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Research Report

Real-time comprehension of Spanish prepositions and prepositional locutions in bilingual children with developmental language disorder: A study based on eye-movement evidence

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Abstract

Background: Function words, and more specifically prepositions and prepositional locutions, are considered to be one of the most important difficulties for children with DLD.
Aims: To examine the capacity of bilingual children with developmental language disorder (DLD) to comprehend different Spanish prepositions and prepositional locutions in a simple sentence structure, for example, *El gato está sobre la mesa/El gato está bajo la mesa* (The cat is on the table/The cat is under the table).
Methods & Procedures: We used simple sentence structures to reduce lexical difficulties in order to focus our evaluation strictly on the grammatical morphemes under study. A total of 96 Spanish and Catalan-speaking participants, divided into four groups, were evaluated in an eye-tracking psycholinguistic experiment: 24 children with DLD (average age = 7.8 years, age range = 4.6–12.6), 24 children with the same chronological age (average age = 7.8 years, age range = 4.6–12.2), 24 children with the same linguistic level (average age = 6.8 years, age range = 4.6–9.4) and 24 adults (average age = 22.5 years, age range = 18–30).
Outcomes & Results: The empirical data show that, despite some differences, bilingual children with and without DLD can comprehend Spanish prepositions and prepositional locutions under the current experimental conditions.
Conclusions & Implications: Our results suggest that the capacity of bilingual children with DLD to comprehend Spanish prepositions and prepositional locutions in real time and within simple sentence structures is preserved.

Keywords: developmental language disorder (DLD), children, comprehension, prepositions, eye-tracking.

What this paper adds

What is already known on the subject

- The empirical literature indicates that children with DLD show important errors in the production of functional words in general, and prepositions in particular. However, unlike other grammatical morphemes (such as clitic pronouns and articles), prepositions have been less studied, and the few existing studies have focused on the dimension of language production, not comprehension.

What this paper adds to existing knowledge

- The present study, composed of two experimental tasks, seeks to determine to what extent the observable difficulty in the linguistic production of prepositions is also present in the comprehension of children with DLD. The empirical results suggest a less atypical comprehension in comparison with our initial

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hypothesis, and the differences that appear between the two tasks, allow us to formulate a theoretical interpretation regarding the mechanisms of their understanding. Thus far, we are not aware of other studies that have evaluated in real time the comprehension of prepositions and prepositional locutions in parallel.

Clinical implications of this study

- Results suggest the presence of a more preserved comprehension of prepositions and prepositional locutions, at least in real-time experimental conditions (eye-tracking) and in simple sentence structures. A less atypical comprehension raises the possibility of a better prognosis for children with DLD. Working with comprehension of simple sentences and the gradual addition of more difficult grammatical morphemes could help to enhance the comprehension of a growing complex grammar.

Introduction

Problems with grammatical morphology are characteristic of children with DLD, according to the empirical literature. Leonard (2014), in a wide review, argues that many of the hypotheses regarding the nature of developmental language disorder (DLD) focus their interest on grammar, because morphosyntactic problems in DLD are noteworthy. Similarly, Mendoza (2012) states that the most severe difficulties in DLD are found in the production and comprehension of grammatical morphemes. In more detail, psycholinguistic research has mostly focused on children's use of verb morphology (Bishop 1997, Conti-Ramsden and Jones 1997, Grinstead *et al*. 2009, Hoover *et al*. 2012; Leonard *et al*. 1997, Sanz-Torrent *et al*. 2008) and the use of function words (Aguilar *et al*. 2007, Auza and Morgan 2013a, 2013b, Bedore and Leonard 2001, 2005, Grela *et al*. 2004) to understand better the nature of DLD.

Auza (2009) and Auza and Morgan (2013a, 2013b) suggest that the problems with grammatical morphology in children with DLD vary according to the characteristics of specific languages. Under their perspective, Romance languages show evidence of fragility in the use of prepositions, articles and clitic pronouns. Empirical research has, to a greater extent, dealt with some of these grammatical morphemes rather than with others, that is, there is more research on clitic pronouns (Jacobson and Schwartz 2002, Morgan *et al*. 2013, Restrepo and Gutiérrez-Clellen 2001, Theodorou and Grohmann 2015, Tuller *et al*. 2011) and articles (Auza and Morgan 2013a, Bedore and Leonard 2001, 2005, Bosch and Serra 1997, Chondrogianni and Marinis 2015, Leonard *et al*. 1992, Polite *et al*. 2011, Stavrakaki and van der Lely 2010), than on prepositions.

Regarding prepositions, the few existing empirical studies generally indicate a significant effect on the production of these grammatical morphemes in children with DLD (Auza and Morgan 2013b, Cipriani *et al*. 1998, Grela *et al*. 2004, Puglisi *et al*. 2005, Sanz-Torrent *et al*. 2008, Watkins and Rice 1991). Studies reporting problems in the use of prepositions show a discrepancy as to which is the most problematic issue in their production, since some of them point towards omission (Auza and Morgan 2013b, Cipriani *et al*. 1998, Sanz-Torrent *et al*. 2008, Watkins and Rice 1991) and others towards substitution (Grela *et al*. 2004, Puglisi *et al*. 2005). For example, Grela *et al*. (2004) evaluated the ability of English-speaking children with DLD (age range = 4.0–7.3 years) to produce the locative prepositions 'in' and 'on' (as in 'Put in the box' and 'Put on the table') and the dative preposition 'to' ('Give it to her'). The dative preposition 'to' was substituted with 'at', 'with' and 'for'. In the case of the preposition 'on', the substitutions occurred with the prepositions 'in' and 'to'; and with the preposition 'in', the substitutions were with 'on', 'up' and 'at'. The results of the study confirmed the initial hypothesis, which stated that children with DLD would make more mistakes than the children in the control groups. The errors that the children with DLD made (substitution of dative prepositions) allowed the authors to suggest a problem in the semantic function of prepositions, rather than in their syntactic function.

The difficulties observed in the production of prepositions by children with DLD may be explained from different perspectives. First, grammatical morphemes (articles, pronouns and prepositions) assume a syntactic function in the connection of different phrasal elements (Grela *et al*. 2004). Leonard (2014) recognizes that, in the case of grammatical morphemes—such as prepositions—syntactic knowledge is essentially required, but that semantic knowledge also plays a role in the difficulty of acquiring and using them. In this sense, the polysemy of prepositions is based on the fact that a single preposition, according to its sentence function, can establish one meaning or another. The surface hypothesis (Leonard 1989, 2014) suggests that children with DLD have a greater difficulty with those grammatical elements that have a shorter duration and are phonologically less salient. On the other hand,

Evans *et al.* (2009) suggest that the difficulty with these kinds of grammatical morphemes is not due to a lack in their perception, but rather caused by a greater cognitive effort made by children with DLD related to their fragile and ineffective use of an implicit learning mechanism. Crosslinguistic studies in children with DLD (Bedore and Leonard 2001, 2005, Leonard 2014, Leonard *et al.* 1987, 1988) have also led to the proposal of the morphological richness account. Under this theoretical perspective, children with DLD who acquire a morphologically rich language use grammatical morphemes more accurately than children with DLD who acquire a language with fewer morphemes. Along the same lines, Mendoza (2012, 2016) argues that, as Spanish is a morphologically rich language, it is worth considering the possibility that Spanish-speaking children with DLD may present a greater capacity to use morphemes compared with other children who speak morphologically poorer languages.

The grammatical morpheme performance of children with DLD who speak Romance languages such as Spanish, Catalan and Italian, is also quite informative. Auza and Morgan (2013b) analysed errors in the production of prepositions by Spanish-speaking children with DLD (age range = 4.0–8.0 years). They evaluated the proper use of seven Spanish prepositions (Spanish: 'a', 'con', 'de', 'en', 'hacia', 'hasta' y 'para')/(English: 'to', 'with', 'from/to/of', 'in/on', 'towards', 'until' and 'for') in a story retelling task with pictures. They found differences in the overall production of prepositions in comparison with that of both age matched and language control groups, with a significantly greater number of omissions. The greatest problem was found in monosyllabic and unstressed prepositions ('a', 'en' and 'con')/('to', 'in/on' and 'with'). Omission of prepositions was also the main error in a task involving production in Brazilian Portuguese-speaking children with DLD in an age range from 3 to 5 years (Puglisi *et al.* 2005). The performance of these children was quantitatively and qualitatively poorer than their typical developing controls (who were 1 year younger than the DLD group). Sanz-Torrent *et al.* (2008) analysed the language of bilingual (Spanish and Catalan-speaking) children with DLD (age range = 3.0–5.0 years) in order to establish error patterns in their language expression. One of the most frequent errors was omission related to different grammatical morphemes (prepositions, determiners, pronouns, etc.). Specifically, prepositions were the most omitted morphemes by children with DLD, whose production was significantly lower than the production of children in a chronological control group, and similar to the production of a linguistic control group. Finally, Cipriani *et al.* (1998) in a longitudinal case study ($n = 1$) with an Italian-speaking child with DLD (age range = 6.2–13.5 years) showed that regarding acquisition of the prepositional system there was a high rate of omission (> 80%) up to the age of 7.9 years. A year later, the rate of omission was lower by almost half (> 44%), and only at 9.4 years the production of prepositions presented a reverted trend, where the tendency of omission (> 18%) was almost equivalent with the tendency of errors (> 16%). The authors concluded that the results of the analysis of prepositions suggested that the child with DLD has a generalized difficulty in selecting the appropriate preposition.

