International Journal of Language & Communication Disorders

INT J LANG COMMUN DISORD, MAY/JUNE 2019,
VOL. 54, NO. 3, 485–498

Research Report

The joint effects of bilingualism, DLD and item frequency on children's lexical-retrieval performance

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(*Received May 2018; accepted December 2018*)

Abstract

Background: Bilingual children and children diagnosed with developmental language disorder (DLD) are characterized by reduced lexical-retrieval abilities. Few studies examined their joint contribution and the mechanisms underlying these effects in the lexical domain.
Aims: To explore the joint effects of bilingualism and DLD by adopting a four-group comparison in which the difference between bi- and monolingual children with DLD is directly compared with that of bi- and monolingual children with typical language development (TLD). In addition, to examine the mechanisms underlying the effects of bilingualism and DLD on children's lexical-retrieval abilities, we tested how item's characteristics (frequency of use) modulate the effects of bilingualism and DLD.
Methods & Procedures: Fifty-eight children (aged 9–14 years) participated in the current study. They were either Hebrew monolingual or Hebrew–English bilinguals and were either diagnosed with DLD or had TLD. Children completed a Hebrew picture-naming task and verbal short-term memory tests. The influence of participants' characteristics, including bilingualism, DLD and verbal short-term memory, as well as item's characteristics (frequency of use) were tested.
Outcomes & Results: Accuracy analysis revealed that bilingual children scored lower than monolingual children and that children with DLD scored lower than children with TLD. Critically, the two factors interacted such that their joint presence resulted in less-than-additive effects. Specifically, although bilingual children with DLD performed worse than all other groups, they performed better than expected under an additive model. Interestingly, monolingual children with DLD performed similarly to bilingual children with TLD. Increased verbal short-term memory was associated with better performance across the four groups. Finally, bilingualism and DLD interacted with item frequency, such that being bilingual, having DLD, or both, resulted in increased sensitivity to item frequency manifested in exceptionally lower performance on low-frequency items.
Conclusions & Implications: The findings suggest that the strength of linguistic representations contribute to the effects of bilingualism and DLD. Further, the presence of bilingualism in the context of DLD does not exaggerate the impact of DLD. Clinically, this suggests that differences between bi- and monolingual children with DLD must be considered in reference to the gap in lexical-retrieval performance observed between bi- and monolingual children with TLD. Finally, because monolingual children with DLD and bilingual children with TLD performed similarly, sensitive diagnostic tools and intervention programmes should be adopted to allow correct identification and treatment of bilingual children with DLD.

Keywords: DLD, bilingualism, frequency, picture naming, working memory.

What this paper adds
What is already known on the subject
It is known that children diagnosed with DLD have difficulty with word retrieval. At the same time, previous research shows that bilingual children are also characterized by reduced lexical-retrieval abilities.

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ISSN 1368-2822 print/ISSN 1460-6984 online
DOI: 10.1111/1460-6984.12454

What this paper adds to existing knowledge
The current study shows that both bilingualism and DLD lead to reduced lexical-retrieval performance, but that their joint presence results in less-than-additive effects. This means that the gap between bi- and monolingual children with DLD in picture-naming performance is smaller than between bi- and monolingual children with TLD. In addition, bilingual children or those with DLD are more strongly affected by the frequency of items.

What are the potential or actual clinical implications of this work?
Clinically, the study shows that any observed difference between bi- and monolingual children with DLD must be considered in reference to the gap between bi- and monolingual children with TLD. In addition, the need for sensitive diagnostic tools was highlighted by the similarity in performance of monolingual children with DLD and bilingual children with TLD. Finally, attention to item characteristics, such as frequency of use and cross-language phonological overlap (cognates), may prove useful in future clinical diagnosis and treatment.

Introduction

Children diagnosed with developmental language disorder (DLD) are often characterized by deficit in lexical-retrieval (or word-finding) difficulty (Dockrell *et al.* 1998, Novogrodsky 2015). For example, children with DLD receive lower scores than children with typical language development (TLD) on fluency tasks (Weckerly *et al.* 2001). However, even when language acquisition mechanisms are intact, lower lexical-retrieval scores may be observed due to reduced linguistic input. One prominent example of such reduced linguistic input can be identified in the case of bilingual children, for which each of their languages receives less input from the environment (Gollan *et al.* 2011). Similar to children with DLD, bilingual children receive lower scores in lexical-retrieval tasks (Gross *et al.* 2014). The joint effect of bilingualism and DLD on lexical abilities, as reflected by the performance of bilingual children with DLD (BiDLD), is not fully understood (for an overview, see Armon-Lotem *et al.* 2015). The aim of the current study is to explore the mechanisms underlying the effects of bilingualism and DLD on lexical retrieval.

Several approaches have been adopted in the literature in order to uncover the joint effect of bilingualism and DLD. One approach examines the effect of DLD within the bilingual population. Studies comparing bilingual children with typical language development (BiTLD) and BiDLD showed that BiDLD perform quantitatively and qualitatively worse than BiTLD across tasks that explored lexical development (Anaya *et al.* 2018, Holmström *et al.* 2016) and other language domains (for an overview, see Armon-Lotem *et al.* 2015).

A complementary approach examines the effect of bilingualism in children with DLD, by comparing the performance of BiDLD and monolinguals with DLD (MoDLD). These studies largely show that in the lexical domain, BiDLD perform qualitatively and quantitatively lower than MoDLD (e.g., Crutchley *et al.* 1997, Tsimpli *et al.* 2016, Westman *et al.* 2008).

Critically, it is not clear whether the difficulty associated with DLD (as revealed by the comparison of BiDLD and BiTLD) and the difficulty associated with bilingualism (as revealed by the comparison of MoDLD and BiDLD) rely on similar mechanisms. In the domain of the lexicon, indirect comparisons were made between BiTLD and MoDLD on standardized tests (Vender *et al.* 2016) by comparing both groups with monolingual norms. For instance, Vender *et al.* (2016) observed that like Italian MoDLD children, Italian BiTLD preschoolers speaking three different first languages (Albanian, Arabic and Romanian) scored significantly lower on a vocabulary comprehension test compared with monolingual norms.

Here we take a more direct approach, examining the mechanisms behind bilingualism and DLD within the same study. Therefore, in the current study we test the joint and interactive contribution of bilingualism and DLD to lexical performance of children by examining four groups of children: MoTLD, BiTLD, MoDLD and BiDLD. In what follows, we review previous studies in the lexical domain, examining the effects of bilingualism and DLD on children's performance.

