and cognitive development). Afterwards, teachers, who had been informed about the diagnosis, identified the children with DLD for the purpose of this study. In private clinics, the diagnosis was made and referred to by the clinic specialists. To confirm the diagnosis of DLD, the children were administered the CEG, the CELF sentence recall subtest, and the K-BIT Matrices subtest, as previously mentioned.

All the participants were native Spanish speakers, attended schools in the Spanish provinces of Granada or Jaén and were in the academic year corresponding to their age. As reported by parents, none of the participants attended to music schools or had received music lessons apart from those of the music subject included in the Spanish educative system. No information on the socioeconomic status of participants was collected. The schools were located in middle-to-high income areas.

## 2.2. Materials

Nonverbal IQ, language abilities and music skills were evaluated in all the participants by administering the following tests.

### 2.2.1. Nonverbal cognitive ability

The Matrices subtest of the Spanish version of the K-BIT (Kaufman & Kaufman, 2000) was used as a measure of nonverbal IQ; this instrument evaluates nonverbal reasoning through analogies. The subtest consists of 48 items, and each correct answer is awarded one point. The Cronbach's alpha coefficient indicated by the test manual is.86.

### 2.2.2. Language abilities

Grammar and vocabulary comprehension and expression skills were evaluated in the study. Grammar comprehension was assessed through the full CEG test (Mendoza et al., 2005), and grammar expression was evaluated through the sentence recall subtest of the Spanish versions of the CELF-4 (Semel et al., 2003) or the CELF Preschool-2 (Wiig et al., 2009). Receptive vocabulary skills were assessed by means of the full PPVT-III test (Dunn & Dunn, 2010), while vocabulary production was studied through the expressive vocabulary subtest of the K-BIT (Kaufman & Kaufman, 2000). These tests and subtests are described below.

The CEG (Mendoza et al., 2005) assesses the comprehension of different grammatical structures in children from 4 to 12 years old. The child is asked to choose which of four pictures best represents the sentence that the examiner says aloud. There are 80 items structured in 20 blocks of increasing difficulty (80 is also the maximum score). The Cronbach's alpha coefficient as reported by the test manual is .91.

The CELF-4 sentence recall subtest (Semel et al., 2006) evaluates morphosyntactic expression by means of sentence repetition. It consists of 32 sentences of increasing difficulty that the participant must repeat. As reported in the manual, the Cronbach's alpha

**Table 1**
Mean and Standard Deviation for Each Group in Age, Nonverbal IQ and Language Ability Tests.

| | Group with DLD ($n = 18$) | | TD group ($n = 19$) | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| CA | 7.43 | 2.25 | 7.64 | 1.97 |
| Nonverbal IQ (K-BIT) | 99.72 | 11.61 | 106.37 | 14.83 |
| CEG Percentile*** | 12.78 | 14.11 | 58.16 | 24.16 |
| Sentence repetition CELF Scaled score*** | 6.94 | 2.58 | 11.95 | 2.68 |
| Receptive vocabulary IQ (PPVT-III)*** | 81.89 | 19.64 | 105.11 | 10.91 |
| Expressive vocabulary (K-BIT) (raw score)** | 25.78 | 7.72 | 33.05 | 5.71 |

Note. CA = Chronological age; K-BIT = Kaufman Brief Intelligence Test; CEG = Grammatical Structures Comprehension Test; CELF = Clinical Evaluation of Evaluation Language Fundamentals; PPVT-III = Peabody Picture Vocabulary Test. ** $p < .01$; *** $p < .001$.

coefficient is 0.95. For the youngest participants, this study used the CELF Preschool-2 (Wiig et al., 2009), intended for ages 3–6 years. The Cronbach's alpha coefficient indicated by the test manual is .91.

The PPVT-III (Dunn & Dunn, 2010) consists of 192 sheets with four pictures each, from which the participant must indicate which picture best represents the meaning of a word given by the examiner. As reported in the test manual, the Cronbach's alpha coefficient is .82.