To our knowledge, only a few studies have evaluated language comprehension in general, and preposition comprehension in particular (Bishop 1982, Hsu and Bishop 2014, Puglisi *et al.* 2005). Bishop (1982), in one of the first studies on comprehension in children with language disorders, evaluated different forms of grammar representation in children with Landau–Kleffner syndrome and children with developmental expressive disorder. The children with the DLD (age range = 8.7–14.11 years) presented mild comprehension problems in comparison with children without a language disorder. Additionally, Hsu and Bishop (2014) argue that understanding of spatial prepositions could result a quite difficult task. For example, the authors make a reference to Test for Reception of Grammar—2 (Bishop 2003), which presents four multiple-choice prepositions items, and argue that the great majority of children with typical language acquisition show a reliable mastery of this construction, not until 9 years of age. The results of this research (age range = 6–11 years) indicate that for many children with DLD, linguistic comprehension is significantly lower in comparison with their peer control group. In addition, the comprehension level of children with DLD aged 8–9 years was comparable with the level of typically developing children aged around 3 years less.

Thus far, we have mainly considered production performance, yet comprehension of grammatical morphemes is also fundamentally important to understanding the nature of DLD. Static (offline) comprehension tasks need to be carefully constructed and standardized tests of comprehension are recommended for diagnosis of DLD (Bishop *et al.* 2017). It is also important to identify that the acquisition of spatial prepositions occurs well into the school years (Durkin 1981). For example, in the TROG-2 (Bishop 2003) there are four multiple-choice items that assess spatial prepositions such as 'the flower is above the cup'. Bishop (2003) found that reliable accuracy of these types of items did not occur until 9 years of age. With reference to children with DLD, we know that they have comprehension difficulties with spatial prepositions as evident in studies that have used the TROG-2 and TROG-E (Hsu and Bishop 2014, Bishop *et al.* 2006) relative to age and linguistically matched controls. Puglisi *et al.*

(2005) also analysed the comprehension of prepositions in the same group of children. In their analysis, they found a delayed but similar pattern of results of the children in the control groups in the comprehension of prepositions. Finally, Andreu *et al.* (2013) proposed that comprehension testing based on static comprehension tests might present limitations in recording children with DLD's real capacity for comprehension. On the contrary, online comprehension tests, such us the eye-tracking method, could be more suitable in capturing the comprehension capabilities of children and adults (Trueswell 2008).

The present study seeks to evaluate the online comprehension of prepositions and prepositional locutions within the margins of the 'visual world paradigm' (Cooper 1974, Tanenhaus *et al.* 1995) through the methodology of eye tracking. This methodological paradigm offers the possibility to analyse the cognitive processing of linguistic elements within a sentence at the moment of the elements' occurrence. Thus, the fixation percentages (in every correct answer) for the experimental task provide valuable empirical information on a person's cognitive processing. According to Trueswell (2008), through the Eye Tracker tool it is relatively easy to obtain a detailed record of the way a participant looks around while listening to an audiovisual stimulus, which offers a description of their visual reference when facing reality (for further information on basic characteristics of eye movements, see Rayner 2009). If we consider that grammatical morphemes guide the comprehension of a sentence, then a poorer processing of prepositions and/or prepositional locutions will be reflected in the execution and in the glance pattern of the language comprehension register. Under this view, it would be expected that children with DLD will have a significantly lower comprehension compared with that of the control groups.

Since children with DLD do not compose a monolithic group (Laws and Bishop 2003), the possibility of a deficit in the comprehension of these linguistic grammatical morphemes and, consequently, of a more limited general linguistic comprehension up to a certain age, may be considered. The persistence of production difficulties with articles and/or clitics until an age up to 13.5 years (Stavrakaki and van der Lely 2010), makes it reasonable to suggest that difficulties with the use of prepositions might also persist until a similar age. Due to their polysemic character, prepositions and prepositional locutions could result to be more difficult in comparison with articles and clitic pronouns. Conversely, if the empirical data of children with DLD are similar to the data of typically developing children, it will be possible to argue in favour of less impaired comprehension of these grammatical morphemes than what is generally thought to exist. In other words, the possibility of a greater capacity to comprehend prepositions and prepositional locutions of the Spanish language by children with DLD could be proposed.

Methods

Participants

One experimental group and three control groups participated in this study: 24 children with DLD (age range = 4.6–12.6 years, average = 7.8 years), 24 children in an Age control group (age range = 4.6–12.2 years, average = 7.8 years), 24 children in a linguistic control group (based on mean length of utterance by words (MLU-w) age range = 4.6–9.4 years, average = 6.8 years), and finally, 24 adult university students, as a language-expert control group (age range = 18–30 years, average = 22.5 years). Regularly, the research on DLD is based on a two control groups' model, which contrasts children with DLD to chronological- and linguistic-matched peers. In the present study, there is also a language expert control group that provides a stronger experimental validity, and a higher certainty on the adequacy of the stimuli. In this sense, the contrast between the language expert control group and the DLD group permits an important comparison reference to understand the magnitude of the differences observed between the DLD group and the children control groups (Age and MLU-w control groups).

All participants in the study are simultaneous bilinguals of Spanish and Catalan that were equally exposed to both languages since birth, according to parental report. In 2018, 52.7% of Barcelona citizens claimed that their initial language was Spanish, and 31.5% Catalan (Idescat 2018). In the school system, there exists an immersion in/to Catalan in kindergarten. Later, in primary school, children receive 2–3 h of Spanish, while the rest of the subjects are taught in Catalan (Joaquim and Humbert 1986; Strubell 1996, Ferrer 2000). According to Alarcón and Garzón (2011), children in Barcelona are equally proficient in both Spanish and Catalan, although the use of Spanish is more popular. For further information about Catalan and Spanish bilingualism and DLD, see Sanz-Torrent *et al.* (2007) and Sanz-Torrent *et al.* (2008).

Children with DLD were recruited from three different institutions: (1) UTAE (Unidad de Trastornos del Aprendizaje Escolar/Hospital Sant Joan de Déu, in English: Unit of School Learning Disorders/Hospital of Sant Joan de Déu); (2) CREDA Narcís Masó (Centro de Recursos Educativos para Deficiencias Auditivas, in English: Centre of Educational Resources for Hearing Impairments); and (3) ATELCA (Asociación del Trastorno Específico del Lenguaje de Cataluña, in English: Association of Specific Language Impairment

of Catalonia). This research took place in 2013–4 and 2014–5, when the term 'SLI' was the most prominently used, so the children were diagnosed with SLI by a speech–language therapist. However, we recognize that children who meet these classic SLI criteria fall under the umbrella of DLD, so we decided to use this last term throughout the paper.

The DLD group and the control groups (AGE and MLU-w) were formed based on the results of the following standardized tests: The Kaufman Brief Intelligence Test (KBIT, Spanish version; Kaufman and Kaufman 2004), the Peabody Picture Vocabulary Test—Third Edition (PPVT-III; Dunn *et al*. 2006), and the Comprehension Test of Grammatical Structures (CEG; Mendoza *et al*. 2006). All the children with DLD received a standard score of a non-verbal IQ of $\geq$ 85 on the matrices subtests of Kaufman Brief Intelligence Test (KBIT-MAT, Spanish version; Kaufman and Kaufman 2004). Receptive and expressive vocabulary was assessed in all groups with the PPVT-III and the vocabulary subtest of Kaufman Brief Intelligence Test (KBIT-VOC), correspondingly. Grammatical abilities, on the other hand, were assessed with the Comprehension Test of Grammatical Structures (CEG; Mendoza *et al*. 2006). This test is a Spanish adaptation of the Test for Reception of Grammar—Version 2 (TROG-2; Bishop 2003) and measures the understanding of different grammatical contrasts. Finally, for the assessment of grammatical expressive complexity, the MLU-w value in words for each child was also calculated. The means of the tests used was 100 and the standard deviation (SD) was 15. For selection of the DLD group, the criteria, in the PPVT-III, CEG and KBIT-VOC, was a score of at least a 1.25 SD below the mean. As shown in tables 1 and 2, the DLD group showed statistical differences in all linguistic tests with respect to children from the Age control group. The descriptive data of the groups are shown in tables 1 and 2.

In order to confirm the diagnosis of children with DLD, language samples were analysed using the Spanish protocol for the Evaluation of Language Delay (AREL; Pérez and Serra 1998). Language profiles based on transcripts of spontaneous speech provided information about the children's morphosyntactic abilities in language production, from which it was determined that they showed a delay of at least 1 year (Bishop 1997). In addition, anamnesis filled out by parents/caretakers also report functional limitations of the language disorder in academic terms, as well as in socioemotional terms. This information was also used to verify that children had no symptoms of impaired reciprocal social interaction.