Lexical effects of DLD in bilingual children

The effect of DLD within the population of bilingual children has been examined in the lexical domain using various measures, including naming (Anaya *et al.* 2018, Kambanaros *et al.* 2015, Khoury Aouad Saliby *et al.* 2017), word associations (Holmström *et al.* 2016) and lexical diversity measures in narrative production (Altman *et al.* 2016). Across these production tasks, the trigger for target selection among the meaning-related alternatives differ (Gollan *et al.* 2011). In each task, a different retrieval trigger is used, with visual objects used in the naming task, a different word in the word

association task and a semantic context in the narrative production task. Critically, although each paradigm taps somewhat different components of the lexical-retrieval processes, the converging pattern from this literature suggests that BiDLD children perform significantly lower than BiTLD children.

For example, in a recent study, 247 English–Spanish bilingual children aged5–11 years, with DLD (BiDLD) or with typical language development (BiTLD) were compared on a naming task in both languages (Anaya *et al.* 2018). The results revealed that BiDLD performed lower than BiTLD in naming accuracy, especially when responses from both languages were considered. In addition, in a case study, Kambanaros *et al.* (2015) compared naming accuracy and types of errors of a multilingual child with DLD (Bulgarian, Cypriot Greek and English) to two groups of Cypriot-Greek BiTLD, one matched on age and the other matched on language scores. The multilingual child with DLD scored lower across the three languages compared with the control groups. Further, the multilingual child with DLD exhibited similar types of errors across the three languages, highlighting comparable lexical-retrieval deficits across languages. These findings are in line with the results from other studies using naming tasks with different bilingual populations (Khoury Aouad Saliby *et al.* 2017) showing comparable deficits across languages. The current study similarly uses a naming paradigm in which lexical retrieval is cued by a visual depiction of the concept.

In word association tasks, in which the lexical retrieval is triggered by a word cue, a similar pattern emerged. Specifically, Holmström *et al.* (2016) examined the effect of DLD on the lexical organization of bilingual children. The authors explored word associations of BiDLD and BiTLD Arabic–Swedish speaking children longitudinally. Findings revealed more syntagmatic associations (e.g., words that rhyme) in the BiDLD group and more paradigmatic associations (e.g., words that share the same word class) in the BiTLD group. Because syntagmatic associations are characteristic of younger children, these findings suggest that BiDLD's lexical organization is slower to develop compared with BiTLD's lexical organization. Lastly, in a narrative production task, in which lexical retrieval is triggered by a semantically coherent context, BiDLD children used less diverse vocabulary compared with BiTLD (Altman *et al.* 2016, Tsimpli *et al.* 2016).

This body of literature suggests that the presence of multiple languages within the child's lexicon does not nullify the effect of DLD in the lexical domain. As noted above, a complementary approach examines whether the presence of DLD nullifies the effect of bilingualism, to be described below.

Lexical effects of bilingualism in children with DLD

Studies that tested MoDLD and BiDLD children on standardized lexical tests reveal lower scores for the BiDLD children compared with the MoDLD (Crutchley *et al.* 1997, Ottem and Jakobsen 2004). Other studies did not use standardized tests, but instead compared BiDLD and MoDLD with relevant control groups including MoTLD and BiTLD (Tsimpli *et al.* 2016, Westman *et al.* 2008) (as is done in the current study). For example, among 6-year-old children at risk for DLD, bilingual children scored lower than monolingual children on measures of vocabulary (naming of body parts) and sentence repetition (Westman *et al.* 2008). In a different study comparing school-aged mono- and bilingual children, although BiDLD children did not differ from MoDLD in expressive vocabulary and sentence repetition tasks, they scored marginally lower on lexical diversity measures in a narrative production task (Tsimpli *et al.* 2016). These findings suggest that in the lexical domain, bilingualism is associated with lower performance than monolingualism, even among children with DLD. Notably, this pattern is contrastive with the pattern observed in the domain of morphosyntax, where MoDLD and BiDLD show similar patterns of performance (e.g., in grammatical morphology; e.g., Armon-Lotem 2014, Paradis *et al.* 2003).

Critically, the presence of a difference between MoDLD and BiDLD children in the lexical domain (Tsimpli *et al.* 2016, Westman *et al.* 2008) does not necessarily imply that bilingualism interacts with DLD to make it worse. Rather, this gap may in fact reflect the typical bi–monolingual gap observed even among children with TLD.

A design that compares all four groups (BiTLD, MoTLD, BiDLD and MoDLD) allows the testing of this issue more directly. Two previous studies that adopted this approach (Rezzonico *et al.* 2015, Westman *et al.* 2008) observed no interaction between bilingualism and DLD in the lexical domain. Specifically, Rezzonico *et al.* (2015) tested 40 preschool children including BiTLD, MoTLD, BiDLD and MoDLD in a narrative production task, yielding among other measures a lexical diversity score. On this lexical-retrieval measure, children with DLD scored lower than children with TLD, but there was no reliable bilingualism effect or an interaction between the two factors. In Westman *et al.* (2008), similarly four groups were tested and no interaction was observed. In another study (Tsimpli *et al.* 2016), the interaction between the two factors was not tested although four groups were sampled. In the current study, we adopt this four-group approach and test for the interactive effects of bilingualism and DLD, and further examine the mechanisms behind

the bilingualism and DLD effects by testing modulations of item frequency, as detailed below.

Mechanisms behind lexical effects of bilingualism and DLD

Bilingualism

Although it is clear that both bilingualism and DLD are associated with low scores in lexical retrieval, it is not clear whether these are rooted in the same mechanisms. In the case of bilinguals, lexical-retrieval difficulty has been explained by two mechanisms. First, bilinguals' reduced lexical-retrieval performance has been explained by the competition bilinguals experience from their other language. In particular, the two languages of bilingual speakers are simultaneously active at all times (Kroll *et al.* 2006). This dual-language activation may lead to *competition* from the alternative representations when bilinguals attempt to retrieve words (Hermans *et al.* 1998).

A second non-mutually exclusive explanation has placed the emphasis on the role of frequency of use (for a discussion, see Kreiner and Degani 2015). Specifically, according to the Frequency-Lag Hypothesis (Gollan *et al.* 2011; formally known as the 'weaker links hypothesis', Gollan *et al.* 2008), bilinguals' representations are less available due to reduced frequency of use in both languages. This is because bilinguals, by definition, have to divide their time between their two languages, and as such have reduced frequency of use for words in each language compared with monolinguals (Gollan *et al.* 2005) leading to lower scores on lexical-retrieval measures.