Finally, in the expressive vocabulary subtest of the K-BIT (Kaufman & Kaufman, 2000), the participant is required to name different pictured objects. The subtest consists of 45 items, and each correct answer is awarded one point. The Cronbach's alpha coefficient indicated by the test manual is .95.

#### *2.2.3. Music skills*

The full Montreal Battery of Evaluation of Musical Abilities (MBEMA) (Peretz et al., 2013), in its brief version, was used to measure music skills. It consists of three subtests (melody, rhythm, and memory), each of which contains 20 trials of tonal melodies (of 5–9 tones, each) together with two training trials, with different instrument timbres (piano, marimba, flute, etc.). In the melody and rhythm discrimination subtests, the participant must judge whether two melodies presented are the same or different (10 same and 10 different). In the different pairs of the melody subtest, the second melody has only one changed tone and no change in rhythm. Conversely, in the different pairs of the rhythm subtest, the second melody includes a change in only one rhythmic grouping and no change in tones. In the memory subtest, melodies previously heard in the test are presented along with new melodies, and the participant must answer whether he or she has previously heard the melody.

### *2.3. Procedure*

The assessment took place in two individual sessions in quiet rooms in the participants' schools or clinics. The CEG, the CELF sentence recall subtest and the Matrices and expressive vocabulary K-BIT subtests were administered in the first session; the MBEMA and PPVT-III were administered in the second session. Each session lasted approximately 35–45 min.

The evaluations were performed by three trained examiners (the last two authors and a PhD student in education sciences). The authors have extensive knowledge and experience in the assessment of all the skills tested in the study. The PhD student also had prior experience in children assessment and was trained by the authors to administer all the tests. Approval for this study was obtained from the Ethical Human Research Committee of the University of Granada (Spain). Data were collected only from children whose parents had returned signed consent forms.

### *2.4. Data analysis*

As is frequently done in music studies (e.g., Elsabbagh et al., 2010; Lee et al., 2020; Trainor, 1997), *d*-prime scores (Green & Swets, 1966) were calculated for each participant on each of the three music subtests. This measurement accounts for both sensitivity and potential answer biases and takes the proportions of hits and false alarms into consideration (Green & Swets, 1966). Occasional extreme values of hits and false alarms (i.e., values of 0 or 1) that arose from the sampling error intrinsic to a limited number of trials and that made it impossible to calculate *d*-prime scores were addressed by using the most common solution proposed for this issue (Stanislaw & Todorov, 1999). Rates of 0 were replaced with 0.5/n, and rates of 1 were replaced with $(n - 0.5)/n$, where $n$ is the number of signal trials (Stanislaw & Todorov, 1999). A *d*-prime score of 0 corresponds to chance performance. A *d*-prime score of -3.29 corresponds to a floor effect (i.e., no hits and the maximum number of false alarms), while a *d*-prime of 3.29 corresponds to a ceiling effect (the maximum number of hits and no false alarms). To ascertain whether group performance on each of the music subtests was at chance, floor, or ceiling levels, separate one-way $t$ tests were conducted.

To study the music skills of the children with DLD compared with those of their TD peers, a two-way mixed ANOVA was carried out with group (DLD and TD) as a between-subjects factor and music subtest (melody, rhythm, memory) as a within-subjects factor. Assumptions of sphericity and homogeneity of variance were fulfilled, as shown with the Mauchly and Levene tests, respectively. Since music skills improve with age (Peretz et al., 2013; Swaminathan & Schellenberg, 2020), to study the possible effect of this variable, the previous analysis was carried out again, including age as a covariate in the model by means of analysis of covariance (ANCOVA).

Finally, to study the relationships between music and language skills, Pearson correlation coefficients were calculated separately for each group.

## 3. Results

The results are presented according to the two aims of the study.