For the selection of the children for the control groups, 260 children were evaluated (age range = 3.9–12.2years). The age-matched control group was equivalent in age (same year $\pm$2 months) to their counterparts

Table 1. Descriptive statistics of individual measures per group and age

Full sample (n = 24)	**Means (SD)**	**Range**	**Means (SD)**	**Range**	**Means (SD)**	**Range**
Age (years)	7.8 (2.2)	4.6–12.6	7.8 (2)	4.6–12.2	6.8 (1.6)	4.6–9.4
MLU-w	4.9 (1.9)	1.1–7.9	8.9 (2.4)	5.2–14.6	5.4 (1.3)	3.4–7.8
PPVT-III	86.5 (16.4)	55.0–114.0	106.4 (6.6)	93.0–117.0	108.1 (8.8)	87.0–121.0
CEG	16.8 (17)	1.0–55.0	40.0 (24.8)	10–95.0	34.54 (24.9)	4.0–75.0
KBIT-VOC	88.6 (15.7)	59.0–127.0	101.3 (24.4)	9.0–137.0	100.1 (14.8)	64.0–120.0
KBIT-MAT	95.6 (15.8)	70–127.0	97.17 (15.40)	61.0–119.0	104.6 (14.4)	55.0–123.0
	DLD1		**AGE1**		**MLU-w1**	
Younger children (n = 12)	**Means (SD)**	**Range**	**Means (SD)**	**Range**	**Means (SD)**	**Range**
Age (years)	6 (1)	4.6–8.2	6.3 (1.2)	4.6–8.2	5.4 (0.7)	4.6–6.4
MLU-w	3.8 (2)	1.1–7.9	7.8 (2)	5.2–11.6	4.5 (0.8)	3.4–6.0
PPVT-III	89.8 (17.2)	55.0–114.0	109.5 (5.8)	102.0–117.0	109.1 (8.9)	93.0–121.0
CEG	16.0 (17.6)	1.0–55.0	34.2 (16.8)	15.0–60.0	37.0 (23.1)	5.0–70.0
KBIT-VOC	90.5 (17.5)	59.0–127.0	92.8 (30.9)	9.0–124.0	97.4 (17.8)	64.0–120.0
KBIT-MAT	98.3 (17.9)	70.0–127.0	99.8 (18.6)	61.0–119.0	104.1 (10.8)	82.0–119.0
	DLD2		**AGE2**		**MLU-w2**	
Older children (n = 12)	**Means (SD)**	**Range**	**Means (SD)**	**Range**	**Means (SD)**	**Range**
Age (years)	9.7 (1.3)	8.3–12.6	9.4 (1.3)	8.3–12.2	8.2 (1)	6.6–9.4
MLU-w	5.9 (1.2)	4.2–7.7	10. 2 (2.2)	7.3–14.6	6.2 (1)	5.0–7.9
PPVT-III	83.3 (15.7)	55.0–110.0	103.3 (6)	93.0–112.0	107.1 (8.9)	87.0–121.0
CEG	17.7 (17)	1.0–50.0	45.8 (30.5)	10.0–95.0	32.0 (27.4)	4.0–75.0
KBIT-VOC	86.8 (14.3)	59.0– 11.0	109.8 (11.6)	88.0–137.0	102.9 (11.3)	73.0–114.0
KBIT-MAT	93.0 (13.8)	76.0–112.0	98.5 (12.2)	68.0–118.0	105.1 (17.8)	55.0–123.0

in the DLD group. The MLU-w control group was equivalent in terms of linguistic level. Each child in the study group was paired with another child according to the MLU-w calculated in words (±0.5 words) and sex. As a result of the wide age range of the DLD group, two chronological subgroups were created: one for younger children (DLD 1: $n = 12$ and age range = 4.6–8.2 years and average = 6.0 years) and one for older children (DLD 2: $n = 12$, age range = 8.3–12.6 years and average = 9.7 years). This chronological classification was extrapolated to the rest of the control groups: Age chronological control group (AGE1: age range = 4.6–8.2 years and average = 6.3 years; and AGE2: age range = 8.3–12.2 years and average = 9.4 years) and MLU-w Linguistic control group (MLU-w1: age range = 4.6–6.4 years and average = 5.4 years; MLU-w2: age range = 6.6–9.4 years and average = 8.2 years). We decided a split point of 8 years and 3 months in order to be consistent with the majority of previous studies on preposition production which were based on samples of children up to the age of 8 (Auza and Morgan 2013b, Grela *et al.* 2004, Sanz-Torrent *et al.* 2008). It also allowed the same number of participants in each subgroup ($n = 12$), although this issue was not central for the decision. The research was approved by the Ethics Committee of the Universitat Oberta de Catalunya. Parents of the children with DLD as well as the adult participants signed a written consent for their participation in the study.

Stimuli

In total, 16 prepositions and 12 prepositional locutions were evaluated in 60 different simple-structure sentences (30 sentences in two different experimental lists: A and B; see List A in appendix C). A prepositional locution is a phrase that resembles a preposition in its syntactic behaviour or meaning (Bosque 2010). The following prepositions were evaluated: Spanish: 'a', 'ante', 'bajo', 'con', 'contra', 'de', 'desde', 'en', 'entre', 'hacia', 'hasta', 'para', 'por', 'sin', 'sobre' and 'tras'; in English: 'to', 'facing/before', 'under', 'with', 'against', 'from/to/of', 'since/from', 'in/on', 'between', 'towards', 'until', 'for', 'through', 'without', 'over/on' and 'behind/after'. In the trials, the experimental task only tested the prototypical representation of each preposition. For example, in figure 1, a stimulus of a preposition can be observed: 'The cat is *on* the table' (Target: cat on the table, Competitor: cat under the table).

The following prepositional locutions were also evaluated: Spanish: 'al lado de', 'alrededor de', 'cerca de', 'debajo de', 'delante de', 'dentro de', 'detrás de', 'encima de', 'en frente de', 'fuera de', 'junto a' and 'lejos de'; English: 'next to', 'around the', 'close to', 'below of/under',

Table 2. Pairwise contrasts between the reference group and the control groups (Welch two sample *t*-test, two-tailed)

	DLD versus AGE		DLD versus MLU-w	
Full sample ($n = 24$)	***T***	***P***	***t***	***p***
Age (years)	–0.04	0.964	1.91	0.063
MLU-w	6.46	0.000	–1.07	0.292
PPVT-III	5.52	0.000	–5.68	0.000
CEG	3.77	0.001	–2.88	0.006
KBIT-VOC	2.14	0.039	–2.62	0.012
KBIT-MAT	0.78	0.442	–2.04	0.047
	DLD1 versus AGE1		**DLD1 versus MLU-w1**	
Younger children ($n = 12$)	***T***	***p***	***t***	***p***
Age (years)	0.44	0.665	1.51	0.149
MLU-w	4.67	0.000	–0.80	0.435
PPVT-III	3.66	0.003	–3.20	0.005
CEG	2.56	0.018	–2.13	0.045
KBIT-VOC	0.41	0.688	–0.81	0.429
KBIT-MAT	0.27	0.791	–0.95	0.352
	DLD2 versus AGE2		**DLD2 versus MLU-w2**	
Older children ($n = 12$)	***T***	***P***	***t***	***p***
Age (years)	–0.55	0.588	3.26	0.004
MLU-w	6.55	0.000	–1.01	0.323
PPVT-III	4.21	0.001	–4.84	0.000
CEG	2.83	0.012	–1.90	0.074
KBIT-VOC	4.45	0.000	–3.21	0.004
KBIT-MAT	0.94	0.356	–1.86	0.078

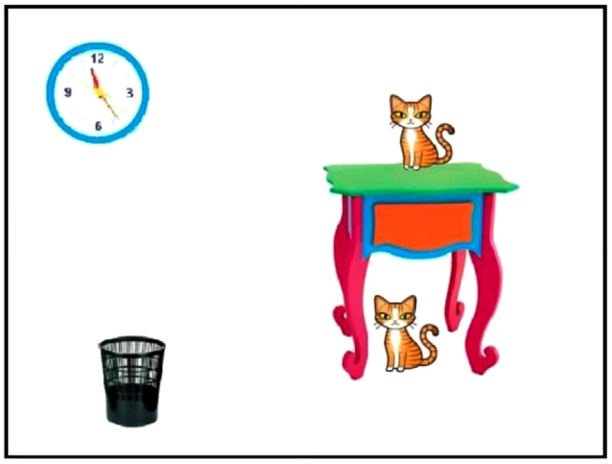

Figure 1. Preposition stimulus.
English: 'The cat is on the table' (Target: cat on the table, Competitor: cat under the table).
Spanish: 'El gato está *sobre* la mesa'.
[Colour figure can be viewed at wileyonlinelibrary.com]

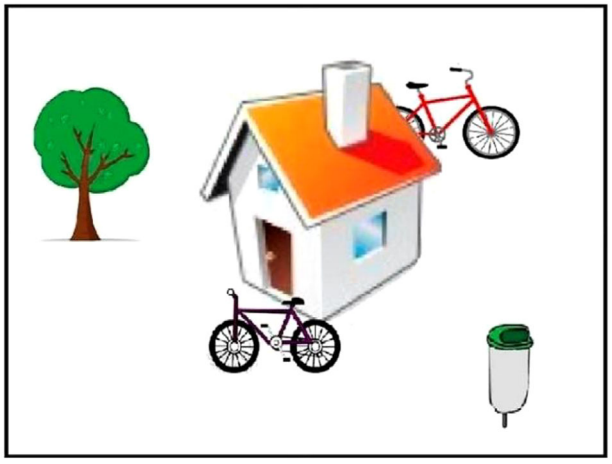

Figure 2. Prepositional locution stimulus.
English: 'The bicycle is *in front of* the house' (Target: bicycle in front of the house, Competitor: bicycle behind the house).
Spanish: 'La bicicleta está *enfrente de* la casa'.
[Colour figure can be viewed at wileyonlinelibrary.com]

'in front of/opposite of', 'inside of', 'behind of', 'above of', 'in front of', 'outside of', 'next to' and 'far from'. The fundamental criterion for the selection of the prepositions and the prepositional locutions was the possibility to represent them graphically. In this sense, prepositions such as: Spanish: 'durante' and 'según', and English: 'during' and 'according to' were discarded because of difficulty in representing them graphically. In figure 2, a stimulus of a prepositional locution can be observed: 'The bicycle is *in front of* the house' (Target: bicycle is in front of the house, Competitor: bicycle is behind the house).