In the current study, we manipulate item frequency because it can help disentangle these two accounts. In general, previous studies consistently show that in a picture-naming task, pictures that correspond to words of higher frequency are named faster and more accurately than those referring to lower frequency items (e.g., Gollan *et al.* 2005). Items with higher frequency of use enjoy higher baseline activation levels and a smaller distance from the threshold needed for selection (for a discussion, see Gollan *et al.* 2008).

Our focus in the current study is on how item frequency may reveal the mechanisms behind the effects of bilingualism on lexical retrieval. Specifically, if the bilingualism disadvantage stems from *competition*, then the bilingualism effect (i.e., difference between bi- and monolinguals, beyond DLD) should be larger for high-frequency words. This is because for these items the alternative translations are highly activated due to their frequency, and may thus create larger competition (Kroll and Gollan 2014). In contrast, if the bilingualism disadvantage stems from *reduced frequency* of use for bilinguals, then the bilingualism effect should be stronger for low-frequency words because for such items the difference between bi- and monolinguals is more pronounced (e.g., Gollan *et al.* 2008). In the current study, we examine the difference between bi- and monolinguals for low- and high-frequency items.

Developmental language disorders

For DLD, difficulty in lexical retrieval may be the result of two general sources. One is that there may be impairments in the linguistic system, with a specific deficit in semantic representations (e.g., Biran *et al.* 2018), in phonological representations (McGregor 1994), in the links between these levels (Friedmann *et al.* 2013), or across levels of the linguistic system (Biran *et al.* 2018, Novogrodsky and Kreiser 2015). Such explanations put the emphasis on the (low) availability of existing representations (Friedmann *et al.* 2013). Accordingly, items with increased frequency of use should be more available and thus alleviate some of this DLD difficulty.

In contrast, other theories suggest that lexical retrieval is reduced in children with DLD due to a general cognitive deficit, not specific to the linguistic system (for a review, see Leonard 1998). For instance, one variant of this theoretical perspective assumes that the deficit is linked to children's inability to process rapid auditory information (e.g., Leonard 1998: ch. 6, Tallal *et al.* 1985). Thus, the deficit in basic auditory (non-linguistic) processing underlies the linguistic behaviour of children with DLD. Extending this line of thought, item frequency should not modulate the DLD effect because the availability of specific linguistic representations is not central to the operation of these general cognitive (auditory) mechanisms. Thus, the DLD effect should be stable across the entire lexical system, in both low- and high-frequency items.

In the current study, we test whether the same mechanisms underlie the effects of bilingualism and DLD in the lexical domain by examining to what extent these effects are modulated by item frequency. To the extent that the difficulties associated with bilingualism and DLD both stem from low availability of lexical representations, then both the DLD effect and the bilingualism effect should be modulated by item-specific frequency. If, however, DLD is tied to deficit in non-linguistic mechanisms, then the effect of item frequency should not interact with DLD. With respect to bilingualism, both theoretical accounts (competition and frequency lag) predict interactions between the bilingualism effect and item frequency, but the direction of this interaction reverses. If bilingualism is tied to competition from the other language, then the bilingualism effect should be stronger for high-frequency items. If, however, it is tied to reduced availability of representations, then the

Table 1. Participant characteristics by language group

	Monolinguals		Bilinguals	
	DLD	TLD	DLD	TLD
Age (months)	132 $(25)_a$	112 $(3)_b$	121 $(21)_a$	119 $(12)_a$
Basic span	3.8 $(.4)_a$	4.6 $(.5)_b$	4.0 $(.7)_a$	4.1 $(.6)_a$
Long span	3.0 $(.5)_a$	3.8 $(.5)_b$	3.2 $(.7)_a$	2.9 $(.6)_a$
Non-word span	2.6 $(.5)_a$	2.9 $(.3)_a$	2.4 $(1.0)_a$	2.7 $(.6)_a$

Note: Values are means (standard deviation). Means in the same row that do not share a subscript differ at $p < .05$ in a *t*-test with Bonferroni correction for multiple comparisons.

bilingualism effect should be stronger for low-frequency items.

Finally, because we test children with diverse linguistic profile, including both bilingual children and children with DLD, we opted to ensure that differences in the internal resources available to the child are accounted for. To this end, we examined verbal short-term memory, which has been implicated as a relevant factor in lexical retrieval of bilingual children (Thorn and Gathercole 1999), and specifically of bilingual children with DLD (e.g., Girbau and Schwartz 2008, Meir 2017).

To summarize, in the current study children completed a picture-naming task and verbal short-term memory tasks in Hebrew. Critically, we compared the performance of four groups of children, including monolingual Hebrew children with typical language development (MoTLD) or with DLD (MoDLD), Hebrew–English bilingual children with TLD (BiTLD) or with DLD (BiDLD). We test whether the effects of bilingualism and DLD interact. Specifically, the joint presence of bilingualism and DLD (BiDLD) may result in extreme difficulty because bilingualism makes the deficit associated with DLD stronger. Alternatively, their joint presence may result in suppressive interaction, such that lexical-retrieval abilities of BiDLD children would be better than expected based on their language profile. Finally, their effects may be additive with no interaction, perhaps suggesting separate mechanisms for bilingualism and DLD. Finally, we further test to what degree these effects are modulated by item frequency and verbal short-term memory.

Materials and methods

Participants

Fifty-eight children aged 9–14 years old participated in the study, 30 children with TLD (15 Hebrew monolingual and 15 English–Hebrew bilingual) and 28 children with DLD (13 Hebrew monolingual and 15 English–Hebrew bilingual) (table 1). Children from all four groups were from middle-to-high socioeconomic status (SES), attending regular classes in regular schools in Israel. SES was determined based on the environment in which the children live, and verified by the cities' rank as determined by the country's Central Bureau of Statistics (2013, 94th percentile). *Bilingual children* were all children for whom English was spoken at home by at least one parent, and Hebrew was the language of communication at school and after-school activities. Hebrew was thus their dominant language of communication. Bilingual children have started attending a Hebrew speaking school no later than kindergarten (age 5), and thus have been intensively exposed to Hebrew for at least 4 years. These details were verified with children's parents.

Children with TLD were recruited through personal connections. *Children with DLD* were recruited from a private clinic and participated in an individual intervention programme once a week. All were diagnosed before the study by an experienced speech and language pathologist, using standardized and non-standardized language tests for school-age children that are used in clinics. They met the exclusionary criteria for DLD (Leonard 1998). In the vocabulary Shemesh test reported in the current study, each of the children scored below the typical age reference score (based on https://www.tau.ac.il/~naamafr/shemesh.pdf).

As shown in table 1, the monolingual children with TLD were significantly younger than the other three groups. Nonetheless, this younger group was not lower in their naming (see figure 1) and memory performance, and in fact, outperformed the other groups on most measures. Thus, age differences are unlikely to account for the observed naming pattern.

