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# Working Memory Skills in DLD: Does Bilingualism Make a Difference?

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**Abstract:** Recent studies have reported that several cognitive domains benefit from bilingualism, including working memory. The aim of the present study is to specifically explore the effects of bilingual experience on different functions of working memory in children with developmental language disorder (DLD) compared to monolingual children with and without DLD. We therefore investigated $n = 42$ German speaking monolingual and bilingual children with and without DLD aged six to eight years. We examined two components of working memory often impaired in DLD: verbal short-term memory and the central executive. We expected bilingual children to outperform their monolingual peers. However, our results do not show any advantage of bilingualism since bilingual typically developing (TD) children did not outperform monolingual TD children and bilingual children with DLD did not outperform monolinguals with DLD; this holds for all measures under investigation. The main outcome is that no disadvantage could be found for bilingual children in cognitive functions. Raising a child bilingually does not exacerbate linguistic and cognitive difficulties in children with DLD. However, our preliminary data suggest it does not lead to cognitive advantages in working memory either.

**Keywords:** working memory; developmental language disorder; bilingualism; bilingual DLD; bilingual advantage



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## 1. Introduction

Developmental language disorder (DLD) is a disorder that particularly affects morphology and syntax while underlying severe intellectual disability, neurological, or other impairments (e.g., social or emotional impairments) are absent (Bishop et al. 2017; Leonard 2014). The research literature on bilingual children with DLD has undergone a change of perspective from a deficit orientation toward an orientation surrounding the advantages of growing up multilingual. The so-called *double delay* has been the subject of lively debate in earlier works. In this perspective, a child with DLD growing up with more than one language in the input would run the risk of experiencing a double delay within language acquisition: bilingualism would exacerbate the delay within some language domains caused by a genuine underlying disorder (Steenge 2006; Korkman et al. 2012; Orgassa and Weerman 2008). In the meantime, evidence has been provided against a double delay in bilingual DLD (Paradis et al. 2003; Scherger 2018; cf. the discussion in Paradis 2010). Some authors even take the opposite perspective by suggesting that bilingualism can be seen as a kind of therapy for children with DLD (Paradis 2010; Hulk and Unsworth 2010). This claim was based on research that identifies positive effects such as facilitative cross-linguistic interaction in the morphosyntactic development of bilingual children, e.g., that of Hulk and Müller (2000), among others. They found quicker development in bilingual children compared to their monolingual peers within particular linguistic domains, such as e.g., verb inflection. This advantage is explained on the one hand by higher cognitive maturation at age of onset (AOO), and on the other hand by internal syntactic complexities (Müller et al. 2002; Jakubowicz and Nash 2001; for a summary on cross-linguistic influence, see also Scherger 2016).

In the same vein, investigating the combined effects of bilingualism and DLD, current research focuses on cognitive effects of bilingualism in terms of a potential bilingual advantage (see the review by Bialystok (2011), the Special Issue in Behavioral Sciences (van den Noort et al. 2019), and the recent Special Issue in the Journal of Cultural Cognitive Sciences (Mishra and Abutalebi 2020) regarding the difficulties in replicating bilingual advantage effects). Studies have reported that bilingualism can have positive effects on cognitive domains such as attentional control, metalinguistic awareness, abstract and symbolic representation and also working memory (e.g., meta-analysis of Adesope et al. 2010; Grundy and Timmer 2017). In the meta-analysis by Grundy and Timmer (2017) focusing on working memory capacity, a significant, small to medium effect size of 0.20 was found in favor of greater working memory capacity for bilinguals than monolinguals (results from 88 effect sizes and 27 independent studies). Their analyses further revealed that the largest effects were observed in children compared to other age groups. Since the bilingual advantage is so controversial in former scientific discourse, the present study focuses on the potential effects bilingualism has on working memory by specifically considering children with DLD and weak working memory skills. Before reviewing previous studies, we will introduce the concept of working memory.

