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ARTICLE

Developmental language disorder in sequential bilinguals: Characterising word properties in spontaneous speech

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Abstract
The current study sought to investigate whether word properties can facilitate the identification of developmental language disorder (DLD) in sequential bilinguals by analyzing properties in nouns and verbs in L2 spontaneous speech as potential DLD markers. Measures of semantic (imageability, concreteness), lexical (frequency, age of acquisition) and phonological (phonological neighbourhood, word length) properties were computed for nouns and verbs produced by 15 sequential bilinguals (5;7) with DLD and 15 age-matched controls with diverse L1 backgrounds. Linear mixed modelling revealed a significant interaction of group and word category on phonological neighbourhood values but no differences across imageability, concreteness, frequency, age of acquisition, and word length measures in spontaneous speech. Outcomes suggest that group-level differences may not be apparent at the word-level, due to the heterogeneous nature of DLD and potential similarities in production during early L2 acquisition.

Keywords: developmental language disorder; sequential bilingualism; word properties; spontaneous speech

Introduction

Developmental language disorder (DLD) is an enduring and dynamic neurodevelopmental disorder, resulting in delayed and impaired language acquisition in the absence of a biomedical cause (McMurray, Klein-Packard, McMurray & Tomblin, 2019). DLD is characterized by a language level lagging significantly behind age-matched peers, with impairments across lexical and morphosyntactic facets of production and comprehension (Bishop, 2017). Recent projects estimate that DLD affects between 7-10% of children (Leonard, 2014; Vender, Garraffa, Sorace & Guasti, 2016). Revisions in diagnostic practice have concluded that children with DLD form a highly heterogenous group, featuring a range of language-based impairments (Bishop, 2017). However, despite revisions, a persistent issue is the lack of sensitivity in language measures for early identification of DLD. This issue is particularly concerning for bilinguals, for whom there is a substantial rate of misdiagnosis (Grimm & Schulz, 2014).

The present exploratory study seeks to identify whether word properties can contribute to accurate DLD identification among sequential bilinguals. As typically-developing (TD) bilinguals can exhibit transient delays in acquisition compared to monolinguals, monolingually-normed instruments can produce a misdiagnosis of DLD (Bedore & Peña, 2008). These conditions pose particular challenges for sequential bilinguals, who acquire their second language (L2) later than their first language (Paradis, 2010) and may be likely to display apparent delays in L2 acquisition compared to monolinguals. As sequential bilinguals are among the largest bilingual subgroups, due to bilingual education schemes and global immigration, identification of sensitive single-language testing in L2 is currently sought, as resources and services in a minority L1 may prove challenging to access (Paradis, Schneider & Sorenson-Duncan, 2013). Given the implications for high misdiagnosis rates, clarification on characteristics of bilingual DLD across several facets is required. The present study therefore proposes an analysis of semantic, lexical, and phonological word properties in the speech of affected and TD bilinguals for a comprehensive view of word knowledge in bilingual DLD.

Bilingualism and the diagnosis of DLD

In the bilingual context, in which an individual uses two or more languages regularly in daily life (Grosjean, 1997), prevalent use of standardized measures normed for monolinguals can contribute substantially to misdiagnosis (Vender et al., 2016). Use of such measures can result in TD bilinguals performing below monolingual peers in vocabulary and morphosyntactic acquisition, in the absence of impairment (Chondrogianni & Marinis, 2011). Generally, a number of factors influence bilingual development, including daily language use, length and amount of L2 exposure, language dominance, the number of speakers with whom a bilingual interacts, and environmental factors, such as parental proficiency and home language use (Chondrogianni & Marinis, 2011). Each of these factors may be neglected by the use of monolingual normed-measures and result in overdiagnosis. Misdiagnosis can extend to either extreme, however; resulting in OVERDIAGNOSIS of DLD among TD bilinguals due to expectations from monolingual norms or UNDERDIAGNOSIS of DLD, from lack of sensitivity to differences between affected and TD bilinguals (Bedore & Peña, 2008).

Current measures of diagnosing DLD in the bilingual context tend to be language-specific and within the domain of morphosyntax (Garraffa, Vender, Sorace & Guasti, 2019). Differences between TD bilinguals and bilinguals with DLD have been observed in the impaired production of tense-marking morphemes in French among French–English bilinguals (Paradis, Crago, Genesee & Rice, 2003) and in erroneous subject-verb agreement in Dutch among Frisian–Dutch bilinguals (Spoelman & Bol, 2012), among others. Beyond morphosyntax, differentiating markers may manifest in phonological markers, such as non-word repetition and/or sentence-repetition tasks (Gathercole & Baddeley, 1990; Vender et al., 2016). Notably, children with DLD also tend to perform poorly on non-word repetition tasks compared to TD peers (Arslan, Broc, Mathy & Olive, 2020). Considering the rate of misdiagnosis in the bilingual context (Bedore & Peña, 2008), however, these markers may be insufficient for accurate evaluation. The recurrent issue of misdiagnosis poses a significant difficulty in clinical fields, as failing to recognize the needs of bilinguals limits their access to language-based services. Testing the language capacities of sequential bilinguals requires markers of greater sensitivity to the bilingual experience of DLD. In particular, examining markers beyond morphosyntax may be beneficial. The approach of the current study, therefore, focuses on single-language, L2 testing and seeks to investigate whether certain word properties in speech can illustrate differences between TD sequential bilinguals and those with DLD.

Word Learning Impairments in DLD

Word-learning deficits in DLD are prevalent cross-linguistically across grammatical categories (Skipp, Windfuhr & Conti-Ramsden, 2002), and manifest in slow vocabulary acquisition and poor performance on naming and fluency tasks (McGregor & Appel, 2002). Children with DLD also tend to rely on nouns more than verbs, due to the syntactic complexity of the latter (Gentner, 2006). While no clear cause of DLD has been determined, word-learning impairments in DLD have been attributed to potential processing deficits in phonological short-term memory and weaker skills in matching form and semantics, constraining the ability to acquire novel words (Gathercole & Baddeley, 1990; Nash & Donaldson, 2005). The interplay between these concepts may be best represented using a model of single-word processing, from Rofes, Mandonnet, de Aguiar, Rapp, Tsapkini and Miceli (2018) (based on Whitworth, Webster & Howard, 2014), where word production depends on the feed forward progression from lexical-semantics to the phonological output lexicon for form retrieval. The flow then progresses to the phonological output buffer, which functions as a temporary storage unit for assembled phonological units prior to articulation (Dotan & Friedmann, 2015). Deficits within DLD are attributed to weaknesses within this flow, resulting in word-learning difficulties.

Lexical processing deficits in DLD

Regarding lexical entries in DLD, Kail, Hale, Leonard and Nippold (1984) developed the storage-elaboration hypothesis, in which delayed language development may result in impoverished lexical representations in DLD. In accordance with the storage-elaboration hypothesis, children with DLD retain smaller lexicons and reduced familiarity with words in their lexicons, incurring access and retrieval issues (McGregor & Appel, 2002). Impoverished lexical entries may manifest at (1) the conceptual level within lexical-semantics, as limited semantic detail per entry or (2) at the level of the lexeme within the phonological output lexicon and/or the phonological buffer, as reduced knowledge of and/or ability to retain phonological forms. In either case, impoverished entries are posited to result in difficulties connecting to other entries, given insufficient detail to form connections based on semantic or phonological similarity, and influencing aspects of processing, due to network limitations between items (Brackenbury & Pye, 2005; Gathercole & Baddeley, 1990; Nash & Donaldson, 2005). As such, measures reflecting the richness of semantic representations (e.g., imageability, concreteness) or relations between representations (e.g., phonological neighbourhood) may be diagnostically informative.