Materials

Naming Task (Shemesh, Biran and Friedman, 2004)

The test includes 100 coloured pictures of nouns from different semantic categories and is appropriate for assessment of school-age children (Novogrodsky and Kreiser 2015). To evaluate Hebrew frequency of the depicted target nouns we extracted frequency ratings from previous norms (Biran and Friedman 2004). These frequency ratings were provided by a group of adult native Hebrew speakers who rated the words on a scale of 1–7 (mean = 4.9, SD = 1.09). The target words ranged from 2.4 to 6.8 and this dimension was added to the analysis models as a continuous variable. Critically, examination of the items revealed that the Hebrew names of 10 of the items had phonological overlap with the corresponding English translation (Hebrew–English cognates, e.g., /salat/ in Hebrew refers to 'salad' in English). Because preliminary analyses revealed that naming of these cognate items differed from that of the non-cognate items for bilingual children, the 10 cognate items were excluded and analyses are based on 90 non-cognate items.

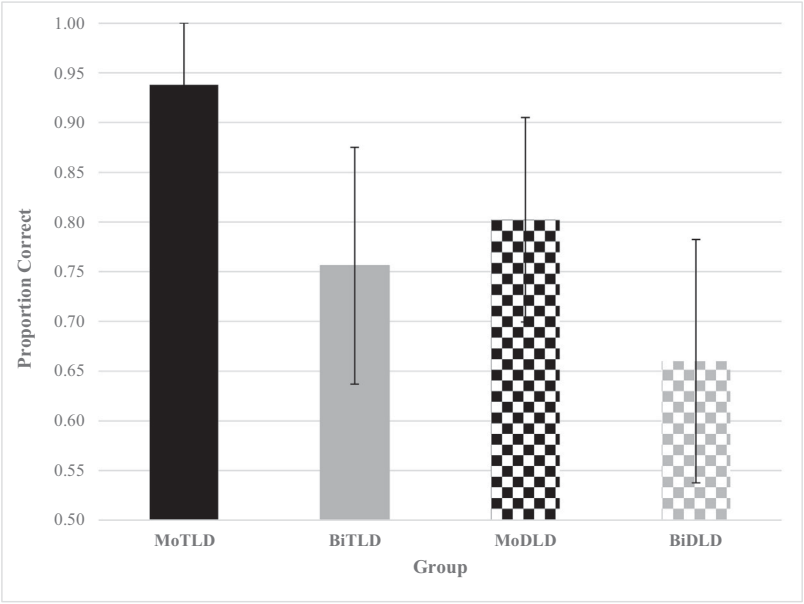

Figure 1. Naming accuracy as a function of group (observed means and standard errors).

Verbal short-term memory

Three tests of word span (basic words, long words and non-words) were administered (Gvi'on and Friedmann 2012). Each span test included six levels, of two to seven word or non-word sequences, with five sequences per level. *The basic word span* test included two-syllable words. *The long word span* test included sequences of four-syllable words. *The non-word span* included two-syllable non-words, constructed by changing a single consonant in real words. Items in the basic and long span were mostly nouns, with the exception of four adjectives, and included a range of items in terms of frequency, imageability, and abstractness. We focused on the basic span in the current analysis.

Procedure

Each participant was tested individually in a quiet room. No time limit was imposed during testing, and no response-contingent feedback was given by the experimenter. All tasks were administered in Hebrew and no communication took place in English during the experiment. Children were first administered the naming task, followed by the sentence completion task (about 15 min) which is reported elsewhere (Novogrodsky and Kreiser 2015), and last by the verbal short-term memory span tasks. In the naming task, children were presented with each picture separately in a fixed (randomized) order, and were asked to provide the name of the picture in Hebrew. No familiarization phase was administered, in accordance with the typical protocol of the Shemesh test (Biran and Friedman 2004). The verbal short-term memory test was administered following the published administration protocol (Gvi'on and Friedmann 2012). Accordingly, the lists of words were produced by the experimenter (a native Hebrew speaker), and the participants were asked to recall the items serially.

Results

Figure 1 presents observed means and standard error (SE) of the naming accuracy by group. Results were analyzed for the set of non-cognate items ($n = 90$), using logistic regression mixed effects models, as implemented in the lme4 library (Baayen *et al.* 2008) in R (version 3.3.1, R Core Team, 2016). In the following tables, estimations of β, SE, Z and p-values are based on the summary () function, whereas F-values are based on the corresponding analysis of variance (ANOVA) () function of the same models.

In the models, fixed effects included bilingualism (mono versus bilinguals, with monolinguals set as the reference) and language impairment (TLD versus DLD, with TLD set as the reference) as well as the interaction between them. The models included random effects of intercepts for participants and items. Maximal random structures including by-item random slopes for bilingualism and language impairment were tested but failed to converge.

Table 2 presents the results based on the interactive model, because the log likelihood ratio test revealed that the complex model including the two-way interaction between bilingualism and DLD was superior to the additive model, $\chi^2(\text{d.f.} = 1) = 4.68$, $p = 0.031$.

Table 2. Linear mixed effect model results based on analysis of variance (ANOVA) () and the summary () functions

Effect	*SS/MS/F* (d.f. = 1)	β	SE	Z	Pr(>|z|)
(Intercept)		3.72	0.30	12.35	<.001*
Bilingualism	57.61	−2.16	0.30	−6.97	<.001*
DLD	29.1	−1.70	0.32	−5.26	<.001*
Bilingualism*DLD	4.87	0.96	0.43	2.21	0.027*

Note: *Significant effect with $p < .05$.

The findings show that bilingual children scored lower than monolingual children and children with DLD scored lower than children with TLD. Interestingly, as presented in figure 1, the two factors interacted.

As seen in table 3, pair-wise comparisons revealed that all groups differed from each other with the exception of the monolingual children with DLD compared with the bilingual children with TLD. Importantly, as reflected in the size of the beta-coefficients, the difference between children with DLD and children with TLD was larger among monolingual children ($\beta = -2.04$) than among bilingual children ($\beta = -0.69$). Thus, the effect of DLD was weaker for bilingual children than for monolingual children. Further, the effect of bilingualism was weaker for children with DLD ($\beta = -1.23$) compared with children with TLD ($\beta = -2.20$).

Thus, the effect of bilingualism and DLD was non-additive and their co-existence suppressed their effects on performance. Still, bilingual children with DLD scored lower than all other groups, but their performance was higher (mean = .69) than expected based on computations from the additive model including bilingualism and DLD (mean = .65).