The construct of **working memory** is understood to be a capacity-limited system describing a set of functions that enable us to temporarily store and manipulate relevant information in memory. One of the most elaborated and most influential conceptualizations of working memory is the multicomponent model by Baddeley (cf. Baddeley 2003; Baddeley and Hitch 1974). This model underwent several revisions (cf. Baddeley et al. 2021 for an overview) and has been used as a theoretical framework in research on typical and atypical language acquisition. In its current version, the model distinguishes four interactive components (cf. Figure 1). The **central executive (CE)** is a kind of superordinate control system that coordinates two modality-specific subordinate systems: the **phonological loop** relevant to linguistic material, and a system for processing visual-static and spatial-dynamic information, the so-called **visual-spatial sketchpad**. The CE allocates processing capacity and attentional resources to these systems, decides which information is relevant, and inhibits irrelevant information. It maintains information and enables simultaneous processing of material of different modalities (e.g., when processing linguistic and visuo-spatial information in a sentence-picture matching task).[1] In particular, the process of inhibition has been argued to be superior in bilingual speakers compared to monolinguals (see discussion by Hilchey and Klein 2011). It is argued that bilinguals frequently engage in inhibitory processes when selecting one of their languages which in turn results in more efficient inhibitory processing. This suggestion is confirmed by some studies (Bialystok et al. 2004) and rejected by others (Arizmendi et al. 2018). The CE is associated with several skills enabling speakers to carry out complex tasks requiring updating and/or manipulation of information rather than pure storage. This is the reason why it is referred to in many works by the term 'working memory' (see also Henry and Botting 2017, p. 21). The CE has a storage system which was introduced by Baddeley (2003) as a separate subsystem, the **episodic buffer**. This buffer integrates the information in the two memory systems (e.g., linguistic and visual-spatial information) into a multidimensional representation by also linking the storage systems to long-term memory (e.g., stored linguistic elements). The skills associated with the CE are typically measured by complex span tasks (Figure 1), the classical task being the digit span backward, in which digits not only have to be maintained in memory but have to be placed in the reverse order during repetition.

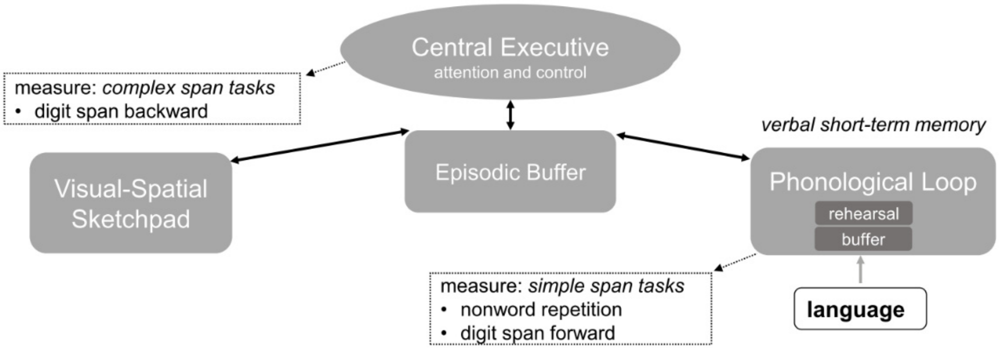


**Figure 1.** Components of working memory based on Baddeley et al. (2021) and relevant measures.

We will describe the phonological loop in more detail as it is the component in Baddeley's model most relevant for language. It comprises a passive phonological store that maintains information for up to two seconds. Memory traces then collapse or are overwritten by new information if they are not further processed, although they can be refreshed by an articulatory control system (rehearsal, a kind of inner speech). The purpose of the phonological loop memory component—also labelled phonological or (in the following) **verbal short-term memory (VSTM)**—is thus to convert speech sounds into a phonological code and to keep linguistic elements (syllables, words, sentences) temporarily available in an exact order. This process is crucial for extracting the relevant morphosyntactic information from the signal during language processing. For measuring VSTM skills, both nonword repetition tasks as well as digit span tasks are considered suitable tools for use in both a clinical setting and in research (Gathercole and Alloway 2006; Hasselhorn et al. 2012). Nonword repetition has traditionally been considered a purer measure of VSTM, although more recent research indicates that both tasks tap into short-term memory and both underlie lexical influences due to the verbal nature of the stimuli (for a discussion see Archibald 2018; Archibald and Gathercole 2007). However, the repetition of digits in the order in which they are given (digit span forward) might place lower demands on working memory (compared to nonword repetition) as the digits used (1–9) are frequent number words that are retrieved with a high degree of automaticity by children attending elementary school (Archibald 2018).

Working memory skills and language abilities are closely linked (Archibald 2018) and different components of working memory are often reported to be impaired in (bilingual) children with DLD. In terms of Baddeley's working memory model (Baddeley 2003; Baddeley et al. 2021), the impairment typically affects VSTM and the CE, as more recent studies have shown (for an overview, see the meta-analyses of Graf Estes et al. (2007) and Henry and Botting (2017), or recent studies such as Delage and Frauenfelder (2020); for results regarding bilingual children, see Blom and Boerma (2017), Pratt et al. (2021), Tuller et al. (2018) and Zebib et al. (2020)).[2] Importantly, VSTM, as measured by nonword repetition tests, has proven to be an effective diagnostic marker for identifying language impairment in monolingual as well as bilingual children (Scherger 2020; Tuller et al. 2018).