The case of impoverished lexical entries in DLD has received empirical support (McGregor, Oleson, Bahnsen & Duff, 2013; Seiger-Gardner & Schwartz, 2008). In assessing production of definitions, McGregor et al. (2013) observed that children with

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DLD retain less knowledge for lexical items by measuring both VOCABULARY BREADTH; the number of known words, and VOCABULARY DEPTH; how well these words are known. Deficits were exemplified by both measures, as children with DLD knew fewer words than their TD counterparts and produced limited definitions of known words. Seiger-Gardner and Schwartz (2008) obtained complementary results using cross-modal picture-word interference tasks to measure picture-naming with both semantic and phonological distractors. As affected participants exhibited significantly longer times to rule out semantically-related distractors, the authors argue that semantic deficits feature as primary issues in DLD.

Phonological Deficits in DLD

Phonological aspects of word knowledge may also reflect vulnerabilities in DLD (Gathercole & Baddeley, 1990; Leonard, 2014; Sheng & McGregor, 2010). Notably, Sheng and McGregor (2010) observed that children with DLD produce phonologically-driven responses rather than semantically-related words in word association tasks. While school-attending children typically shift from a reliance on phonological information to semantic information in word-association tasks (Cronin, 2002), children with DLD may exhibit an enduring reliance on phonological qualities. Moreover, deficits in phonological working memory have been specifically implicated in monolinguals with DLD (Arslan et al., 2020; Gathercole & Baddeley, 1990) and sequential bilinguals with DLD (Engel de Abreu & Gathercole, 2012). Gathercole and Baddeley (1990) originally postulated that limitations in phonological storage impinge on word-learning in DLD, particularly as measures of phonological memory correlate positively with vocabulary. Difficulties temporarily storing phonological information within the phonological buffer may constrain word-learning ability and vice versa, as affected children perform consistently poorly on non-word repetition tasks (Coady & Evans, 2008; Vender et al., 2016). Among pertinent factors to consider when examining phonological memory, word length may play a role in word-learning, as children with DLD may struggle to acquire words of greater length in light of deficits within phonological working memory, relying disproportionately on shorter words (Gathercole & Baddeley, 1990). Over time, phonological memory deficits may impact adversely on semantic aspects of word knowledge, as the flow of mapping meaning to form is disrupted (Nash & Donaldson, 2005).

Word Learning in Typically-Developing Bilinguals

Application of the storage-elaboration hypothesis and phonological storage deficits in DLD may clarify differences between TD sequential bilinguals and bilinguals with DLD. While TD bilinguals may appear to demonstrate delays in vocabulary development (Gollan, Montoya, Cera & Sandoval, 2008), storage deficits along semantic and/or phonological aspects of lexical acquisition are not considered the root cause. The frequency-lag hypothesis of Gollan and colleagues (2008) postulates that bilingual children may demonstrate word processing delays as using a dual-language system may result in splitting the frequency of word use between both languages. Bilinguals may typically have fewer opportunities for word exposure and production in both languages, resulting in potentially lower frequencies of activation for items (Gollan et al., 2008). Moreover, the effect of divided engagement between both languages may lead to the formation of 'weaker links' between the semantics and phonology of lexical entries when compared to monolingual peers (Gollan et al., 2008). Consequently, word representations of TD bilinguals are not considered impoverished, however, but merely more difficult to access, given the frequency reduction per item.

Looking to differentiating markers between affected and TD bilinguals, Marini, Sperindè, Ruta, Savegnago and Avanzini (2019) noted that Italian–German bilinguals with DLD between the ages of 7-10 years demonstrated differences in lexical skills and phonological memory abilities when compared to age-matched controls. Bilinguals with DLD demonstrated reduced phonological short-term memory capacities, lower scores on vocabulary comprehension and naming tasks, and a significantly higher rate of semantic errors. Differences in processing abilities between bilinguals with DLD and TD controls between the ages of 9 – 14 years in single-language testing were also observed by Degani, Kreiser and Novogrodsky (2019). Specifically, the authors contrasted monolingual Hebrew-speaking and Hebrew–English bilingual groups with and without DLD on picture-naming tasks to mark interaction between bilingualism, DLD, and item frequency. Bilinguals with DLD exhibited significantly poorer performances and displayed larger item frequency effects than TD peers. In this sense, bilinguals with and without DLD can be accurately differentiated from one another and, moreover, the investigation of semantic, lexical and phonological word properties may aid group differentiation.

Characterising word properties in nouns and verbs

Measures of word properties in nouns and verbs have previously been used to characterize the language profiles of individuals with aphasia (Rofes, de Aguiar, Ficek, Wendt, Webster & Tsapkini, 2019). As children with DLD are posited to retain impoverished lexical entries whether due to or in addition to phonological storage deficits, a similar approach may clarify these positions by examining the spontaneous speech of affected bilinguals. Moreover, children with DLD tend to struggle with verbs more so than with nouns in English (Thordardottir & Weismer, 2001). This disparity is attributed to the syntactic complexity of verbs, rendering them more difficult to acquire (Gentner, 2006; Skipp et al., 2002). In general, children with DLD appear restricted to a smaller verb lexicon, tending to produce a greater number of nouns. In this case, analysis of noun and verb use and their contingent word properties in speech may aid DLD characterization in bilinguals.

Considering the storage-elaboration hypothesis, deficits in semantic representations of lexical items may manifest in semantic word properties, such as imageability and concreteness. Imageability, defined as the ease with which a mental image is evoked by a word, is considered a measure of semantic feature richness (Bird, Howard & Franklin, 2003). Concreteness, while thematically similar to imageability and highly correlated, refers to the degree to which a concept is tangible (Brysbaert, Warriner & Kuperman, 2014; Rofes et al., 2018). Both have been implicated as highly relevant factors in early word-learning, as Howell and Becker (2001) argue that both define the ease with which a word is learnt. Highly imageable words also tend to be processed with greater ease (Montgomery, Gillam, Evans, Schwartz & Fargo, 2019) and highly concrete words are deemed easier in recall tasks than abstract items (Sadoski, Goetz & Fritz, 2016). Given the roles attributed to imageability and concreteness in early word-learning, it is predicted that children with DLD rely on highly imageable and concrete words in their production.

Frequency and age of acquisition are two lexical measures related to the ease of lexical selection and/or access (Gibson, Peña & Bedore, 2014) and may reflect characteristic differences between bilinguals with/out DLD. Firstly, a reliance on highly frequent words may be a discernible trait among sequential bilinguals with DLD (Levie, Ben-Zvi & Ravid, 2017; Nash & Donaldson, 2005). This position is supported by Brackenbury and Pye (2005), who posit that lexical deficits among children with DLD are connected to impairments within the phonological output lexicon. Frequency effects may reflect the organization of lexical entries or access to these entries (Friedmann, Biran & Dotan, 2013). Examination of frequency measures may be sufficiently sensitive to provide accurate distinctions between TD and affected sequential bilinguals, as bilinguals with DLD exhibit greater reliance on frequent items when compared to control groups (Degani et al., 2019). The age of acquisition (AoA) of a word also influences word processing and correlates negatively with frequency measures (Montgomery et al., 2019). Words learnt early in life tend to be processed faster and with greater ease than words acquired later (Ghyselinck, Lewis & Brysbaert, 2004). Both lexical frequency and AoA are argued to be potent predictors of lexical naming and processing (Colombo & Burani, 2002), in which highly frequent words and those acquired at a younger age facilitate processing.