In addition, the results show that monolingual children with DLD did not significantly differ from bilingual children with TLD. In fact, the marginal difference between them was such that the monolingual children with DLD outperformed the TLD bilingual children.

Additional prediction variables

To test the possibility that individuals with different linguistic profiles are differentially affected by the availability of different items in memory, we examined the contribution of two important factors – one pertaining to the internal resources available to the child and the other related to the external availability of the stimulus. In particular, children's score on a verbal short-term memory task (basic span) reflecting internal resources and the frequency of the word associated with the presented picture, reflecting external availability of the stimulus, were added as predictors to the model. Verbal short-term memory and Item frequency were treated as continuous variables and were centred before analysis. Both factors resulted in significant influences on performance such that higher verbal short-term memory and higher frequency were associated with better performance ($F(1) = 15.19$, $\beta = 1.13$, SE = .29, $z = 3.94$, $p < .001$; F(1) = 34.52, $\beta = .98$, SE = .17, $z = 5.86$, $p < .001$, respectively). The model including the interaction between them did not improve fit, χ^2 (d.f. = 1) = 2.49, $p = 0.114$.

Next, we examined whether the critical variables in the current study, bilingualism and DLD, improve the fit of the model. As noted in table 4, in this additive model, bilingualism and DLD significantly affected performance, even after the other predictors (verbal short-term memory and item frequency) were entered into the model. Specifically, bilingual children scored lower than monolingual children, and children with DLD scored lower than children with TLD.

Finally, we examined the interactions among these variables. The model including the four-way interactions did not converge. To allow convergence, and because verbal short-term memory did not significantly interact with item frequency ($F = 2.55$, $p = .11$), with bilingualism ($F < 1$) or with DLD ($F = 1.17$, $p = .28$), we retained in the model the three-way interaction among bilingualism, DLD and item frequency, keeping the main effect of verbal short-term memory in the model. This model, presented in table 5, improved the fit relative the additive model including only the main effects of verbal short-term memory, item frequency, bilingualism and DLD (table 4), χ^2(d.f. = 4) = 10.988, $p = 0.026$.

The results of the model show that bilingual children scored lower than monolingual children did, and children with DLD scored lower than children with TLD. The two-way interaction between bilingualism

Table 3. Linear mixed effect model results based on analysis of variance (ANOVA) () and the summary () functions

	Effect	*SS/MS/F* (d.f. = 1)	β	SE	Z	Pr(>|z|)
Monolinguals: effect of DLD	MoDLD versus $MoTLD_a$	38.39	−2.04	0.33	−6.80	<.001*
Bilinguals: effect of DLD	BiDLD versus $BiTLD_a$	4.84	−0.69	0.31	−2.20	.028*
DLD: effect of Bilingualism	BiDLD versus $MoDLD_a$	15.44	−1.23	0.31	−3.93	<.001*
TLD: effect of Bilingualism	BiTLD versus $MoTLD_a$	48.66	−2.20	0.32	−7.00	<.001*
	MoDLD versus $BiTLD_a$	3.17	0.63	0.35	1.78	0.075±

Note: Subscript 'a' denotes the reference level. *Significant effect with $p < .05$. ± marginally significant effect with $p < .1$.

Table 4. Linear mixed effect model results based on analysis of variance (ANOVA) () and the summary () functions

Effect	*SS/MS/F* (d.f. = 1)	β	SE	Z	Pr(>|z|)
(Intercept)		0.91	0.94	0.97	
Verbal short-term memory	30.07	0.59	0.21	2.84	.005*
Item frequency	32.99	0.98	0.17	5.86	<.001*
Bilingualism	56.50	−1.66	0.22	−7.60	<.001*
DLD	14.45	−0.87	0.23	−3.80	<.001*

Note: *Significant effect with $p < .05$.

Table 5. Linear mixed effect model results based on analysis of variance (ANOVA) () and the summary () functions

Effect	*SS/MS/F* (d.f. = 1)	β	SE	Z	Pr(>|z|)
(Intercept)		3.34	0.30	11.30	<.001*
Verbal short-term memory	29.54	0.51	0.22	2.32	0.020*
Item frequency	33.92	0.58	0.21	2.79	0.005*
Bilingualism	55.04	−1.73	0.32	−5.39	<.001*
DLD	13.84	−1.00	0.38	−2.66	0.008*
Bilingualism*DLD	0.87	0.29	0.46	0.63	0.529
Item frequency *Bilingualism	2.82	0.46	0.15	3.04	0.002*
Item frequency*DLD	1.52	0.44	0.16	2.69	0.007*
Bilingualism*DLD* Item frequency	5.47	−0.46	0.19	−2.39	0.017*

Note: *Significant effect with $p < .05$.

and DLD was not significant, but the three-way interaction among bilingualism, DLD and item frequency was significant. To unpack this three-way interaction, and better understand how item frequency affects children with different linguistic profile, we examined the effect of bilingualism and item frequency separately for children with DLD and TLD. As shown in table 6 and figure 2, TLD bilingual children were influenced by item frequency more strongly than TLD monolingual children, but bilingual children with DLD were influenced by item frequency in the same way as monolingual children with DLD.

We further examined the effects of DLD and item frequency separately for monolinguals and bilinguals. As shown in table 7 and figure 2, in the monolingual group, MoDLD were marginally more strongly affected by item frequency compared with MoTLD, whereas in the bilingual group, both BiDLD and BiTLD were similarly affected by item frequency.

The item frequency effect was significant in all four groups (MoTLD $\beta = 0.72$, SE = .32, $z = 2.28$, $p = .02$; BiTLD $\beta = 0.96$, SE = .20, $z = 4.94$, $p < .001$; MoDLD $\beta = 0.99$, SE = .20, $z = 4.89$, $p < .001$; BiDLD $\beta = 1.04$, SE = .18, $z = 5.95$, $p < .001$). However, as seen in figure 2, the influence of item frequency was reduced for MoTLD, such that the difference in performance between low- and high-frequency items was relatively small in this group. In contrast, in the other three groups, performance on low-frequency items was much lower than on high-frequency items. Critically, the influence of item frequency, as indicated by the slope, was similar across the three groups. This pattern suggests that bilingualism and DLD both lead to increased frequency effects, but their effects are not additive. To illustrate, if bilingualism and DLD had additive effects, BiDLD children should have scored 30% on low-frequency and 89% on high-frequency items, when in fact they scored higher than expected on low-frequency items (47% and 87% respectively). The patterns show instead that when children are both bilingual and with DLD, the effect of item frequency is not different from that of BiTLD or of MoDLD.