### *3.1. Music skills*

The separate one-way $t$ tests showed that the TD group performed above chance level on the three music subtests ($p < .001$). Participants with DLD also performed above chance on the rhythm ($p < .05$) and memory ($p < .01$) subtests. However, their performance was at chance on the melody subtest ($p = .11$). There was neither a floor nor a ceiling effect on any task for either group ($p < .001$ in all cases).

Descriptive results for each group on each of the music skills assessed are shown in Table 2. In a descriptive way, the scores obtained by the children with DLD were lower than those of the TD children. This difference was found to be significant when carrying out the two-way mixed ANOVA. Thus, there was a significant effect of group: participants with DLD performed significantly worse than their TD peers ($F(1, 35) = 7.04$, $p = .012$, $r = 0.41$). No significant effects were found for either the music subtest or the interaction between variables ($p > .05$). When studying the possible effect of age by means of ANCOVA, there was a significant effect of this variable ($F(1, 34) = 35.79$, $p < .001$, $r = 0.72$); otherwise, the results were the same as those of the ANOVA.

### *3.2. Relationships between music and language skills*

The results of the Pearson correlations are shown in Table 3. Generally, for both groups, there were significant relationships between the three music skills and the language abilities measured in this study. For the group with DLD, nearly all the correlations were statistically significant. Only for music memory and grammar reception did the correlation approach significance. For the TD group, all the correlations were significant except for that between memory and sentence repetition.

## 4. Discussion

This research aimed to study the musical rhythm discrimination, melodic discrimination and music memory skills of Spanish-speaking children with DLD compared with those of TD peers of the same CA. It also aimed to analyze whether, as observed in children with DLD who speak stress-timed languages (Corriveau & Goswami, 2009; Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015), the music and language skills of Spanish-speaking children with DLD are also related. Below, the results regarding each of these aims are discussed. Then, limitations of the study, lines of future research, and clinical implications of this research are outlined.

With regard to the first aim, as hypothesized, the music skills of children with DLD were significantly lower than those of TD children. This was the case regardless of the children's age, as shown when this variable was introduced as a covariate in the statistical analyses. From these results, it may be concluded that the musical skill impairment in children with DLD compared with TD children holds true among speakers of Spanish (a syllable-timed language), as previously observed among speakers of stress-timed languages (Corriveau & Goswami, 2009; Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015).

The study predictions were based on temporal sampling theory and the prosodic-phrasing hypothesis, according to which the problems faced by children with DLD in discriminating the acoustic parameters involved in stress have a negative cascading impact on both language and music, since stress plays an important role in both domains (Goswami, 2015, 2016, 2019). The acoustic parameters used to convey stress in Spanish are the same as those found in stress-timed languages such as English (Martínez-Castilla & Peppé, 2008; Peppé, 2009; Quilis, 1981). Although Spanish has traditionally been considered a language in which rhythm depends not on the stress but on the syllable (Dauer, 1983), it has lexical stress (i.e., stress is used to distinguish between word meanings), and accents recur at regular intervals (Dauer, 1983; Dupoux et al., 1997). Based on these accounts as well as the relationship between rhythm in language and music (see Ladányi et al., 2020, for a review), the music impairments found in Spanish-speaking children with DLD are to be expected.

Children with DLD who speak French, another syllable-timed language, also present with problems with music tasks (Bedoin et al., 2016; Clément et al., 2015). French has no lexical stress, but stress is used at a different level (e.g., for phonological phrase boundaries) (Dupoux et al., 1997). In fact, as claimed by Dauer (1983), a tendency for stresses to recur regularly could be considered universal among languages. Given that, the question is why, in Italian, another syllable-timed language with lexical stress (Caccia et al., 2019), no significant differences have been found between children with DLD and TD peers of the same CA on a task assessing musical rhythmic sequence discrimination (Caccia & Lorusso, 2021). The children who participated in the study by Caccia and Lorusso (2021) were 10–13 years old; therefore, they were older than those in this research. However, in light of our findings regarding the lack of an effect of age on the differences between the music skills of children with DLD and those of TD children, this factor does not likely explain the differences in the studies' results. Differences in the tasks used to evaluate rhythmic skills could help account for the different results. In both studies, a discrimination task was administered, and thus, participants were required to state whether pairs of musical stimuli were the same or different. Nevertheless, while the stimuli presented here were formed by 5–9 tones (as mentioned in the Methods section), those used by Caccia and Lorusso (2021) were composed of only 3 tones. Therefore, the latter task may have been easier, at least for the TD children. Thus, although Caccia and Lorusso (2021) concluded that rhythm processing is problematic for children with DLD only when linguistic (rather than musical) information is involved, the authors also considered that a ceiling effect in TD children may have precluded the finding of significant differences.