Looking to phonological word properties and word category, verbs generally tend to be shorter than nouns in English (Black & Chiat, 2003). Word-learning is also affected by word length (Gathercole & Baddeley, 1990) and phonological neighbourhood, defined as the number of lexemes with overlapping phonology when one phoneme of that word is altered, either through deletion, substitution or addition (Leonard, 2014). Mainela-Arnold, Evans and Coady (2010) proposed that children with DLD struggle to distinguish phonologically similar words, indicating that words with dense neighbourhoods cause great difficulty in production. Other studies have indicated the words with a greater number of neighbours may generally be accessed with greater ease than those with fewer neighbours (Vitevich & Sommers, 2003). As such, the influence of phonological neighbourhood density on word-learning remains inconclusive. However, words with many phonological neighbours are also typically shorter and neighbourhood effects related to lexical impairments may co-exist with greater ease in producing longer words with fewer neighbours (Storkel, 2004). Word length may otherwise affect performance in the opposite direction, as shorter words may be processed with greater ease than longer words. This word length effect may be attributed to a storage deficit in phonological working memory, specifically the phonological buffer (Gathercole & Baddeley, 1990).

The present study

The present study proposes exploratory analysis of word properties in nouns and verbs in the production of age-matched sequential bilinguals with and without DLD. Spontaneous speech samples in L2 English will be analysed for possible effects of word properties by comparing affected sequential bilinguals and their TD peers. The following six-word properties will be analysed: i) imageability, ii) concreteness, iii) frequency, iv) age of acquisition, v) phonological neighbourhood and vi) word length in phonemes, extracted separately for nouns and verbs. As theories of phonological working memory deficits and/or the presence of impoverished lexical representations in DLD have gained empirical support, potential manifestations of these impairments will be examined through the effects of these word properties. Given the exploratory nature of this study, the heterogeneity of DLD and influential effects of bilingual factors, such as typological distance between languages, general predictions for the performance of sequential bilinguals with DLD were formulated alone.

Research Question

Do patterns of word properties within nouns and verbs in spontaneous speech reflect group-level differences between TD sequential bilinguals and sequential bilinguals with DLD?

Predictions for Sequential Bilinguals with DLD

Sequential bilinguals with DLD are predicted to demonstrate:

i) Predominant use of nouns, rather than verbs, in spontaneous speech,

In relation to word properties therein,

i) Greater reliance on highly imageable, and concrete lexical items,
ii) Greater reliance on highly frequent lexical items with low AoA values,
iii) Greater reliance on lexical items with smaller numbers of phonemes and/or a reliance on words with smaller phonological neighbourhoods.

Method

Participants

Spontaneous speech transcripts of 30 sequential bilinguals were included in the current study: 15 TD bilinguals and 15 bilinguals with a diagnosis of DLD. Participants were selected from a larger sample, which was originally collected by Paradis and colleagues (2013) in Edmonton and Toronto regions of Canada. The original sample comprised 252 TD sequential bilinguals and 28 sequential bilinguals with DLD. Generally, these children came from newcomer families who had immigrated to Canada with parents born outside of Canada, all of whom spoke a non-English L1. Exclusionary criteria for the overall sample included diagnosis of ASD, diagnosis of hearing impairment, known speech-sound disorders and/or evidence of severe intellectual disability. While diversity of L1 is notable across the sample (see Table 1), all children were primarily exposed to their L1 during the first 2-3 years of life and began acquiring English as L2 upon attending

Table 1. L1 Background of Participants

L1	TD Bilinguals	Bilinguals with DLD
Spanish	4	4
Cantonese	3	3
Arabic	2	2
Punjabi	2	2
Gujarati	1	1
Farsi	1	1
Urdu	1	1
Vietnamese	1	1

English-medium preschool programmes. The current sample was selected using the matched-pairs approach: each child within the DLD grouping was matched with a counterpart from the TD group, where possible, using L1, age at testing and length of exposure to English *(months)* as control variables.

Typically-developing sequential bilinguals

15 TD sequential bilinguals were included in the current study; 11 male and 4 female. The mean chronological age of children was 69 months *(range = 58-78 months, standard deviation = 5.7 months).* TD children were exposed to an average of 23.5 months of English prior to recruitment. During original data collection, it was established that the home language was predominantly L1 for twelve participants, both L1 and English for one participant and predominantly English for two participants. Regarding child language production in the home, nine participants produced mostly their L1, four participants produced both their L1 and English equally, and two participants produced mostly English. For the original sample, participating TD children were recruited from both schools in the region and from contact with agencies that aid newly-immigrated families (see Paradis et al., 2013 for details on recruitment).

Sequential bilinguals with DLD

15 sequential bilinguals with a diagnosis of DLD were selected for the current study; 11 male and 4 female. The mean age of children within this grouping was 67 months *(range = 60-76 months, standard deviation = 5.11 months).* Children within this grouping had an average of 26 months of exposure to English. The home language across bilinguals with DLD was predominantly L1 for seven participants, both L1 and English for five participants, and predominantly English for three participants. In terms of child language production, six participants produced mainly L1, one participant typically produced both L1 and English equally, and eight participants produced mostly English at home. Sequential bilinguals with a diagnosis of DLD had been referred to the original study by speech and language therapists within schools and/or from specific preschool programmes catering to children with language delays.

Both groups were matched for chronological age of testing and exposure length to English (see Table 2). Additional characteristics pertaining to both groups are displayed in Table 2, including measures of language and development, nonverbal IQ, and socioeconomic status as represented by the years of mothers' education. A significant difference was observed in mothers' years of education between both groups *($t = 2.28$, $p < .05$),* in which the mothers of TD sequential bilinguals had spent a greater number of years in education. Standardised scores on the Columbia Mental Maturity Scales (CMMS; Burgemeister, Blum & Lorge, 1954) accompanied the transcripts of the current sample, and indicated that nonverbal IQ scores among TD sequential bilinguals were significantly higher than those within the DLD grouping, *($t = 4.571$, $p < .05$).*

Additionally, measures of language development were obtained for each participating child. During the original data collection of Paradis et al. (2013), scores of language and development were compiled using the Alberta Language Development Questionnaire (ALDEQ; Paradis, Emmerzael & Sorenson-Duncan, 2010), values of mean length of utterance (MLU) and two measures of lexical diversity, defined as the scope of vocabulary used by an individual: Type Token Ratio (TTR) and D (Owen & Leonard, 2002) using

Table 2. Participant Characteristics across TD and DLD Groups

	Typically Developing			Bilinguals with DLD		
	n	*M*	*SD*	n	*M*	*SD*
Female	4			4		
Male	11			11		
Age (*months*)		69.3	5.8		67.3	5.11
English Exposure (*months*)		23.5	10.9		26.3	11.49
Mother's education (*years*)		14.1*	2.88		11.33*	3.79
CMMS		112.21*	11.68		93.13*	10.7
ALDEQ		0.8*	0.1		0.45*	0.1
MLU		4.21*	0.94		3.43*	0.8
Lexical Diversity (*D*)		58.77	14.5		52.59	10.19
Type Token Ratio (*TTR*)		0.4	0.05		0.39	0.06

**indicates a significant difference*

CLAN (MacWhinney, 2003). TTR refers to the total number of different words used divided by the total number of words uttered, while D is the index of modelling a curve of multiple TTR samplings and identifying a model of best fit. Both TTR and D are considered reliable indices of lexical diversity in child language (Owen & Leonard, 2002).

As anticipated, total scores from the ALDEQ indicated that TD bilinguals obtained higher scores in language development compared to their peers with DLD ($t = 7.838, p < .05$). Similarly, differences between groups based on MLU were observed ($t = 2.445, p < 0.05$), where MLU values across TD sequential bilinguals were higher than those of bilinguals with DLD. Neither measure of lexical diversity indicated significant differences between groups; D ($t = 1.348, p > 0.05$) and TTR ($t = -0.05, p > 0.05$).

Procedure

Transcripts of free-play interactions were obtained from the original research (Paradis et al., 2013), which took place within school and home settings. During the recording sessions, children were engaged in conversation with the researcher in the presence of an additional observer. For each participating child in the current sample, a transcript with a minimum of 100 utterances during each recording session was analysed.