Discussion

The current study examined the joint effects of bilingualism and DLD on children's lexical-retrieval ability. Four groups of children were compared, including MoTLD, BiTLD, MoDLD and BiDLD, on their accuracy in a picture-naming task. Consistent with previous findings and our prediction, bilingual children scored lower than monolingual children (e.g., Gross *et al.* 2014). In addition, children with DLD achieved lower accuracy than children with TLD (Biran *et al.* 2018, Dockrell *et al.* 1988).

Critically, the presence of both bilingualism and DLD within the same child resulted in a pattern consistent with a suppressive interaction. Namely, although BiDLD children scored lower than all other groups, they performed better than would be expected based on the additive contribution of their linguistic characteristics. In addition, our results suggest that BiTLD children performed similarly to the MoDLD children.

The presence of multiple languages within the child's lexicon resulted in lower accuracy in a picture-naming task. This bilingualism effect was found for both TLD children and children with DLD. The finding observed within the TLD groups is consistent with the literature showing that bilinguals present reduced lexical retrieval both among adults (Gollan *et al.* 2005) and among children (e.g., Gross *et al.* 2014). Further, the effect of bilingualism in the lexical domain among children with DLD is also consistent with findings from previous studies (Crutchley *et al.* 1997, Ottem and Jakobsen 2004). This bilingualism effect could be explained by both competition resulting from the dual activation of both languages of the bilingual child (Hermans *et al.* 1998, Kroll *et al.* 2006, 2014) and by the lower frequency of use of words in each language for bilinguals compared with monolinguals (Gollan *et al.* 2005, 2011).

Table 6. Effects of bilingualism and item frequency as a function of DLD from the linear mixed effect models reported in the text

		Accuracy				
		SS/MS/F (d.f. = 1)	β	SE	Z	Pr(>|z|)
TLD	(Intercept)		3.44	0.34	10.25	<.001*
	Short-term memory span	30.92	0.80	0.37	2.17	0.03
	Bilingualism	26.31	−1.64	0.35	−4.68	<.001*
	Frequency	21.69	0.50	0.22	2.25	0.025*
	Bilingualism*Frequency	7.98	0.45	0.16	2.83	0.005*
DLD	(Intercept)		2.40	0.32	7.51	<.001*
	Short-term memory span	0.17	0.38	0.29	1.30	0.193
	Bilingualism	17.64	−1.42	0.33	−4.28	<.001*
	Frequency	38.72	1.02	0.19	5.42	<.001*
	Bilingualism*Frequency	0.05	0.03	0.13	0.23	0.819

Note: *Significant effect with $p < .05$.

We discuss the contribution of these mechanisms when considering the effect of item frequency below.

In addition to the effect of bilingualism on children's lexical retrieval, the present study further shows that the presence of DLD hinders performance. In particular, both among monolingual children and among bilingual children, we observed that DLD was associated with reduced picture-naming accuracy. This finding is naturally predicted from the diagnosis of DLD, by which children with DLD experience difficulty in lexical retrieval (Leonard 1988).

Critically, the four-group approach we adopted allowed us to examine not only the main effects of bilingualism and DLD but also the joint and interactive contribution of these two factors. Our analysis revealed that the two factors interacted, such that their joint effect was non-additive. Notably, this was a suppressive interaction, such that the presence of both factors does not exaggerate the difficulty. Rather, it leads to better performance than would be expected in an additive model. This is not to say that BiDLD children performed better than their monolingual controls, but that in their case, bilingualism did not add to the difficulty in performance as much as it did for TLD children. Thus, although BiDLD children perform worse than MoDLD children, this difference does not indicate that bilingualism makes DLD worse.

The observed interaction between bilingualism and DLD in the current study contrasts with two previous studies in which no interaction was observed. Specifically, Rezzonico *et al.* (2015) and Westman *et al.* (2008) tested four groups of preschool children in

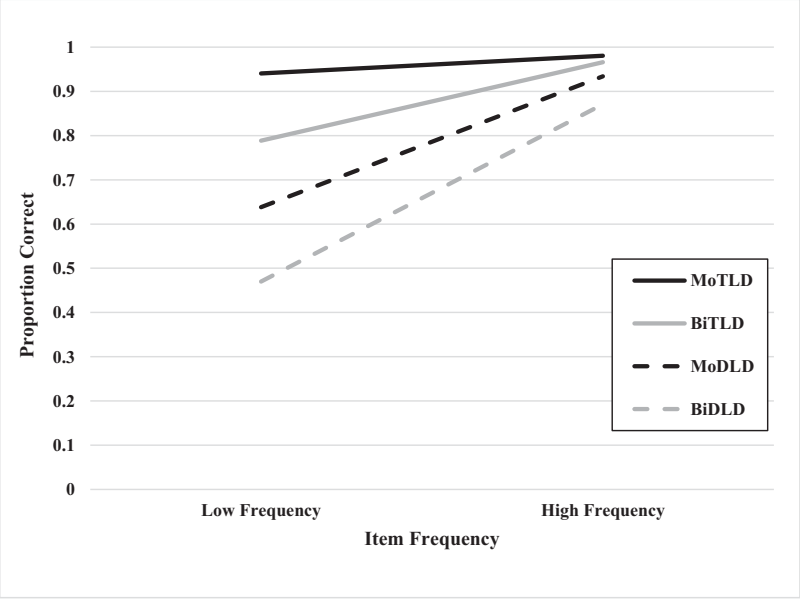

Figure 2. Naming accuracy as a function of item frequency and group (estimated means, based on 1 SE (standard error) below (low frequency) and above (high frequency) the mean).

Table 7. Effects of DLD and item frequency as a function of bilingualism from the linear mixed effect models reported in the text

		Accuracy				
		SS/MS/F (d.f. = 1)	β	SE	Z	Pr(>|z|)
Monolingual	(Intercept)		3.76	0.37	10.08	<.001*
	Short-term memory span	18.96	0.31	0.38	0.83	.406
	DLD	13.32	−1.52	0.47	−3.22	.001*
	Frequency	18.74	0.66	0.25	2.61	.009*
	DLD*Frequency	3.56	0.35	0.18	1.91	.057±
Bilingual	(Intercept)		1.64	0.26	6.33	<.001*
	Short-term memory span	5.55	0.63	0.29	2.20	.028*
	DLD	4.51	−0.63	0.29	−2.14	.032*
	Frequency	38.35	1.01	0.18	5.73	<.001*
	DLD*Frequency	0.02	0.02	0.11	0.15	.884

Note: *Significant effect with $p < .05$. A '±' denotes a marginally significant effect with $p < .1$.

lexical-retrieval tasks (narrative production and naming, respectively). Although they found reliable effects of DLD, they did not find interactions between bilingualism and DLD. One reason for the different pattern of results may be the age of the tested participants. In particular, it is possible that the younger children tested in previous studies were closer to floor performance, minimizing the sensitivity to observe interaction. This may be especially critical with small samples (Rezzonico *et al.* 2015). Further, in the study of Westman *et al.* (2008) children with TLD were compared with children at risk for DLD, such that the diagnosis was not confirmed, whereas in the current study children with confirmed DLD diagnosis were tested, perhaps tapping a more homogeneous group.