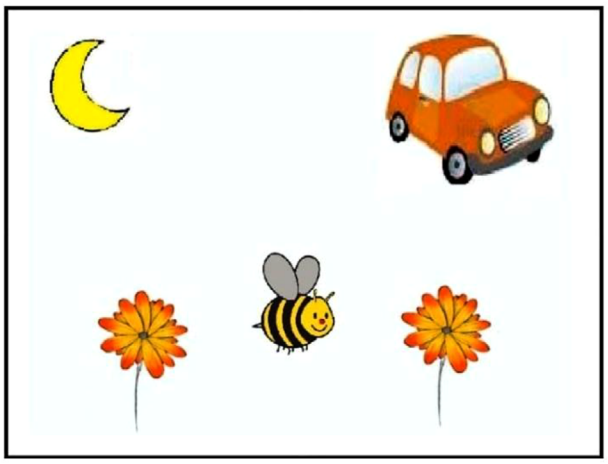

Figure 3. Stimulus of Preposition of movement or direction.
English: 'The bee flies *towards* the flower, *from* the flower' (Target: second flower, Competitor: first flower).
Spanish: 'La abeja vuela *hasta* la flor, *desde* la flor'.
[Colour figure can be viewed at wileyonlinelibrary.com]

In the case of prepositions, each stimulus contrasts a preposition either with its opposite or a different one ('The cat is *below/on* the table', 'The girl walks *to/through* the park'). In each image, two elements appear in the form of distracters and have no direct relation with the preposition under study but contribute to the contextualization of the scene. The composition of the scene changes with respect to the nature of the preposition under study. In this sense, when studying a preposition of movement or direction (Spanish: 'a', 'de', 'desde', 'hacia' and 'hasta'/English: 'to', 'from/to', 'since/from', 'towards' and 'until') the image corresponding to the object of the preposition or prepositional locution appears twice (figure 3: 'The bee flies *towards* the flower/*from* the flower'). When we study a preposition of static representation (Spanish: 'ante', 'bajo', 'con', 'contra', 'en', 'entre', 'para', 'por', 'sin', 'sobre' and 'tras'/English: 'facing/before', 'under', 'with', 'against', 'in/on', 'between', 'for', 'through', 'without', 'over/on' and 'behind/after'), the image corresponding to the subject of the sentence appears twice (figure 1: 'The cat is *under/on* the table'). Finally, due to the complexity of the scene in some cases (Spanish: 'entre', 'para', 'por' and 'hacia'/English: 'between', 'for', 'through' and 'towards'), images corresponding to both the object and the subject appear twice (figure 4: 'The train goes *through/towards* the tunnel').

As in the case of prepositions, each stimulus representing prepositional locutions was contrasted with its opposite or with a different one ('The bicycle is *in front of/behind* the house'/'The bus is *in front of/next* to the store'). Similar to what was described for the stimuli with prepositions, two related distractor elements were

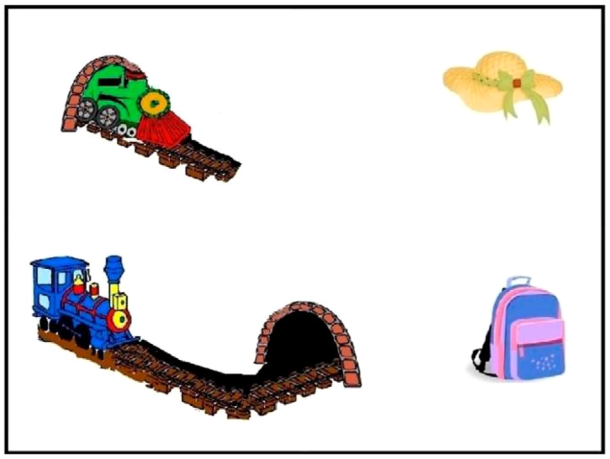

Figure 4. Stimulus of Preposition of movement or direction.
English: 'The train goes *towards* the tunnel' (Target: train towards the tunnel, Competitor: train through the tunnel).
Spanish: 'El tren va *hacia* el túnel'.
[Colour figure can be viewed at wileyonlinelibrary.com]

introduced in the scenes. In this condition the composition of the scene did not change, since the prepositional locutions considered were all statics. Therefore, in every stimulus the subject is duplicated (e.g., 'The bus is *in front of*/*next* to the store'). Each item had a specific configuration of the regions of interest (RoIs), depending on the positions of the objects. RoIs were always a square area covering the whole picture. Given our design, this variability in positions is not problematic, since the same picture served as visual stimuli for both contrasting preposition or prepositional locutions in Spanish (e.g., one version pictured 'on' and the other 'under'). Consequently, the target and competitor in a given display rotated across experimental lists.

It is worth mentioning that prepositions and prepositional locutions maintain a polysemic and heterogeneous character (Bosque 2010). In this sense, many of the analysed prepositions of this study had different semantic values. For example, the preposition '*de*' (English: 'from'/'to'/of) was used in its different meanings: Spanish: 'Las flores *de* la niña'/English: 'The flower *of* the girl' (in a possessive sense, in English the phrase would be 'The girl's flower') and Spanish: 'La niña camina *de* la fuente a la otra fuente'/English 'The girl walks *from* the fountain to the other fountain' (in a directional sense). As mentioned above, two experimental lists were created (Lists A and B). Each participant was exposed only to one condition of each scene ('The cat is *under* the table' or 'The cat in *on* the table'). The visual stimuli were created by images of 800 × 600 pixels and presented as video format (800 × 600 pixels) on a monitor screen 17′′ TFT of Tobii T120 Eye Tracker set to 1024 × 768 pixels. Each stimulus has four graphic elements (target, competitor and two distractors). A female native Spanish speaker recorded the experimental sentences at a normal speaking velocity at 44,100 Hz. Recordings were edited using a sound editing software which allowed the clear-cut segmentation of the words with a distance of a 1000 ms between each onset (see appendix D). Collaborators and authors of this research evaluated and selected the different stimuli in search of the highest possible adequacy.

Procedure

Data was collected through the Tobii Studio Software. Each participant received the following instructions: 'You will see some images and you will hear a sentence, search as quickly as possible for the correct image and continue looking at it.' Before the beginning of the experiment, a calibration of 20 s was performed, as well as four example trials. The stimuli were presented in a random order in List A or B. A cross appeared at the centre of the screen before the appearance of each stimulus in order to guide the gaze of the participant. Each stimulus lasted around 6000 ms and the experiment was performed in 6 min.

Data analysis

For the location of each object in the visual context, a corresponding area of interest for the location and size of the displayed pictures was defined using the software Tobii Studio. Critically, while the number of objects varied across items, all items presented a target and competitor object, which are the focus of this analysis. The Tobii system provides participants' gaze location at both the horizontal and vertical axes each 833 ms (sample rate of 120 Hz). Consequently, it was possible to determine whether each gaze sample was located inside of any of the areas of interest. Critical time windows started at 3000 ms after the beginning of the sentence, marking the start of the first silent window following the critical preposition (3000–4000 ms from sentence onset), with the second marking the critical noun (4000–5000 ms from sentence onset) and the third, the second silent window, which appeared after the critical noun (5000–6000 ms from sentence onset). Using the R Project software, steps of 1 ms were examined per participant. Trial and visual objects for each of these time windows and a value of 1 was given to the area of interest that participants were fixating on at time step. For visualization, fixations were aggregated into 50-ms steps (figure 5).