Considering the relevance of rhythm in temporal sampling theory (Goswami, 2015, 2016, 2019), this study hypothesized that, among the music skills studied here, rhythm discrimination would be particularly impaired in Spanish-speaking children with DLD.

**Table 2**
Mean and Standard Deviation of D-Prime Scores on Each Music Subtest and Each Group.

| | Group with DLD | | TD group | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| Melody | 0.38 | 0.97 | 1.10 | 1.10 |
| Rhythm | 0.55 | 1.08 | 1.46 | 1.18 |
| Memory | 0.78 | 0.99 | 1.60 | 1.22 |

**Table 3**
Pearson Correlations Between Music and Language Abilities in Each Group.

| | | Grammar reception (CEG) | Sentence repetition (CELF) | Vocabulary reception (PPVT-III) | Vocabulary expression (K-BIT) |
|---|---|---|---|---|---|
| Group with DLD | Melody | 0.51* | .67** | .57* | .55* |
| | Rhythm | 0.51* | .64** | .63** | .57* |
| | Memory | 0.40+ | .75*** | .76*** | .64** |
| TD group | Melody | 0.67** | .61** | .75*** | .72** |
| | Rhythm | 0.71** | .68** | .72*** | .67** |
| | Memory | 0.52* | .30 | 0.56* | .60** |

Note. CEG = Grammatical Structures Comprehension Test; CELF = Clinical Evaluation of Evaluation Language Fundamentals; PPVT-III = Peabody Picture Vocabulary Test; K-BIT = Kaufman Brief Intelligence Test; + $p = .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.

However, no significant differences were found in performance on any of the three music subtests, and performance on the melody subtest was at chance level in the children with DLD. Both the rhythm and melody discrimination tasks included natural musical stimuli; thus, both rhythm and pitch cues were present in the two tasks; i.e., the melodies were composed of pitched notes with different durations. However, discrimination needed to be performed based on only one of these cues in each task. If children with DLD present impairments in rhythm perception, it is plausible that these impairments may pose difficulties when the children must focus on pitch cues within rhythmic melodies; this may explain the results found for the melody subtest. However, prior research has also found impairments in musical pitch discrimination when the stimuli do not include rhythmic cues (Cumming, Wilson, Leong, et al., 2015). Pitch is one of the acoustic markers of stress (Llisterri et al., 2003; Peppé, 2009; Quilis, 1981) highlighted in temporal sampling theory, and higher pitch thresholds have been found in children with DLD (Cumming, Wilson, & Goswami, 2015; Mengler et al., 2005; Richards & Goswami, 2019). This could explain the impairment found on the melody subtest in this study.

Participants with DLD also performed below their TD peers on the memory subtest. Impairments in phonological short-term memory have been proposed as a framework to account for DLD (e.g., Gathercole & Baddeley, 1990; Jackson et al., 2019), and prior research has found a significant relationship between music processing and auditory memory in children with DLD (Heaton et al., 2018; Jentschke et al., 2008). Therefore, together with difficulties in pitch and rhythm processing, auditory memory problems could help explain this result. It should be emphasized that, when accounting for DLD, one should embrace a complex view by considering the possibility that multiple underlying deficits are present (Bishop, 2006). Thus, the deficits proposed based on temporal sampling theory and the prosodic-phrasing hypothesis (e.g., Cumming, Wilson, & Goswami, 2015; Goswami, 2015, 2016, 2019; Goswami et al., 2016) could coexist with auditory memory problems in children with DLD.