The current study does not provide a clear explanation for the *reason* that BiDLD performed better than would be expected given their linguistic background (their bilingualism and their DLD). Nonetheless, a tentative suggestion may be considered. Specifically, it is possible that the presence of ambiguity in the bilingual lexicon of a child with DLD, due to the existence of two labels for each meaning representation, provides these children with better scaffoldings/cues in the retrieval process. In particular, children with DLD can benefit from supporting cues in order to retrieve a word (Ebbels *et al.* 2012). Therefore, it is possible that a translation of a word in the other language (e.g., 'rake' for the Hebrew /magrefa/) can be used by bilingual children with DLD as an effective retrieval cue through the overlapping semantic features of the two words. This is clearly speculative at this point and await future studies in which such a retrieval cue mechanism is directly measured.

Interestingly, our findings further demonstrate that the performance of children with either DLD or bilingualism was similar, with a marginal advantage for MoDLD over BiTLD children. Moreover, as seen in figure 1, the variance within three of the groups (BiTLD, MoDLD, BiDLD) is relatively large, leading to substantial overlap of the distributions. This pattern suggests that diagnosis of a given child into one of these 3 groups is difficult to make based on only one lexical-retrieval task, especially when this task includes a set of items which was not specifically developed for this population (see cognate discussion below). Notably, the degree of distributional overlap across the three groups may vary with factors such as bilinguals' years of exposure to their languages (Altman *et al.* 2019). Indeed, Altman *et al.* (2019) showed that the number of years bilingual children are exposed to their second language is positively correlated with their performance on standardized linguistic tests. Relatedly, the manner in which the two languages were acquired, namely simultaneous versus sequential bilingual acquisition (Thordardottir *et al.* 2015) may further modify behaviour especially for younger children. Specifically, because simultaneous bilinguals have been exposed to their two languages from birth, their years of exposure and accumulated frequency of use are similar across their two languages. Further, it is possible that the degree of cross-language competition manifests itself differently in sequential versus simultaneous bilinguals (for a discussion, see, e.g., Li 2009). Additional factors such as differences in circumstances of use (e.g., Green and Abutalebi 2013), or the similarity between the child's two languages, may further influence performance of TLD and DLD bilingual children. This inherent variance in bilingual population (e.g., Kaushanskaya and Prior 2015) highlights the complexity in diagnosing DLD among bilingual children, and calls for the development of additional sensitive measures and standardized tests that are tailored for this population (Armon-Lotem *et al.* 2015).

Verbal short-term memory

Variability in the internal resources that children bring to the task may further impact the performance of all four groups. In the current study we focused on verbal short-term memory because this factor has been implicated as an influential one in lexical retrieval,

specifically among bilingual children with DLD (Girbau and Schwartz 2008, Meir 2017). Consistent with this previous literature, we observed that children with higher verbal short-term memory performed better on the picture-naming task. The fact that we observe this typical modulation of behaviour by individual differences in verbal short-term memory strengthens the validity of our findings more generally. This effect was stable across the four groups of children in the current study. Notably, however, the lack of interaction among short-term memory, bilingualism, DLD and word frequency may be the result of limited power. Most critically for the goals of the current study, the effects of bilingualism and DLD remained reliable even after controlling for individual differences in verbal short-term memory. Thus, the differences observed between bi- and monolinguals, and between children with DLD and with TLD cannot be reduced to group differences in verbal short-term memory (Claessen and Leitão 2012). Future studies, with larger samples, may be able to better test interactions among short-term memory and individual based (bilingualism and DLD) and item-based (word frequency) factors.

Item frequency

An important feature of the current study was the investigation of both participant linguistic characteristics and item specific characteristics within the same study. In particular, in addition to exploring the role of verbal short-term memory, bilingualism and DLD, as participant characteristics, we tested the influence of item frequency on children's lexical-retrieval performance. The results show that pictures associated with words of higher frequency resulted in overall higher naming accuracy compared with those with lower frequency of use. This finding is consistent with previous literature (e.g., Gollan *et al.* 2005) and may reflect the higher baseline activation levels of higher frequency words (Gollan *et al.* 2008).

Importantly, we further examined whether the effect of item frequency is stable across the four groups. We found increased item frequency effects in three of the four groups of children. Particularly, monolingual children with TLD exhibited relatively shallow item frequency effects, whereas the other three groups (MoDLD, BiDLD, BiTLD) exhibited a larger difference between low- and high-frequency items. This is not to say that monolingual children with TLD are insensitive to the frequency of use of the presented items, as the effect of item frequency was reliable in this group as well. However, the findings show that the influence of item frequency, as indicated by the slope, was larger and comparable across the other three groups. We discuss this pattern by examining the interactions between frequency and bilingualism and between frequency and DLD, as detailed below.

With respect to the effect of bilingualism, we observed that both groups of bilinguals (BiTLD and BiDLD) exhibited larger item frequency effects than monolinguals. As alluded to earlier, two theoretical accounts have been put forth to explain why bilinguals experience reduced lexical-retrieval abilities. One highlights the *competition* resulting from dual-language activation (Kroll *et al.* 2006, 2014) whereas the other stresses the reduced *frequency* of use of words in each of the bilinguals' languages (Frequency Lag; Gollan *et al.* 2011). Both theoretical accounts predict interactions between the bilingualism effect and item frequency, but the direction of this interaction is contrastive. Specifically, if bilingualism disadvantage is tied to reduced availability of representations then the bilingualism effect should be stronger for low-frequency items, because these items are of especially low frequency in bilinguals compared with monolinguals (Gollan *et al.* 2008). In contrast, if the bilingual disadvantage in lexical retrieval is tied to competition from the other language, then the bilingualism effect should be stronger for high-frequency items. This is because on such high-frequency items, the competitive translations from the other language may also enjoy high frequency of use, which in turn make them more effective competitors (Kroll and Gollan 2014). The results of the current study suggest a larger difference between bi- and monolinguals on low-frequency items, supporting the predictions of the frequency lag hypothesis (Gollan *et al.* 2011). According to this conceptualization, all representations of bilingual speakers are of lower frequency than those of monolinguals. This gives rise to larger differences between low- and high-frequency items among bilinguals. Indeed the current finding of larger bilingualism effects for low-frequency items is in line with previous investigations (Gollan *et al.* 2008).