For statistical analysis, the log-transformed fixation proportion ratio between the target and the competitor (log ratio; Arai *et al.* 2007) was calculated per participant and per trial. To obtain the log ratio, the proportion of fixation towards the target plus a constant

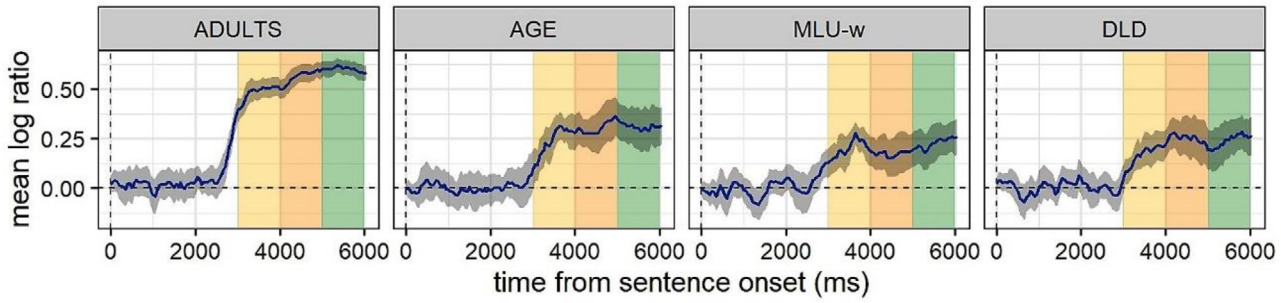

Figure 5. Mean fixation proportion log-ratio between target and competitors by group and time window in the prepositions task. Grey areas represent the within-subject adjusted 95% confidence intervals. [Colour figure can be viewed at wileyonlinelibrary.com]

(i.e., 1) was divided by the proportion of fixation towards the competitor plus the same constant. Thus, in the log-transformed values, positive numbers represent the preference towards the target and negative numbers represent the preference towards the competitor. Inferential analysis was conducted with linear mixed-effects regressions (LMER, lmerTest in R). LMER analysis can model the variation of participants and items around the predictors, which is an important advantage in the context of psycholinguistics data, where there is variation among participants and items added to that of the experimental manipulation (Clark 1973). For these data, we began using maximal structure, and simplified it whenever the model did not converge. Doing so, recommendations of removing random correlation first given in Barr *et al.* (2013) were followed.

Results are divided in two groups. First, two main analyses concerning preposition comprehension are presented, and then results on the comprehension of prepositional locutions. The first two main analyses of prepositions include a contrast between the experimental group against the Age control group, the MLU-w control group, and the Adult control group, and a similar analysis by each time window. Appendices A and B provide a secondary analysis in which we contrast the DLD group against the Age and the MLU-w control group; and younger versus older children (DLD1, AGE1 MLU-w1 versus AGE2, DLD2 and MLU-w2). Appendices A and B also present a similar analysis by time window.

The first analysis used a successive difference contrast (MASS package in R) to compare the changes in time along the three time windows of interest. In both analyses, a treatment contrast (MASS package in R) was used to compare the between-subject predictors (i.e., independent groups). Thus, in both analyses, the intercept of the model represented the mean log-transformed fixation proportion ratio between target and competitor for the DLD group across the three time windows. The estimates, standard error of the mean, *t*-values and *p*-values (lmerTest package in R) were reported.

The LMER structure of the first analysis included the fixed factors of participants' group as between-subject predictor, time window as within-subject predictor and the interaction between them. It also included random intercepts for participants and items, a random slope of time window for subjects, and of group and time window for items. The second LMER structure included group as the single predictor, random intercepts for participants and items and a random slope of group for items.

Result

Figure 5 shows the time course plots for the log-transformed fixation proportion difference between the target and the competitor objects, averaged by participants for each independent group and with error bands depicting the within-subjects adjusted 95% confidence intervals for the prepositions task.

Two main effects can be observed: first, all participants are capable of distinguishing the target from the competitor beginning with the first time window. This preference continues in the second and the third time windows. The second effect is the evident advantage for the Adult control group in terms of speed and effect size compared with the children groups. Visual comparison among the children groups evidence a relative advantage for the Age control group, in particular from the second time window. The LMER clarify these differences. The LMER results are presented in table 3.

Results confirmed what was observed in the graphs, which essentially is the significant difference between the Adult control group and the DLD experimental group. This is true, both in the global analysis ($\beta = 0.315$, SE $= 0.044$, $t = 7.124$, $p < 0.001$) and across the three critical time windows ($\beta = 0.315$, SE $= 0.046$, $t = 6.885$, $p < 0.001$; $\beta = 0.307$, SE $= 0.055$, $t = 5.552$, $p < 0.001$; $\beta = 0.364$, SE $= 0.056$, $t = 6.441$, $p < 0.001$, respectively).

Table 3. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor in the prepositions task

	Estimate	SE	*T*	*p*	
(Intercept)	0.158	0.036	4.423	0.000	***
Age control	0.071	0.036	1.987	0.050	.
MLU control	0.035	0.036	0.978	0.331	
Adult control	0.315	0.044	7.124	0.000	***
Time window 2-1	0.089	0.035	2.508	0.014	*
Time window 3-2	0.075	0.037	2.003	0.048	*
Age control: Time window 2-1	–0.024	0.050	–0.488	0.626	
MLU control: Time window 2-1	–0.109	0.050	–2.184	0.031	*
Adult control: Time window 2-1	–0.008	0.050	–0.157	0.876	
Age control: Time window 3-2	0.001	0.053	0.015	0.988	
MLU control: Time window 3-2	–0.052	0.053	–0.986	0.327	
Adult control: Time window 3-2	0.049	0.053	0.926	0.357	

Table 4. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor by time window in the prepositions task

	Estimate	SE	*T*	*p*	
Time window 1					
(Intercept)	0.158	0.035	4.477	0.001	***
Age control	0.071	0.037	1.947	0.060	.
MLU control	0.035	0.036	0.980	0.332	
Adult control	0.315	0.046	6.885	0.000	***
Time window 2					
(Intercept)	0.246	0.044	5.652	0.000	***
Age control	0.047	0.049	0.956	0.343	
MLU control	–0.073	0.053	–1.374	0.178	
Adult control	0.307	0.055	5.552	0.000	***
Time window 3					
(Intercept)	0.232	0.044	5.249	0.000	***
Age control	0.072	0.055	1.312	0.195	
MLU control	–0.017	0.054	–0.305	0.761	
Adult control	0.364	0.056	6.441	0.000	***

No other significant effects are observed. Only a marginal difference is found between DLD and Age control, both globally, and in the first time window as revealed by the window-by-window analysis (table 4). In general terms, the comprehension skills tested in real-time eye tracking experiments suggests that the DLD group's performance is not significantly different from the Age control groups. Finally, we eliminated the stimuli of some prepositions that graphically represent movement or directionality (e.g., 'a', 'de', 'desde', 'hacia' and 'hasta' in Spanish; and e.g., 'to', 'from/of', 'since/from', 'towards' and 'until' in English) because all groups of children (DLD, AGE and MLU-w) registered very low levels of target recognition, which indicated a lack of comprehension and an arbitrary performance.

Data analysis, critical time windows and number of contrasts on prepositional locutions were identical to the prepositions analysis. We also present the same secondary analysis among the three children groups and the younger and older children in appendices A and B.

Figure 6 shows the time course plots for the log-transformed proportion of fixation difference between the target and the competitor objects for the prepositional locutions task. Records present the time shifts of the dependent variable averaged by participants in each independent group. Error bands (grey area around the line) show the within-subjects adjusted 95% confidence intervals.

Two observations from figure 6 are evident. First, participants from all groups are capable of identifying the target from the first time window, and this preference is maintained along the following critical time windows. Second, the Adult control group has a clear advantage both in terms of speed and the size of the preference effect, relative to the other groups. The results from the LMER analysis in table 5 show two reliable effects. A significant overall difference between DLD group and the Adult control group was found ($\beta = 0.378$, SE $= 0.047$, $t = 8.002$, $p < 0.001$). Additionally, a significant difference between the DLD group and the age control group was

Table 5. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor in the prepositional locutions task

	Estimate	SE	*t*	*p*	
(Intercept)	0.244	0.038	6.442	0.000	***
Age control	0.116	0.045	2.551	0.013	*
MLU control	0.053	0.048	1.121	0.267	
Adult control	0.378	0.047	8.002	0.000	***
Time window 2-1	0.015	0.028	0.540	0.590	
Time window 3-2	0.020	0.028	0.709	0.480	
Age control: Time window 2-1	0.111	0.039	2.817	0.005	**
MLU control: Time window 2-1	0.001	0.039	0.029	0.977	
Adult control: Time window 2-1	0.018	0.039	0.468	0.640	
Age control: Time window 3-2	–0.026	0.037	–0.711	0.478	
MLU control: Time window 3-2	0.007	0.037	0.187	0.852	
Adult control: Time window 3-2	–0.015	0.037	–0.406	0.685	

Table 6. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor by time window in the prepositional locutions task

	Estimate	SE	*t*	*p*	
Time window 1					
(Intercept)	0.227	0.038	5.981	0.000	***
Age control	0.051	0.043	1.183	0.246	
MLU control	0.050	0.042	1.188	0.243	
Adult control	0.370	0.045	8.274	0.000	***
Time window 2					
(Intercept)	0.242	0.044	5.461	0.000	***
Age control	0.162	0.051	3.182	0.002	**
MLU control	0.052	0.054	0.958	0.343	
Adult control	0.389	0.055	7.119	0.000	***
Time window 3					
(Intercept)	0.262	0.045	5.865	0.000	***
Age control	0.136	0.058	2.327	0.023	*
MLU control	0.058	0.059	0.991	0.325	
Adult control	0.374	0.060	6.233	0.000	***

also observed ($\beta = 0.116$, SE $= 0.045$, $t = 2.551$, $p < 0.05$).