Turning to the second aim of the study, importantly, significant relationships between music and language skills were found. This was seen in both the TD children and the participants with DLD. In both groups, all the relationships among vocabulary, grammar and rhythm and melody discrimination were significant, while this was not always the case for the relationships between memory and grammar. As explained above, performing the rhythm and melody discrimination tasks requires the processing of cues related to stress, while the memory task involves other demands. Therefore, temporal sampling theory can explain the relationships found in this research. To our knowledge, no prior study conducted with children with DLD who speak another syllable-timed language (e.g., Italian or French) has found a significant association between music and language skills. These results concur with those previously found in children with DLD who speak a stress-timed language (Cumming, Wilson, Leong, et al., 2015; Sallat & Jentschke, 2015). Therefore, it is suggested that the perceptual consequences derived from temporal sampling theory and the prosodic-phrasing hypothesis are similar in both stress-timed and syllable-timed languages.

Despite the relevant contributions of this study, its limitations should also be considered. First, although the theoretical framework assumed in this study proposes auditory discrimination impairments in DLD for the key acoustic parameters involved in stress, as has been found in children with this disorder who speak a stress-timed language (e.g., Corriveau et al., 2007; Cumming, Wilson, & Goswami, 2015; Mengler et al., 2005; Richards & Goswami, 2015, 2019), these low-level auditory processes were not evaluated in the study. Phonological memory was not evaluated either, although, as suggested before, this may also be important for explaining the music processing impairments presented by children with DLD. This study was part of a larger project. Including more tests to evaluate both low-level auditory processes and phonological memory would have required too many assessment sessions, which would have made the study unfeasible. Additionally, although the sample size of this study was similar to or even larger than those in prior research (e.g., Bedoin et al., 2016; Caccia & Lorusso, 2021; Clement et al., 2015; Heaton et al., 2018), the number of children with DLD assessed here was relatively small, which represents another weakness.

Considering these limitations, possible lines of future research can be suggested. Studies should assess acoustic discrimination thresholds and phonological memory in Spanish-speaking children with DLD and assess their relationship with music and language skills. In particular, given the connections found between the ability to process musical rhythm and linguistic prosody (Caccia & Lorusso, 2021), future work should further pursue this line of research. Future studies should also include more participants to provide stronger evidence regarding the findings of this research.

The results of this study may have clinical implications. Specifically, the relationships found between music and language skills may pave the way for the development of possible language intervention programs based on music stimuli. Music represents a type of auditory stimulus that has a marked rhythm with intensified stress cues; this is particularly the case in songs, where the stresses from musical beats and lyrics are combined (Goswami, 2017). From a temporal sampling account, given the relevance of stress for both music and language and provided that there is a relationship between the two areas, as found in this study, music may become a means to improve the language skills of children with DLD. Evidence already exists in this area. Through a priming procedure, it has been shown that, despite the music impairments of children with DLD, exposing these children to musical material with a clear metrical structure (i.e., regular marked beats or stresses) improves their performance on grammaticality judgment tasks (Bedoin et al., 2016; Przybylski et al., 2013). Future studies should continue this line of research.

## 5. Conclusions

In summary, this study is the first to examine the rhythm discrimination, melody discrimination and memory skills of Spanish-speaking children with DLD compared with those of TD peers of the same CA. The children with DLD showed impairments in the three music skills assessed in the study, and these impairments were in turn related to their language difficulties. The results are consistent with the proposals formulated from temporal sampling theory (Goswami, 2015, 2016, 2019) and suggest that similar musical difficulties may be found in children with DLD whether they speak stress-timed or syllable-timed languages.

## CRediT authorship contribution statement

**Pastora Martínez-Castilla:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Funding acquisition. **Nuria Calet:** Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing. **Gracia Jiménez-Fernández:** Investigation, Resources, Writing – review & editing.

## Data Availability

Data will be made available on request.


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