Data analysis

Nouns and verbs in each transcript were identified using CLAN (MacWhinney, 2003) with the following code: *freq +t*CHI +z100u.* Using the *freq* command, frequency information for each word produced by the child was tabulated within their first 100 utterances. Nouns and verbs were then manually extracted. In the case of ambiguity regarding lexical category – for instance, a lexical item that is used as both a noun and a verb (e.g *hug, dress*) – grammatical category was determined by examining the transcript for the speaker's use and then labelling it accordingly. Nouns and verbs produced by each participant were then compiled into separate files and loaded into the N-Watch programme (Davis, 2005) separately for each participant. Values for frequency (CELEX database: (Baayen, Gulikers & Piepenbrock, 1995)), the number of phonemes, phonological neighbourhood, and imageability (Bristol norms database: Stadthagen-Gonzalez & Davis, 2006) were obtained within the N-Watch programme. Values for concreteness (from Brysbaert et al., 2014) and AoA (from Kuperman, Stadthagen-Gonzalez & Brysbaert, 2012) were then identified manually for each item.

For nouns, where a child produced the plural form of a nouns (e.g., dogs), the plural form was analysed for frequency, phonological neighbourhood, and length in phonemes. As most plural nouns were not available for imageability, concreteness, and AoA, ratings for the singular form were used where a plural rating was unavailable (n = 113 entries, 13% of items). Verb entries were initially examined in the form the child produced (e.g., past tense inflection.). Where the original form was unlisted, values for the base form were used (n = 68 entries, 8%). Words returning the value of "-1" across categories were excluded from the analysis, as this value served to indicate that the word was unlisted in the N-Watch programme. Out of 866 unique entries, the number of missing values across categories are as follows: imageability (n = 155 entries, 18%), concreteness (n = 8 entries, < 1%), frequency (n = 2 entries, < 1%), and AoA (n = 16 entries, 1%). Both phonological variables had complete datasets. After compiling values for each variable per target word, descriptive statistics were calculated per participant and grammatical category using RStudio (R Core Team, 2018; R Studio Team, 2019).

Statistical analysis

Proportional differences in the production of nouns and verbs were assessed using a two-sample test for equality of proportions. Word properties were then assessed using linear mixed models and the lme4 package (Bates, Mächler, Bolker & Walker, 2015) with RStudio (R Core Team, 2018; R Studio Team, 2019). Additional packages used included "tidyverse" (Wickham et al., 2019) "ggplot2" (Wickham, 2016) and the "sjPlot" package (Lüdecke, 2021) for data visualisation. Given skewed distributions across imageability, concreteness, frequency and age of acquisition measures as anticipated for child language, these four variables were log-transformed to comply with assumptions of linear mixed modelling. Measures of phonological neighbourhood and number of phonemes were treated as count-based variables and analysed by generalised linear mixed models using the Poisson distribution and log canonical link. Each word property was analysed in a separate model with *group membership (k = 2; TD, DLD)* and *grammatical category (k = 2; nouns, verbs)* acting as predictor variables and with the inclusion of participant as a random effect. Preliminary models including (i) word and (ii) participant L1 as additional random effects resulted in model overfitting in both cases and were subsequently excluded from each model of best fit, as appraised using likelihood ratio tests described by Winter (2013).

Results

In this section, statistics relating to the proportional use of nouns and verbs are first presented, followed by descriptive and inferential statistics for each word property. Properties have been grouped within respective categories; semantic properties of imageability and concreteness are first presented, followed by lexical properties of frequency

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and AoA, and phonological properties of neighbourhood (PN) and word length in phonemes thereafter. For specifics relating to each model, see Appendices B and C.

Word Category

The production of nouns and verbs amongst TD sequential bilinguals and sequential bilinguals with DLD was tabulated, with the total number of produced nouns and verbs reported in Table 3. To examine the proportions of nouns and verbs used between sequential bilinguals with DLD and TD sequential bilinguals, a two-sample test for equality of proportions was computed using RStudio (R Core Team, 2018; R Studio Team, 2019). It was observed that the use of both nouns and verbs did not appear to differ proportionally between groups, ($\chi^2 = 0.6038, p = 0.435$). Sequential bilinguals with DLD and TD sequential bilinguals did not differ in their proportional production of nouns and verbs, indicating that high reliance on nouns is not disproportionate in cases of DLD in this sample.

Word properties across nouns and verbs

To test whether values of word properties differed across groups and word category, separate linear mixed models were computed for i) imageability, ii) concreteness iii) AoA and iv) frequency using the lme4 package (Bates et al., 2015) in R (R Core Team, 2018; R Studio Team, 2019) with the alpha level established at *0.05.* PN and word length were treated as count response variables and required separate generalised linear mixed models using the Poisson distribution and log link function (Anderson, Verkuilen & Johnson, 2012). In each case, word properties were treated as functions of the following fixed effects; group ($k = 2;$ TD/DLD) and word category ($k = 2;$ Noun/Verb). As the overall dataset contained multiple observations per participant, participant was included as a random effect in each model to satisfy the independence assumption. For details relating to group means across L1, see Appendix A. In relation to contrasts, predictor variables were sum contrast coded *(-0.5, 0.5)* across both linear and generalised methods of model analyses for mean-centring to aid interpretation of main effects (Schad, Vasishth, Hohenstein & Kliegl, 2020). Table 4 reports means and standard deviations for each word property across group and word category.

Semantic Properties: Imageability, Concreteness

A linear mixed model of log-transformed imageability ratings, *lmer(log(Imageability) ~ Group + Word_Category + (1|participant)),* revealed no significant differences across group ($\widehat{\beta} = 0.016$, *standard error* = 0.011, $t = 1.494$, $p = 0.135$). A significant main effect of word category on imageability ratings was observed ($\widehat{\beta} = 0.388$, $se = 0.0105$, $t = 37.037$,

Table 3. Production of Grammatical Category across Groups

Group	Nouns	%	Verbs	%
Bilinguals with DLD	419	*53%*	378	*47%*
TD Bilinguals	502	*51%*	490	*49%*

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Table 4. Mean and Standard Deviations of Word Properties

	TD		DLD	
	Nouns	Verbs	Nouns	Verbs
	M(sd)	*M(sd)*	*M(sd)*	*M(sd)*
Imageability	572.56 *(64.11)*	389.41 *(108.18)*	569.98*(67.52)*	384.66 *(102.03)*
Concreteness	4.46 *(0.64)*	3.07 *(0.94)*	4.49 *(0.63)*	3.05 *(0.91)*
Frequency	14847.6 *(26310.4)*	106540.7 (*193167.4)*	11985.42 *(22619.08)*	128426 *(545546)*
AoA	4.38 *(1.23)*	4.28 *(0.95)*	4.46 *(1.37)*	4.30 *(0.95)*
PN	11.2 *(8.8)*	16.9 *(8.1)*	10.6 *(8.9)*	17.9 *(7.7)*
Word Length	4.236 *(1.44)*	3.42 *(1.2)*	4.35 *(1.55*	3.27 *(1.0)*