The results from the second LMER analysis (table 6) are consistent with those from the first analysis. We observed a significant effect between the experimental group (DLD) and the adult control group, on each time window ($\beta = 0.370$, SE $= 0.045$, $t = 8.274$, $p < 0.001$; $\beta = 0.389$, SE $= 0.055$, $t = 7.119$, $p < 0.001$; $\beta = 0.374$, SE $= 0.060$, $t = 6.233$, $p < 0.001$, respectively). This analysis also clarifies that the advantage observed for the age control group appears in the second time window ($\beta = 0.162$, SE $= 0.051$, $t = 3.182$, $p < 0.01$) and the third time window ($\beta = 0.374$, SE $= 0.060$, $t = 6.233$, $p < 0.001$) but not in the first one.

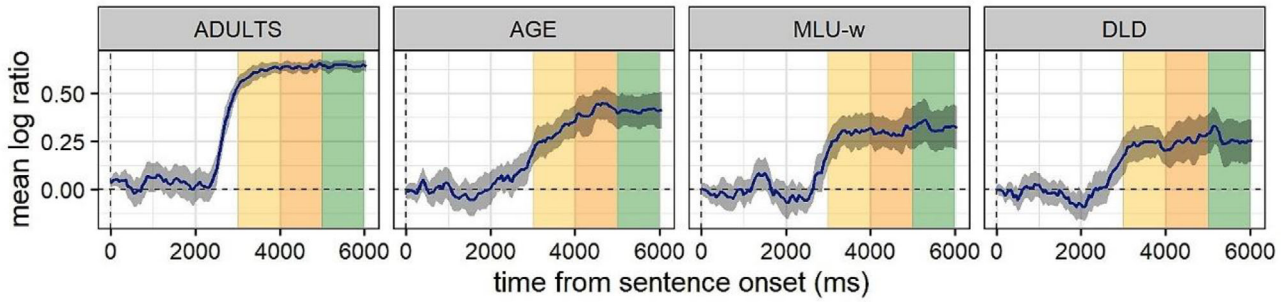

Figure 6. Mean fixation proportion log-ratio between target and competitors by group and time window for the prepositional locutions task. Grey areas represent the within-subject adjusted 95% confidence intervals. [Colour figure can be viewed at wileyonlinelibrary.com]

Discussion

The objective of the study was to record and analyse the capacity of bilingual children with DLD to comprehend, in real time, different prepositions and prepositional locutions within a simple sentence structure in Spanish. The research findings indicate, despite some differences, both children with DLD and children in the control groups can comprehend prepositions and prepositional locutions in simple sentences in Spanish.

In the case of the prepositions, the analysis of the three windows (table 4) indicates that children with DLD (age range = 4.6–12.6 years) present with real-time comprehension skills that are not significantly different from that of the chronological control group, which spreads homogeneously from the beginning to the end of the stimuli. Both young children (DLD1, AGE1 and MLU-w1; age range = 4.6–8.2, 4.6–8.2 and 4.6–6.4 years) and older children (DLD2, AGE2 and MLU-w2; age range = 8.3–12.6, 8.3–12.2 and 6.6–9.4 years) similarly comprehend the different prepositions (see appendix A, figure A1, tables A1 and A2). The global analysis also confirms these outcomes (table 3).

In the case of prepositional locutions, the analysis of the three time windows (table 6) shows a significant difference between the DLD group and the Age control group. In more detail, in the first window of analysis, which represents 1000 ms of silence immediately after the linguistic key (prepositional locution), the three groups of children (DLD, AGE and MLU-w) present a similar level of comprehension. However, in the second and third window of analysis, a significant difference is observed between the DLD group and the Age control group. The DLD group also presents a similar performance to the MLU-w control group. Again, the global analysis (table 5) confirms this result. Statistically, the effect found between the DLD group and the Age control group regarding prepositional locutions appears to be mainly due to the difference between the older children (DLD2 and AGE2), and also the younger children (DLD1 and AGE1) especially at the last 1500 ms of the task (see appendix B, figure B1, tables B1 and B2). Thus, the pattern of comprehension is more heterogeneous and statistically different. Consequently, it can be argued that the DLD group responds relatively well, and that the Age group responds significantly better. This suggests that children with DLD do not exactly develop in the same way as children with typical language development in their comprehension of prepositional locutions and that their performance would tend to be slightly different in this respect. Further, we can see that younger TD children and children with DLD (age range = 4.6–8.2 years), in the first time window of analysis (3000–3999 ms), present a relatively high fixation proportion towards the target, but nevertheless, in the following time windows (4000–5999 ms), they do not maintain the visual gaze proportion at the same rate as older TD children do. As such, the advantage of older children without DLD could have to do, on the one hand, with a greater ability to process sentences more quickly and effectively and, on the other, a better established knowledge of these linguistic structures.

The compound structure of prepositional locutions in Spanish (Spanish: 'al lado de', 'alrededor de', 'cerca de', 'debajo de', 'delante de', 'dentro de', 'detrás de', 'encima de', 'en frente de', 'fuera de', 'junto a' and 'lejos de'; English: 'beside/next to', 'around', 'close to', 'under/below of', 'in front of/opposite of', 'inside of', 'behind of', 'above of', 'in front of', 'outside of', 'next to' and 'far from') could also have an effect on the difference observed between both groups of children (DLD and AGE). Linguistically, it is known that prepositions assume a syntactic function in the connection of different phrasal elements (Grela *et al.* 2004). This assumption also applies to prepositional locutions, in which case the connection of more than one morphological morpheme within the context of different phrasal elements could produce more difficulties in children with DLD. Greater cognitive effort made by children with DLD when comprehending language, as suggested by Evans *et al.* (2009), could account for the observed difference with prepositions and prepositional locutions. According to this view, this performance does not relate to a lack in perception, but to a greater cognitive effort made by children with DLD due to their fragile and ineffective use of an implicit learning mechanism. This suggests that the issue of comprehending the relatively more complex structure of prepositional locutions may add both a linguistic and a cognitive load to these types of tasks for children with DLD.

Finally, we argue that the prepositional locution task (figure 6) is less difficult in comparison with the preposition task (figure 5), since the fixation proportions of all four groups is higher with prepositional locutions and lower with prepositions. In other words, in the relatively more difficult task (prepositions) there are less significant differences between the DLD group and the age group, and the complexity of the task is reflected in a more homogeneous comprehension pattern between the two groups. On the contrary, when the complexity of the task is relatively less (prepositional locutions), the pattern of comprehension is more heterogeneous, and there are more significant differences between children with DLD and chronological age-matched peers. In this sense, as stated above, children with DLD responded well, but age-matched peers responded significantly better. Possibly, the observed effect is related to the higher phonological salience of prepositional locutions in the Spanish language, since the advantage in

terms of comprehension concerns all children, with and without DLD, as well as adults.

In sum, the main research findings in this study indicate, despite some differences regarding the comprehension of prepositional locutions, that both children with DLD and children in the control groups can, in general, comprehend prepositions and prepositional locutions in simple sentences in Spanish. Several authors have suggested that children with DLD tend to perform better in comprehension tasks than in production tasks (Andreu *et al.* 2016, Castro-Rebolledo *et al.* 2004, Dale *et al.* 2003, Leonard 2014, Puglisi *et al.* 2005). Specifically referring to Spanish-speaking children with DLD, Leonard (2014) supports the idea that they have better skills in language comprehension than in language production. Other studies using the eye-tracking method to investigate language comprehension in Spanish have also introduced empirical evidence, pointing to a less impaired linguistic comprehension in children with DLD (Andreu *et al.* 2011, 2013, 2016). Our study also supports this last idea empirically. However, it is relevant to highlight that our findings refer to the comprehension of Spanish grammatical morphemes within simple structures, using an online technology, and that assessment of more complex structures using the same technology is still required. Research on the offline comprehension of more complex structures by children with DLD in Spanish has shown significant differences between these children and a control group (Coloma *et al.* 2013; Coloma *et al.* 2017, Coloma and Pavez 2017). Future studies would have to evaluate the comprehension of children with DLD in circumstances that integrate elements of these two lines of research: the online methodology that adequately captures the cognitive processes of DLD linguistic comprehension, and the evaluation of more complex sentence structures closer to the linguistic reality surrounding children with DLD.

Prepositions and prepositional locutions have received little attention in the field of DLD research (Auza and Morgan 2013b). The age of the children with DLD in studies that evaluated the use of prepositions ranges from 3 to 8 years (Auza and Morgan 2013b, Grela *et al.* 2004, Puglisi *et al.* 2005, Sanz-Torrent *et al.* 2008). All of these studies are empirical in nature and generally indicate a significant effect on the production of these grammatical morphemes in children with DLD, that is, the DLD group performs worse when compared with the control groups. In this sense, the present study (age range = 4.6–12.6 years and average = 7.8 years) differs from the above mentioned studies (age range = 3–8 years). Studies that have evaluated prepositions in children with DLD above 8 years of age (range = 6–14.11 years) (Bishop 1982, Cipriani *et al.* 1998, Hsu and Bishop 2014) suggest that children with DLD present important difficulties in the production and/or comprehension of function words in general, and prepositions in particular. These considerations would suggest that difficulties with the production of prepositions extend beyond 8 years of age. Our secondary analyses, which directly contrasted age differences within the DLD group, revealed that younger children with DLD evidence an overall weaker preference for the correct object compared with older children with DLD in both the preposition ($\beta = 0.080$, SE = 0.027, $t = 2.992$, $p < 0.01$) and the locution ($\beta = 0.107$, SE = 0.029, $t = 3.63$, $p < 0.001$) experiments (see the top and bottom panels on the right in figures A1 and B1). Future research should simultaneously investigate language production and language comprehension under similar experimental conditions to better understand age-related effects and the nature of these abilities in children with DLD.