As for the DLD, we observed that both groups of children with DLD (MoDLD and BiDLD) exhibited large frequency effects of similar magnitude. Contrastive predictions can be made in the case of DLD based on the two general approaches to the lexical-retrieval deficit. First, difficulty in lexical retrieval may be the result of impairments in the linguistic system (Ebbels *et al.* 2012, McGregor 1994, Friedmann *et al.* 2013, Novogrodsky and Kreiser 2015). Because these explanations emphasize the (low) availability of existing representations (Friedmann *et al.* 2013), one may predict that items with reduced frequency of use should be less available and thus aggravate the DLD difficulty. In contrast, other models posit that lexical retrieval is reduced in children with DLD due to a general cognitive deficit, not specific to the linguistic system (for a review, see Leonard 1998). For example, as

suggested by Tallal *et al.* (1985, for a review, see Tallal and Gaab 2006), children's inability to process rapid auditory information may be the cause of the observed language difficulty in children with DLD. Importantly, such deficits in basic auditory (non-linguistic) processing is not expected to vary as function of linguistic frequency of use. Thus, the DLD effect should be stable across the entire lexical system, in both low- and high-frequency items. In contrast to this prediction, our results show that the effect of DLD interacted with item frequency, such that overall the effect of frequency was larger for children with DLD compared with children with TLD. As seen in figure 2, the deficit for children with DLD, compared with TLD, is especially evident for low-frequency items. This increased frequency effect provides support for the theoretical models emphasizing the locus of the impairment in the linguistic system itself.

Because increased frequency of use appeared to diminish the effects of bilingualism and DLD in the current study, we predict that continuous use of the target language will work to decrease these effects even more. Accordingly, natural experience with the language on the part of TLD children may lead to smaller differences between mono- and bilingual older children. For children with DLD, such continuous use may entail strategies of intervention that are tailored at increased use, repetition, practiced retrieval etc. This issue awaits future empirical research.

Of note, although the current findings support the linguistic system as the locus of the language deficit in DLD, it is possible that additional contributing factors affect children's linguistic performance. Such factors may include indirect modulations by cognitive and social dimensions (see Hirosh and Degani 2018 for similar suggestions).

Interestingly, either being bilingual or being DLD is enough to make children more sensitive to item frequency, but the two factors have less than an additive effect. As explained in the context of figure 2 above, the difference between low- and high-frequency items is comparable for children who are both bilingual and DLD and for children who are either bilingual or have DLD.

This finding is consistent with the overall pattern of performance described above, by which the joint effect of bilingualism and DLD is interactive. This interaction is in the direction of suppression, such that it does not exaggerate the difficulty. Rather it leads to better performance than would be expected if the effects were additive. Future studies should explore whether a similar pattern of interaction between bilingualism and DLD is revealed in other linguistic measures of lexical retrieval (e.g., verbal fluency) and more contextualized language tasks (e.g., sentence completion).

In the current study, we only analyzed children's naming performance on pictures for which the Hebrew name did not overlap phonologically with the English translation (see the Methods section above). However, preliminary analysis on the few (ten) cognate items included in the set revealed that MoDLD and BiDLD did not differ in their lexical-retrieval performance on these items. This pattern is consistent with previous literature on bilingual adults (e.g., Sadat *et al.* 2016), showing comparable performance on cognates across groups, and with the cognate facilitation effect for bilingual children (e.g., Poarch and Van Hell 2012). Such findings may be due to the fact that the joint use of the lexical form across both languages increases the frequency of these items, or to the fact that the form overlap for cognate words leads to reduced competition across languages. Therefore, performance on cognate items may nullify a bilingualism effect and allow one to uncover the DLD effect across children. This result may intuitively suggest that such cognate items may be useful for clinical diagnosis and treatment of bilingual children (e.g., Kambanaros *et al.* 2017). Unfortunately, with the few cognate items available in the current set, there was no reliable difference between the TLD and DLD groups, both among the monolingual and among the bilingual children, on these items. Within the context of DLD, direct comparisons of children's performance on cognate and non-cognate items await additional research.

An additional limitation of the current study is linked to the treatment of potential modulations of the frequency of the (English) translations of the target Hebrew words. In particular, although target language (i.e., Hebrew) item frequency was directly tested, the specific set used in the current study precluded in depth investigation of the effects of both target and non-target language (i.e., English) item frequency.[1] Future studies in which the two factors are jointly tested in the context of children with DLD may illuminate the pattern of interactions, including competition and cooperation between translation equivalents, among these children.

Finally, the current sample represents only children from middle to high SES. This restricted SES variance precluded in depth investigation of this important variable in our study (Meir and Armon-Lotem 2017). Studies focusing on the effect of SES should adopt the four-group approach we advocate here to test further the interactions of bilingualism, DLD and SES.

To summarize, our findings show that both bilingualism and DLD influence children's lexical-retrieval performance, as measured in a picture-naming task. The four-group design adopted in the current study allowed examination of the joint effects of these factors. The findings revealed interactive effects, in that in the presence of one factor the effect of the other is reduced. As a result, although bilingual children with DLD score

lower than all other groups, they in fact perform better than would be expected based on the additive effects of bilingualism and DLD. This finding highlights that any comparison between MoDLD and BiDLD children must take into account the basic performance gap between MoTLD and BiTLD children. In addition, the pattern of results of the current study show comparable performance of BiTLD and MoDLD children, underscoring the importance of developing sensitive diagnostic tools and intervention programmes to allow correct identification and treatment of bilingual children with DLD. In the context of bilingualism and DLD, attention to item characteristics, such as frequency of use and cross-language phonological overlap (cognates) may prove useful in future clinical diagnosis.

Acknowledgements

The authors thank Thalia Richter and Einat Oz-Vecht for assistance with the data collection. During the writing of this manuscript, Tamar Degani was funded by an EU-FP7 grant (number CIG-322016) and Rama Novogrodsky by an ISF grant (number 1068/16). ***Declaration of interest:*** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Note

1. For the current item set there was a moderate correlation ($r = .45$) between the Hebrew frequency and the frequency of the English translations (log Subtlex Frequency, taken from the English Lexicon Project; Balota *et al.* 2006). As a result, it was difficult to test both frequency effects (Hebrew versus English) simultaneously because the model including both Hebrew frequency and English frequency failed to converge.

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