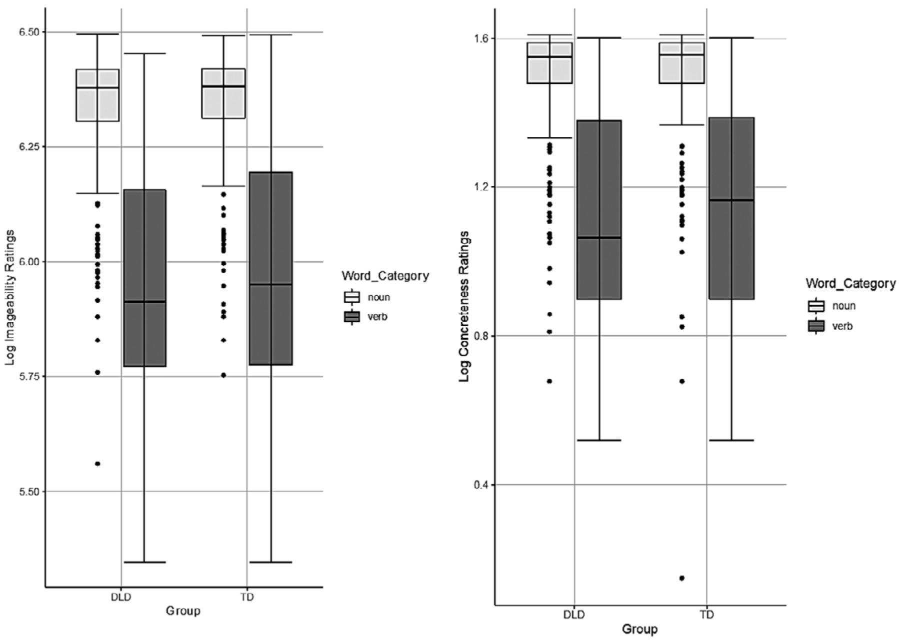

Figure 1. Boxplots of Imageability and Concreteness ratings across group and word category

p < 0.05) in which nouns produced during spontaneous speech held higher ratings than verbs (see Figure 1). Similarly, a linear mixed model of log-transformed concreteness ratings, *lmer(log(Concreteness) ~ Group + Word_Category + (1|participant)),* revealed no significant differences across group *(* $\widehat{\beta}$ = 0.0106*, se = 0.0147, t* = 0.725*, p* = 0.4683*),* though a main effect of word category was observed *(* $\widehat{\beta}$ = 0.3789, *se* = 0.0121, *t* = 31.25, *p < 0.05),* in which concreteness ratings across nouns were also higher than those for verbs (see Figure 1). Model comparisons revealed that the model of best fit did not specify any interaction term between both fixed effects for imageability or concreteness. Generally,

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these results suggest that the words produced by TD sequential bilinguals and those with DLD do not differ based on their imageability or concreteness ratings, but that verbs produced by both groups were significantly lower in ratings of imageability and concreteness than nouns.

Lexical Properties: Frequency, Age of Acquisition

A linear mixed model of log-transformed frequency ratings as a function of word category and group, *lmer(log(Frequency) ~ Group + Word_Category + (1|participant))*, indicated that group was not a significant predictor ($\widehat{\beta}$ = 0.016, *se* = 0.0914, *t* = 0.179, *p* =0.858). A significant main effect of word category was observed for frequency ratings ($\widehat{\beta}$ = -1.5698, *se* = 0.0845, *t* = -18.574, $p < 0.05$), in which verbs tended to have higher frequency ratings than the nouns produced (See Figure 2). Model comparisons revealed that the model of best fit did not specify any interaction term between both fixed effects for lexical frequency. Generally, results indicate that word category acts as a significant predictor of frequency ratings, with highly frequent verbs tending to emerge in spontaneous speech across both groups of children. A linear mixed model of log-transformed AoA ratings as a

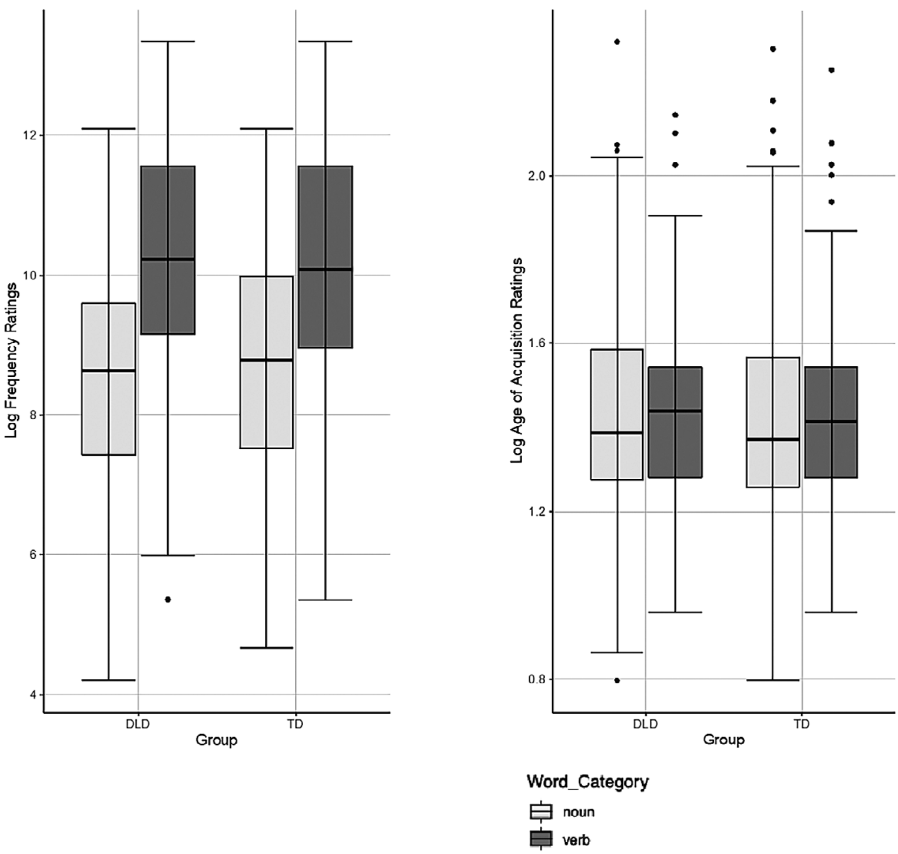

Figure 2. Boxplots of Frequency and Age of Acquisition ratings across group and word category

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function of group and word category, *lmer(log(AoA) ~ Group + Word_Category + (1| participant))*, revealed that neither group ($\widehat{\beta}$ = -0.0144, *se* = 0.016, *t* = -0.883, *p* = 0.377) nor word category ($\widehat{\beta}$ = -0.012, *se* = 0.0120, *t* = -1.013, *p* = 0.3109) carried significant main effects (see Figure 2). In this case, effects of age of acquisition did not manifest in the use of nouns and verbs produced during spontaneous speech, revealing neither a word category effect nor a group effect. The average AoA rating for words produced across both groups was 4.23, suggesting that both groups tended to use words with lower AoA ratings than their age expectation of 5;9 and 5;7 respectively. Neither lexical property demonstrated group-led differences between patterns of frequency or AoA in words produced during spontaneous speech.

Phonological Properties: Phonological Neighbourhood, Word Length

A generalised linear mixed model using the Poisson distribution and the log scale as canonical link, *glmer(PN ~ Group + Word_Category + Group*Word_Category +(1| participant), family = poisson(link = "log"))*, revealed a main effect of word category for phonological neighbourhood measures of words ($\widehat{\beta}$ = -0.4758, *SE* = 0.013, *z* = -36.4218, $p < 0.05$) but no main effect of group ($\widehat{\beta}$ = -0.0025, *SE* = 0.022, *z* = -0.1146, *p* = 0.909) (see Figure 3). A significant interaction between group and word category, however, was noted ($\widehat{\beta}$ = -0.104783, *SE* = 0.026, *z* = -4.008, $p < 0.05$). Generally, this result indicates that sequential bilinguals with DLD and TD sequential bilinguals do not differ in production concerning the number of phonological neighbours a word may have, but that values for phonological neighbourhood for verbs were higher overall than values for nouns amongst the entire sample. Looking to the interaction effect marked in the model, as illustrated in an interaction plot in Figure 4, it is notable that the magnitude of the word category effect appears stronger across participants within the DLD grouping than their TD peers. In this case, the disparity between nouns and verbs in terms of phonological neighbours is more extreme for sequential bilinguals with DLD, who produced verbs with high numbers of phonological neighbours when compared to nouns.