Despite the fact that the eye-tracking tool is far from being sufficiently portable or economically and methodologically accessible in the clinical field, the empirical research outcomes of the type of study we have conducted here might ensure useable information for speech language therapists to design a more adjusted psycholinguistic intervention in children with DLD. We argue that the task in this experiment is clinically useful in order to assess the basic language comprehension of children with DLD, and that the empirical differences seem to be more linked to performance factors. Relatedly, it is important to acknowledge that, since the task requires only comprehension of a single grammatical morpheme (a preposition or a prepositional locution), differences in real world tasks may also be linked to performance issues.

Some broader clinical implications can also be offered. For instance, a clinical intervention could begin with the implementation of simple sentences containing prepositions and prepositional locutions, since they have been shown to be understood by children with DLD. This way, it might be possible to advance the consolidation of these particular markers in a way that addresses performance rather than competence. Once the performance limitations in simple sentences were overcome, addition of new elements in the simple structure of the sentence may be added in order to make them more complex in linguistic and cognitive terms, but in a controlled manner, since such complex comprehension tasks involve skills beyond linguistic knowledge and competence (Frizelle *et al.* 2017) that can presumably lead to cognitive overload. Such an intervention could approach real world discursive contexts in which prepositions and prepositional locutions can be more successfully comprehended and performance could improve. Working with the comprehension of simple

sentences and the gradual addition of more difficult grammatical morphemes could help to enhance the comprehension of a growing complex grammar. Since the problem regarding prepositions and prepositional locutions seems more related to production than to comprehension, this last ability (comprehension) should function as an aid in the production of prepositions and prepositional locutions. For example, morphological awareness could be used for the identification of correct or incorrect prepositions in sentences, since comprehension of these morphological function words is preserved.

Future studies with the use of different and more user-friendly technologies could perhaps better elucidate the difference in competence and performance for children with DLD. Under our perspective, in terms of intervention, the functional comprehension of these children in day-to-day natural linguistic contexts requires both the identification of the typical mistakes they make in order to strengthen language knowledge, and the use of sentences with lower processing load. The synthesis of new and/or more complex language constructions and low processing load contexts, in the presence of visual scenes, might encourage the appropriate use of the grammatical morphemes under consideration, and raise the possibility of a better prognosis. Future studies should also include a language exposure questionnaire in order to determine and/or confirm bilingualism so that factors relative to language exposure can be better refined and understood when examining the comprehension abilities of bilingual children with DLD.

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Appendix A

Prepositions

Appendix A presents two further analyses, which involved a comparison between the experimental group and the two child groups, and the age predictor. The first analysis includes a direct comparison among time windows, and the second contrasts these groups and the age predictor in each time window separately. Data analysis is identical to that in the previous contrasts (tables A1 and A2).

The results from the linear mixed-effects regressions (LMER) analysis reflect these differences. Tables A1 and A2 show a reliable effect of the age predictor (DLD1 versus DLD2). Interestingly, while the global analysis (table A1) shows an overall effect of children's age ($\beta = 0.080$, SE $= 0.027$, $t = 2.992$, $p < 0.01$), the window-by-window analysis reveals that this effect does, in fact, appear only in the second window ($\beta = 0.108$, SE $= 0.037$, $t = 2.939$, $p < 0.01$). Finally, the analysis presented in table A2 shows a significant difference between the DLD group and the age control group only in first time window ($\beta = 0.071$, SE $= 0.035$, $t = 2.019$, $p < 0.05$).

Table A1. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor in the prepositions task

	Estimate	SE	*t*	*p*	
(Intercept)	0.212	0.035	6.115	0.000	***
Age control	0.063	0.034	1.848	0.070	.
MLU control	–0.018	0.034	–0.529	0.599	
Time window 2-1	0.089	0.038	2.358	0.021	*
Time window 3-2	–0.014	0.033	–0.428	0.669	
Age	0.080	0.027	2.992	0.004	**
Age control: Time window 2-1	–0.024	0.052	–0.468	0.641	
MLU control: Time window 2-1	–0.109	0.052	–2.093	0.039	*
Age control: Time window 3-2	0.025	0.046	0.548	0.584	
MLU control: Time window 3-2	0.057	0.046	1.242	0.215	
Time window 2-1: Age	0.071	0.037	1.933	0.056	.
Time window 3-2: Age	–0.012	0.032	–0.373	0.709	
Age control: Age	0.004	0.033	0.122	0.903	
MLU control: Age	0.015	0.033	0.438	0.663	
Age control: Time window 2-1: Age	–0.005	0.052	–0.091	0.927	
MLU control: Time window 2-1: Age	0.005	0.052	0.095	0.924	
Age control: Time window 3-2: Age	0.037	0.046	0.817	0.414	
MLU control: Time window 3-2: Age	–0.009	0.046	–0.188	0.851	

Table A2. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor by time window in the prepositions task

	Estimate	SE	*t*	*p*	
Time window 1					
(Intercept)	0.158	0.035	4.511	0.001	***
Age control	0.071	0.035	2.019	0.048	*
MLU control	0.035	0.036	0.977	0.334	
Age	0.036	0.037	0.979	0.349	
Age control: Age	–0.005	0.040	–0.130	0.898	
MLU control: Age	0.014	0.041	0.343	0.736	
Time window 2					
(Intercept)	0.246	0.041	6.018	0.000	***
Age control	0.047	0.044	1.080	0.287	
MLU control	–0.073	0.048	–1.542	0.137	
Age	0.108	0.037	2.939	0.009	**
Age control: Age	–0.010	0.044	–0.226	0.822	
MLU control: Age	0.019	0.053	0.364	0.721	
Time window 3					
(Intercept)	0.232	0.043	5.462	0.000	***
Age control	0.072	0.053	1.371	0.177	
MLU control	–0.017	0.050	–0.328	0.744	
Age	0.095	0.046	2.085	0.051	.
Age control: Age	0.027	0.056	0.489	0.629	
MLU control: Age	0.011	0.061	0.173	0.864	

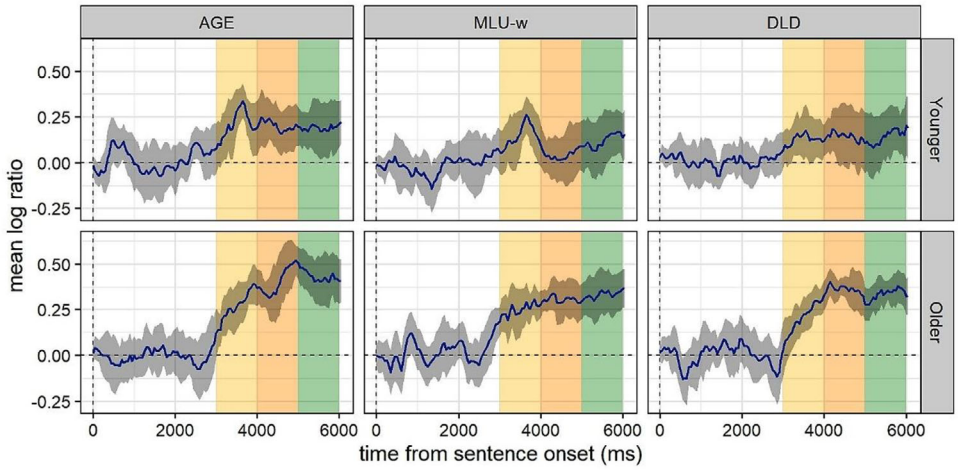

Figure A1. Mean fixation proportion log-ratio between target and competitors by group, time window and age for the prepositions task. Grey areas represent the within-subject adjusted 95% confidence intervals. [Colour figure can be viewed at wileyonlinelibrary.com]

Appendix B

Prepositional locutions

Appendix B presents two further analyses. The first contrasts the experimental group with the two child groups, with an age predictor and across time windows as a factor. The second does the same, but window by window. All aspects of data analysis are identical to those in the previous contrasts (tables B1 and B2). The results presented in figure B1 show that older children from all groups demonstrate a large preference for the target compared with the competitor. However, among younger children there seem to be some differences between the three groups of interest. Younger children with DLD seem to face some difficulty in distinguishing between the target and the competitor. The younger children in the age control group seem more able to do so. The younger children from the MLU-w control group, for their part, also prefer the target relative to the competitor; however, in a less clear and stable way relative to the younger age control group children or older children in general.