Similarly to the measure of phonological neighbourhood, a generalised linear mixed model using the Poisson distribution and the log scale as canonical link was operationalised for word length in phonemes, *glmer(LEN_P ~ Group + Word_Category +(1| participant), family = poisson(link = "log"))*, where no interaction effect was specified in the model of best fit. Values of word length in phonemes revealed a significant main effect of word category ($\widehat{\beta}$ = 0.2499, *se* = 0.0246, *z* = 10.143, $p < 0.05$), in which nouns tended to be of greater length than verbs produced during spontaneous speech (see Figure 3). No significant main effect of group was observed ($\widehat{\beta}$ = -0.0082, *se* = 0.0246, *z* = -0.333, *p* = 0.739). In this manner, group differences did not manifest in the word length in phonemes of nouns and verbs produced in spontaneous speech.

To account for the potential influence of length in phonemes on phonological neighbourhood, an exploratory model for phonological neighbourhood was computed to include the mean word length produced by each participant as a random slope. The exploratory generalised linear mixed model, *glmer(PN ~ Group*Word_Category + (1| participant) + (mean word_length| participant), family = poisson(link = "log"))*, resulted in a singular fit, indicating an overfitted structure. Mean word length accounted for little variance in the overfitted model, while the interaction between group and word category remained significant while controlling for mean length across participants ($\widehat{\beta}$ = -0.028, *se* = 0.006, *z* = -4.646, $p < 0.05$).

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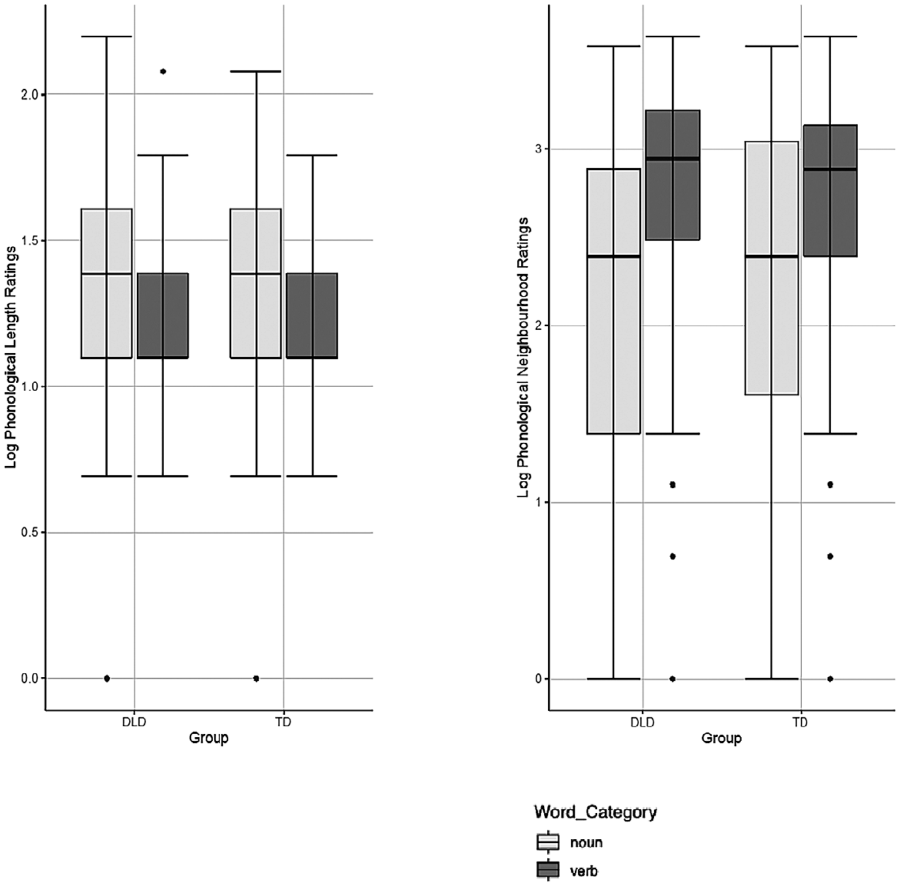

Figure 3. Boxplots of Phonological Length and Phonological Neighbourhood ratings across group and word category

Discussion

The objective of the current study was to investigate whether word properties in nouns and verbs reflect differences between sequential bilinguals with and without DLD. As children with DLD are posited to exhibit impoverished lexical entries and/or phonological storage deficits, bilinguals with DLD were predicted to exhibit characteristic patterns of noun and verb use along semantic, lexical, and phonological properties. Nouns and verbs in spontaneous speech were analysed across six-word properties; imageability, concreteness, frequency, AoA, phonological neighbourhood and word length. Sequential bilinguals with DLD did not demonstrate an overreliance on nouns compared to their TD counterparts, as no proportional difference in noun and verb production between groups was noted. Using separate linear mixed-models for semantic and lexical properties and separate generalised mixed-models for phonological properties, no main effect of group emerged along any of the six word properties. Word category acted as a significant predictor of five of the listed properties, with age of

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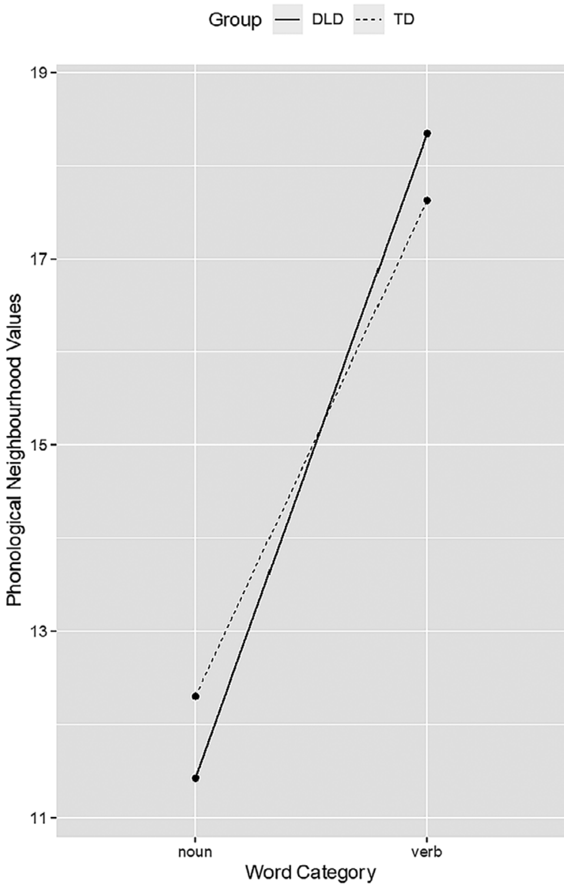

Figure 4. Interaction plot of Phonological Neighbourhood ratings across group and word category

acquisition as the lone exception. Phonological neighbourhood values revealed a model of best fit including an interaction term between group and word category, indicating that the magnitude of difference between nouns and verbs in this measurement was greater for sequential bilinguals with DLD. Broadly, results indicate that nouns, verbs, and their contingent word properties, with the exception of an interaction effect of group and word category on phonological neighbourhood, do not indicate characteristic differences between groups.

While sequential bilinguals with DLD are posited to rely predominantly on nouns and retain low levels of verb diversity (Sanz-Torrent, Serrat, Andreu & Serra, 2008; Thordardottir & Weismer, 2001), no clear difference in the proportions of nouns and verbs produced were observed between affected and TD groups. This may be partly attributable to the fact that both groups were relatively early in their acquisition of L2. Moreover, while children with DLD are posited to rely on 'GAP verbs' (Rice & Bode, 1993), which may reveal possible group disparity, analysis of the quality of verbs used was beyond the scope of the current study.

Production of Word Properties in Spontaneous Speech

Regarding the storage-elaboration hypothesis (Kail et al., 1984), bilinguals with DLD were predicted to rely on highly imageable and concrete words. The spontaneous speech of affected bilinguals did not differ from their TD counterparts, as both groups produced highly imageable and concrete items. This is particularly apparent in the case of concreteness, as the mean value for noun concreteness across both groups was *4.49,* based on a rating scale of 1-5 (Brysbaert et al., 2014). Though verbs tend to have much lower values of imageability and concreteness when compared to nouns, as affirmed by word category emerging as a significant predictor of both measures individually, verbs produced in the current study culminated in mean values toward the higher end of the scales. This pattern reflects the view of Howell and Becker (2001) that imageability and concreteness facilitate early word-learning, given their relation to interpretable sensorimotor experiences. The lack of group differentiation on these properties may be a further manifestation of early L2 word-learning, particularly as children in both affected and TD groups were appraised in L2 English.

Regarding lexical properties, both groups depended on highly frequent verbs, while frequency values for nouns were significantly lower. This finding follows the argument that verbs tend to be more challenging for children and specifically in the case of DLD, resulting in the use of highly frequent verbs (Thordardottir & Weismer, 2001). This result is also consistent with predictions that sequential bilinguals with DLD were likely to rely on highly frequent items. A similar pattern was also noted for TD sequential bilinguals, however, resulting in a lack of group differentiation. This finding may align with the frequency-lag hypothesis (Gollan et al., 2008), as TD bilinguals face reduced frequency of lexical items compared to monolinguals. Particularly as sequential bilinguals were appraised in L2 English, a reliance on highly frequent verbs in L2, regardless of impairment, may reflect an early word-learning strategy for L2. In this case, examining frequency values for words produced during spontaneous speech may be unlikely to clarify distinctions between affected and TD bilinguals. Further, AoA values reflected neither a word category nor a group difference. Generally, the average value for words produced by both groups was *4;3* years of age. Looking to the current study's demographic, this mean value is over a year younger than the mean age for participants (see Table 2.), revealing that both groups exhibit a lag compared to norms for monolinguals. This finding is also unsurprising, as these children are acquiring English later than monolingual English speakers and will likely demonstrate a later trajectory of acquisition.

Looking to phonological properties, no group differences emerged based on word length while nouns produced by both groups were significantly longer than verbs. Generally, sequential bilinguals with DLD were predicted to rely on shorter words, as deficits within DLD are postulated to arise from a phonological storage impairment (Gathercole & Baddeley, 1990). While this may be the case, TD sequential bilinguals demonstrated a similar pattern. Given no disparity in length effects between groups, elaboration on a possible phonological storage deficit in DLD requires further study in the bilingual population.

Additionally, research indicates that children with DLD retain difficulties in distinguishing phonological neighbours (Mainela-Arnold et al., 2010; Storkel, 2004). While no main effect for group emerged for this property, verbs produced had significantly higher numbers of phonological neighbours than nouns. The significant interaction effect between group and word category as predictive of phonological neighbourhood density warrants further discussion, as the difference in phonological neighbour values between nouns and verbs was of greater magnitude for bilinguals with DLD. While small, this

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effect is contrary to expectations for acquisition in DLD, as greater density is associated with greater lexical competition, which is challenging for children with DLD with respect to phonological neighbours (Mainela-Arnold et al., 2010). This finding is, however, in line with the research of Vitevich and Sommers (2003), who generally posit that words with denser neighbourhoods, as noted among verbs in the current study, may be easier to access. As words with denser phonological neighbourhoods may be shorter in length (Storkel, 2004), a further avenue of study may be to investigate whether sequential bilinguals with and without DLD are using similar strategies to use shorter words at the expense of phonological neighbourhood, as no effect of length was noted. Exploratory analysis sought to account for the potential influence of average word length per participant on phonological neighbourhood values, resulting in an overfitted model. It is notable, however, that the interaction effect between word category and group remained significant while controlling for mean length. As such, while results cannot shed definitive support for a deficit in phonological storage mechanisms, as postulated by Gathercole and Baddeley (1990), usage patterns of both groups reflect the characteristic that verbs tend to be shorter than nouns in English (Black & Chiat, 2003).

Generally, no main effect of group emerged based on semantic, lexical, and phonological properties in single words. Looking to theoretical implications, these outcomes cannot clarify the presence of impoverished lexical entries in the case of bilinguals with DLD, as posited by Kail et al. (1984). While speech produced by affected bilinguals reflected a reliance on highly imageable, concrete and frequent items that are low in AoA ratings, performance of TD bilinguals also conforms to these conditions. It is possible that differences may not be discernible at the single-word level, as both groups may be relying on similar strategies for early stages of L2 acquisition. This possibility is discussed in greater detail in the following sub-section. Additionally, while these results cannot shed definitive support for a deficit in phonological storage mechanisms, as postulated by Gathercole and Baddeley (1990), it is curious that TD sequential bilinguals produce similar patterns of use, though to a lesser magnitude than their affected peers. Elaboration on the possibility of children with DLD harbouring impoverished lexical entries (Kail et al., 1984) and/or deficits in phonological storage (Gathercole & Baddeley, 1990), however, can only be speculative and requires greater study, particularly in the area of phonological properties.

Similarities between Sequential Bilinguals with and without DLD

Several possible explanations may clarify the lack of group differences between TD sequential bilinguals and those with DLD. Firstly, the impairments arising within the classification of DLD are highly heterogeneous, with different children demonstrating varying impairments (Bishop, 2017). While word-learning deficits tend to be initial indicators of potential impairment (Sheng & McGregor, 2010), certain children may have word knowledge deficits in the area of semantics, while others may indicate a deficit within the phonological buffer, resulting in noise at the group-level in word property analysis. Future studies may benefit from examining word properties using single-case statistical analysis (Crawford & Garthwaite, 2002). Moreover, at the group-level, varying impairments encompassed by DLD may appear more pronounced in more complex language facets relying on word-learning abilities, like morphosyntax, rather than emerging at the single-word level. This may be particularly applicable to the current sample, as groups differed across measures of MLU but not in relation to lexical diversity (see Table 2).

Secondly, the bilingual experience of the current sample varies in terms of individual L2 exposure and the influence of both age and exposure to L2 may be highly prominent. While previous studies of Degani et al. (2019) and Marini et al. (2019) noted significant contrasts between TD and affected bilingual groups across controlled tasks, such as picture-naming, phonological memory capacity and vocabulary comprehension, participants were between the ages of 7 and 10 and 9-14 years respectively with greater exposure to L2. The current study examined the spontaneous speech of younger bilinguals engaging in early stages of L2 acquisition, which may mask group differences between affected and TD groups. Exposure to L2, while balanced across groups, varied across individual children with a range between 11 and 49 months of total L2 exposure. Overall, this culminates in half of the sample being exposed to under two years of L2 English. It has been proposed that surface level similarities between multilingual children and children with DLD may disappear following a minimum of two years of L2 exposure, or longer, depending on a child's own needs and conditions (Garraffa et al., 2019; Marinis & Chondrogianni, 2010). It may be the case that both groups were at similar stages in early L2 acquisition and that gaps in subtle areas, such as the word-level, may emerge beyond the two-year cut-off, once TD bilinguals have sufficient exposure to make sizeable leaps in acquisition. In relation to the aim of the current study, however, a waiting period of two or more years would not satisfy language-based needs, as this creates a challenge for applying early intervention techniques. Sequential bilinguals may require a separate, more sensitive approach to diagnosis that emerges at an earlier point than two years post-exposure.

Thirdly, the examination of word properties to differentiate between affected and TD bilinguals may prove fruitful in more controlled tasks, such as picture-naming, non-word repetition or cross-linguistic lexical tasks (Degani et al., 2019; Haman & Pomiechowska, 2015; Vender et al., 2016). While there are naturalistic benefits to the analysis of spontaneous speech, outcomes of the current study are insufficient to comment on the possibilities of DLD resulting in impoverished lexical entries and/or deficits in phonological working memory. In this case, a wider range of testing materials may be necessary to appraise the language development of sequential bilinguals, prioritising experimental control and the consideration of factors pertinent to the bilingual experience, such as length and degree of exposure to L2.