Table B1. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor in the prepositional locutions task

	Estimate	SE	*T*	*p*	
(Intercept)	0.244	0.037	6.623	0.000	***
Age control	0.116	0.043	2.667	0.010	**
MLU control	0.053	0.046	1.171	0.247	
Time window 2-1	0.015	0.030	0.496	0.621	
Time window 3-2	0.020	0.030	0.673	0.503	
Age	0.107	0.029	3.635	0.001	***
Age control: Time window 2-1	0.111	0.043	2.588	0.011	*
MLU control: Time window 2-1	0.001	0.043	0.027	0.979	
Age control: Time window 3-2	–0.026	0.042	–0.624	0.534	
MLU control: Time window 3-2	0.007	0.042	0.164	0.870	
Time window 2-1: Age	0.058	0.030	1.919	0.057	.
Time window 3-2: Age	0.000	0.030	–0.010	0.992	
Age control: Age	–0.043	0.041	–1.057	0.294	
MLU control: Age	–0.016	0.041	–0.383	0.703	
Age control: Time window 2-1: Age	–0.015	0.043	–0.340	0.734	
MLU control: Time window 2-1: Age	–0.034	0.043	–0.802	0.424	
Age control: Time window 3-2: Age	0.018	0.042	0.428	0.670	
MLU control: Time window 3-2: Age	–0.004	0.042	–0.094	0.925	

Table B2. Main and interaction effects in the linear mixed-effects regression on fixation proportion log-ratio between target and competitor by time window in the prepositional locutions task

	Estimate	SE	*t*	*p*	
Time window 1					
(Intercept)	0.227	0.037	6.070	0.000	***
Age control	0.051	0.042	1.203	0.240	
MLU control	0.050	0.042	1.201	0.239	
Age	0.069	0.031	2.191	0.040	*
Age control: Age	–0.040	0.042	–0.954	0.350	
MLU control: Age	0.008	0.041	0.205	0.839	
Time window 2					
(Intercept)	0.242	0.043	5.636	0.000	***
Age control	0.162	0.049	3.273	0.002	**
MLU control	0.052	0.051	1.006	0.321	
Age	0.127	0.034	3.677	0.001	***
Age control: Age	–0.054	0.049	–1.112	0.272	
MLU control: Age	–0.026	0.049	–0.532	0.598	
Time window 3					
(Intercept)	0.262	0.044	5.923	0.000	***
Age control	0.136	0.058	2.353	0.023	*
MLU control	0.058	0.059	0.993	0.326	
Age	0.126	0.040	3.131	0.003	**
Age control: Age	–0.036	0.057	–0.644	0.523	
MLU control: Age	–0.030	0.057	–0.527	0.601	

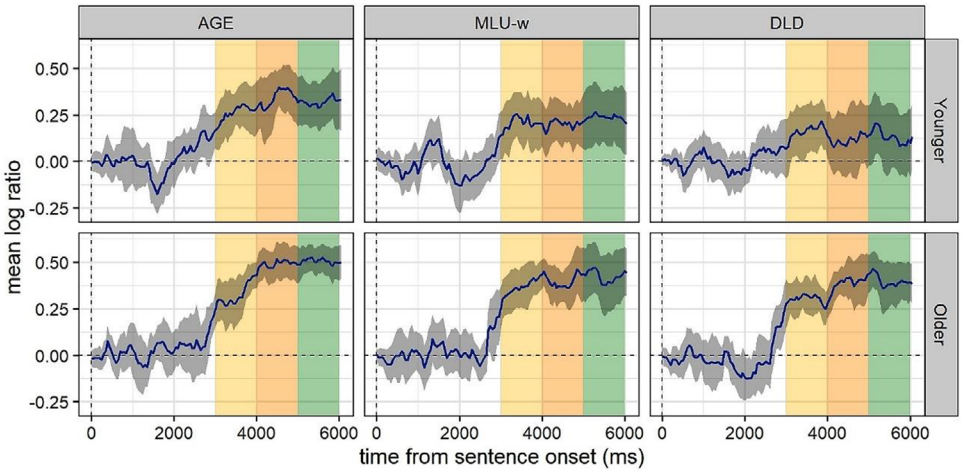

Figure B1. Mean fixation proportion log-ratio between target and competitors by group, time window and age for the prepositional locutions task. Grey areas represent the within-subject adjusted 95% confidence intervals. [Colour figure can be viewed at wileyonlinelibrary.com]

These contrasts are consistent with the previous analysis. Overall, the graphs show a clear advantage for older children relative to younger children in all three groups. Interestingly, all three younger children groups exhibit an initial trend towards the target in the first critical time window. However, this trend vanishes in the second and third time windows. Older children, by contrast, began to prefer the target over the competitor in the first time window and maintained such preference in the second and third time windows. This pattern is confirmed by the significant effect of the age predictor in the global analysis ($\beta = 0.107$, SE $= 0.029$, $t = 3.63$, $p < 0.001$), and in the window-by-window analysis.

Appendix C

Prepositions and prepositional locutions

Table C1. Prepositions and prepositional locutions used in List A

Preposition/prepositional locution	Item	Target	Competitor
1. *bajo*	*El gato está bajo la mesa* (The cat is under the table)	Cat under the table	Cat on the table
2. a	*El niño va a la cama desde la otra cama* (The boy goes to the bed from the other bed)	Bed in front of the boy	Bed behind the boy
3. *de*	*La niña camina de la casa* a la casa (The girl walks from the house to the house)	House behind the girl	House in front of the girl
4. *de*	*El perro pasea del árbol al árbol* (The dog goes from the tree to the tree)	Tree behind the dog	Tree in front of the dog
5. *hasta*	*La niña camina hasta la fuente desde la fuente* (The girl walks to the fountain from the fountain)	Fountain in front of the girl	Fountain behind the girl
6. *desde*	*La abeja vuela desde la flor a la flor* (The bee flies to the flower from the flower)	Flower behind the bee	Flower in front of the bee
7. *hacía*	*La niña salta hacía la cama* (The girl jumps towards the bed)	Bed in front of the girl	Bed behind the girl
8. *entre*	*El señor camina entre los árboles* (The gentleman walks between the trees)	Man between the trees	Man in front of the trees

Continued

Table C1. Continued

Preposition/prepositional locution	Item	Target	Competitor
9. *para*	*La flor es para la niña* (The flower is for the girl)	Girl without a flower	Girl with a flower
10. *por*	*La niña va por el parque* (The girl goes through the park)	Girl in the park	Girl towards the park
11. *hacía*	*El tren va hacía el túnel* (The train goes towards the tunnel)	Train towards the tunnel	Train through the tunnel
12. *con*	*El perro está con la oveja* (The dog is with the sheep)	The sheep on the side of the dog	The sheep opposite the dog
13. *en*	*El chico está en el autobús* (The boy is on the bus)	Boy in the bus	Boy outside the bus
14. *sin*	*La señora va sin sombrero* (The lady goes without a hat)	Lady without a hat	Lady with a hat
15. *tras*	*El chico grita tras el árbol* (The boy shouts behind the tree)	Boy behind the tree	Boy in front of the tree
16. *por*	*La chica va por la montaña* (The girl goes through the mountain)	Girl through the mountain	Girl towards the mountain
17. *ante*	*El coche está ante la casa* (The car is in front of the house)	Car in front of the house	Car behind the house
18. *sobre*	*El libro está sobre la cama* (The book is on the bed)	Book on the bed	Book under the bed
19. *entre*	*Los árboles están entre los columpios* (The trees are between the swings)	Trees between the swings	Trees around the swings
20. *junto a*	*El niño canta junto a la escuela* (The boy sings next to the school)	Boy next to the school	Boy inside the school
21. *enfrente de*	*La bicicleta está en frente de la casa* (The bicycle is in front of the house)	Bicycle in front of the house	Bicycle behind the house
22. *encima de*	*El regalo está encima de la mesa* (The present is on the table)	Present on the table	Present under the table
23. *delante de*	*La niña corre delante de la granja* (The girl runs in front of the farm)	Girl in front of the farm	Girl behind the farm
24. *detrás de*	*La pelota está detrás del árbol* (The ball is behind the tree)	Ball behind the tree	Ball in front of the tree
25. *debajo de*	*El gato está debajo de la ventana* (The cat is under the window)	Cat under the window	Cat on top of the window
26. *al lado de*	*El autobús para al lado de la tienda* (The bus stops next to the store)	Bus next to the store	Bus in front of the store
27. *dentro de*	*El ratón está dentro de la taza* (The mouse is inside the cup)	Mouse inside the cup	Mouse outside of the cup
28. *fuera de*	*El peluche está fuera de la caja* (The teddy bear is outside of the box)	Teddy bear outside of the box	Teddy bear inside the box
29. *cerca de*	*El avión está cerca de la nube* (The plane is near the cloud)	Plane near the cloud	Plane away from the cloud
30. *lejos de*	*La niña está lejos de la nevera* (The girl is far from the fridge)	Girl far from the fridge	Girl near the fridge

Notes: The above sentences were the items in List A. List B was composed of the opposite targets and competitors in comparison with List A. For example, List B/item 12: *El perro está contra la oveja* (The dog stands opposite/across from the sheep).
The prepositions represented in items 2–11 were eliminated due to their low validity.
In some cases (i.e., items 19 and 20), the stimuli contrast a preposition with a prepositional locution: *El niño canta junto a la escuela* (The boy sings next to the school) versus *El niño canta en la escuela* (The boy sings inside the school).

Appendix D

Structure of the audio stimuli

Table D1. Summary of the structure of the audio stimuli

Subject	Verb	Preposition/prepositional locution	(Silence)	Complements	Final silence
0–999 ms	1000–1999 ms	2000–2999 ms	3000–3999 ms	4000–4999 ms	5000–5999 ms