Strengths and Limitations

Some limitations within the current study require address. Firstly, values for semantic and lexical properties were not obtained from databases specific to child language norms but were compiled using adult speakers (Brysbaert et al., 2014; Kuperman et al., 2012; Stadthagen-Gonzalez & Davis, 2006). Specifically, measures of frequency may not adequately represent child language use, as frequency ratings obtained had standard deviations exceeding mean values, reflecting a high degree of variance. While using monolingually-normed AoA values can enable some comparisons between monolinguals and bilinguals, this carried particular limitations in the current study as interpretations are constrained for application to the sequential bilingual context alone. Additionally, while analysis comprised the separation of nouns and verbs, the comprehensive databases used in the current study do not enable word category distinctions between ratings and it was not possible to classify word input into the N-Watch programme. However, the effect of certain entries returning a norm value reflecting both noun and verb usage is unclear, as

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results speak to the validity of this approach, such as the distinctions overall between nouns and verbs in terms of semantic, lexical and phonological variables.

Moreover, due to the focus of the study on sequential bilinguals with diverse L1 backgrounds, certain bilingual factors such as typological distance between L1 and L2 were excluded from the analysis. Additional factors, such as the number of speakers with whom children engage in L2 and the language environment of L2 acquisition may account for a certain degree of variance in their respective bilingual experience. Despite certain limitations, however, the present study approached a growing global issue in failures to cater to sequential bilingual children. Accurate identification of DLD in L2 is paramount in bilingual research, given the lack of representation of the bilingual experience in certain clinical measures and the growing populations of L2 speakers with varying L1 backgrounds. Moreover, this study combined two different approaches to word-learning impairments in DLD – namely, the posited presence of impoverished lexical entries (Kail et al., 1984) and the possibility of a phonological storage deficit (Gathercole & Baddeley, 1990). In doing so, the scope of analysis encompassed a comprehensive range of variables spanning semantic, lexical and phonological aspects of word knowledge.

Conclusions

The primary goal of this research was to ascertain possible markers of DLD across semantic, lexical, and phonological word properties in the spontaneous speech of sequential bilinguals to facilitate diagnosis in the bilingual context. Results suggest that sequential bilinguals with and without DLD in early stages of L2 acquisition demonstrate similar word-learning strategies, leading to vocabularies which are comparable in terms of word imageability, concreteness, frequency, age of acquisition, and length. Analysis of the word properties of monolinguals with and without DLD alongside those of sequential bilinguals is needed to appropriately characterise the word-learning strategies of sequential bilinguals with and without DLD and determine how these may differ from monolingual counterparts. Further clarification on potential differences between sequential bilinguals with and without DLD is needed, particularly in relation to possible phonological markers, as group effects did not emerge across any individual marker, but the disparity between verb and noun phonological neighbourhoods was slightly different between groups. Continued efforts for diagnosis within the sequential bilingual population require prioritisation, particularly in early L2 acquisition as early intervention alternatives may not be readily available to newcomer families (Paradis et al., 2013). As the analysis of word properties may be masked by similar early-learning strategies within the first two years of L2 exposure and given the heterogeneity of impairments within DLD, future studies should comprise a blend of tests representing language development and possible phonological and morphosyntactic markers in early L2 acquisition to further the goal of misdiagnosis reduction in the sequential bilingual population.

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Appendices

Appendix A. Mean values of word properties across L1 groups.

L1	Group	Imag.	Con.	Freq.	AoA	PN	LenP
Arabic	TD	459	3.63	66032	4.27	14.2	3.82
	DLD	487	3.94	66475	4.25	13.6	3.75
Cantonese	TD	492	3.88	51307	4.26	13.5	3.87
	DLD	448	3.56	115029	4.56	15.2	3.76
Farsi	TD	451	3.45	51856	4.66	13.8	3.99
	DLD	487	3.90	52814	4.51	12.3	4.09
Gujarati	TD	468	3.64	73385	4.64	13.2	3.96
	DLD	481	3.67	62281	4.28	14.4	3.7
Punjabi	TD	464	3.67	85757	4.37	14.1	3.69
	DLD	484	3.87	57434	4.27	14.0	3.82
Spanish	TD	492	3.86	51910	4.26	14.7	3.82
	DLD	478	3.79	53103	4.40	14.2	3.86
Urdu	TD	482	3.78	74261	4.25	14.9	3.61
	DLD	479	3.92	57751	4.44	12.9	4.04
Vietnamese	TD	509	3.91	45502	4.22	12.9	3.92
	DLD	543	4.31	16342	4.18	13.2	3.92

Abbreviations: Imag = Imageability, Con = Concreteness, Freq= Frequency, AoA = Age of Acquisition, PN = Phonological Neighbourhood, LenP = Word Length in Phonemes

Appendix B. Parameters, & Coefficients for Linear Mixed Models

Property	Parameter	Beta	Standard-Error	Confidence Interval	*t*-statistic	*p*-value
Imageability	*Intercept*	6.1467	0.006	6.136 – 6.158	1101.256	< 0.05***
	Group	0.016	0.011	−0.0051 – 0.03845	1.494	0.135
	Word Category	0.388	0.0105	0.367 – 0.408	37.037	< 0.05***
Concreteness	*Intercept*	1.3008	0.0074	1.286 – 1.315	176.578	< 0.05***
	Group	0.0106	0.0147	−0.018 – 0.0394	0.725	0.4683
	Word Category	0.3789	0.0121	0.355 – 0.4028	31.25	< 0.05***
Frequency	*Intercept*	9.3865	0.04573	9.2974 – 9.4763	205.216	< 0.05***
	Group	0.016	0.0914	−0.1624 – 0.1949	0.179	0.858
	Word Category	−1.5698	0.0845	−1.736 – −1.405	−18.574	< 0.05***
AoA	*Intercept*	1.416	0.0081	1.4006 – 1.4326	173.44	< 0.05***
	Group	−0.0144	0.016	−0.046 – 0.01748	−0.883	0.377
	Word Category	−0.012	0.0120	−0.0357 – 0.01138	−1.013	0.3109

Variance of Random Effects in Linear Mixed Models

Property	Random Effect	σ	ε
Imag	*Participant*	0.014	0.2148
Con	*Participant*	0.0241	0.24645
Freq	*Participant*	0.0986	1.806
AoA	*Participant*	0.02739	0.24516

Abbreviations: Imag = Imageability, Con = Concreteness, Freq= Frequency, AoA = Age of Acquisition.

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Appendix C. Model Parameters for Generalised Linear Mixed Models

Property	Parameter	Beta	Standard-Error	Confidence Interval	*z*–statistic	*p*–value
Phon. Nhood	*Intercept*	2.6194	0.0111	2.5967 – 2.6416	108.1987	< 0.05***
	Group	−0.0025	0.0222	−0.0477 – 0.04199	−0.3333	0.909
	Word Category	−0.4758	0.0131	−0.5015 – −0.4502	10.1426	< 0.05***
	Interaction	−0.1048	0.0261	−0.1560 – −0.0536	1.4715	< 0.05***
Word Length	*Intercept*	1.3327	0.01232	1.308467 – 1.356750	108.199	< 0.05***
	Group	−0.0082	0.02464	– 0.0565 – 0.0400	−0.333	0.739
	Word Category	0.2499	0.02464	0.2016 – 0.2982	10.143	< 0.05***

Variance of Random Effects in Generalised Linear Mixed Models

Property	Random Effect	σ
PN	*Participant*	0.06
LenP	*Participant*	0.06
MLen	*Mean Length| Participant*	0.004

Abbreviations: PN = Phonological Neighbourhood, LenP = Word Length in Phonemes, MLen = Mean Length in Phonemes per participant

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