*Working Memory Components in Bilingual Children with DLD*

With respect to typical language acquisition, the above-mentioned meta-analysis by Grundy and Timmer (2017) points overall to a bilingual advantage for greater working memory capacity. However, much controversy remains when different relevant components such as VSTM and CE are investigated: While some study results suggest negative or no effects of bilingualism with respect to one or both of these working memory components (e.g., Buac et al. 2016; Engel de Abreu 2011; Talli and Stavrakaki 2020), in other studies a better performance of bilingual children (including sequential and simultaneous bilinguals) compared to monolingual children was shown (e.g., Blom et al. 2014; Marini et al. 2019), indicating a bilingual advantage. However, to date, very few studies have focused on bilingual children with DLD with respect to different working memory components. As with research on children with TD, the findings from comparing monolingual children with DLD to their bilingual peers with DLD are also mixed. Boerma and Blom (2020) conducted a longitudinal study testing mono- as well as bilingual children with TD and DLD (each $n$ = 32) aged 5–6 years (first testing) to 7–8 years (3rd time point) with tasks of VSTM (digit span forward) and CE (digit span backward). In line with the authors' previous findings (Blom and Boerma 2017), they were able to show an effect of a bilingual advantage in their study: Bilingual children with DLD performed significantly better than monolingual children on the CE task (and, interestingly, also on non-verbal visual-spatial memory skills), but only when language skills were controlled for. The effect was most pronounced with respect to the first testing wave at age 5–6 years. With respect to VSTM, however, no differences were observed. Moreover, the bilingual advantage did not emerge in the TD group. Similar working memory measures were used in a study by Talli and Stavrakaki (2020). They tested VSTM (by a digit span forward task as well as a nonword repetition test) and CE (digit span backward) in 8-year-old mono- and bilingual children with DLD (each $n$ = 16) and without DLD ($n$ = 20 monolinguals and $n$ = 18 bilinguals). However, in contrast to the results obtained by Boerma and Blom (2020) they could not find a beneficial effect of bilingualism in DLD, neither for VSTM nor CE, as there were no significant differences between the two clinical groups. Moreover, with respect to the TD groups, monolingual children outperformed bilingual children on both VSTM tasks. Likewise, prior studies could not find beneficial effects of bilingualism in children with DLD regarding the CE and/or VSTM: Here, no differences between monolingual and bilingual children with DLD were reported (Thordardottir and Brandeker 2013; Ziethe et al. 2013). However, this outcome might have occurred due to floor effects resulting from the very low performance of children with DLD in VSTM and CE tasks (discussed e.g., by Boerma and Blom 2020). Using a different CE task measuring updating and working memory (a nonverbal 2-back task, in which a sequence of digits presented two positions back has to be remembered), Peristeri et al. (2019) tested 8-year-old mono- and bilingual children with and without DLD and found no difference in accuracy or reaction times between the mono- and the bilingual groups. However, bilingual children were more effective compared to their monolingual peers using this kind of executive working memory skill when attributing mental states (in *theory of mind* tasks). Meir (2017) tested a sample of 5–6-year-old bilingual children ($n$ = 90 without DLD; $n$ = 18 with DLD) with VSTM tasks (digit span forward tasks and nonword repetition) and reported negative effects of bilingualism in the group of participants with DLD. Those effects were only observed with respect to the nonword repetition task tested in their L1 and disappeared when lexical skills were controlled for. In contrast, a bilingual advantage was observed in their L2. The authors concluded that the negative effects of bilingualism in DLD only arise in tasks with a greater linguistic load (such as nonword repetition and sentence repetition). In this study, however, CE skills were not tested. In sum, those latter studies reporting no, or even negative effects of bilingualism pose a challenge to Boerma and Blom's (2020, p. 10) claim that working memory abilities (referring to the CE component) might be a relative strength of bilingual children with DLD compared to their monolingual peers with DLD.

The reason that cognitive functions (especially working memory) are of particular interest in studying DLD is their interplay with grammatical skills, which are often severely impaired in this disorder. Recent studies have revealed significant correlations or predictive relationships between VSTM skills and/or CE skills and productive and/or expressive morphosyntactic skills in children with DLD (e.g., Delage and Frauenfelder 2020; Frizelle and Fletcher 2015; Montgomery et al. 2018; Röhm 2020; but see Calder et al. 2022 or Penke and Rothweiler 2018 who could not find such correlations). In the context of bilingualism, some recent studies have shown that grammatical abilities were strongly linked to working memory skills (Talli and Stavrakaki 2020; Zebib et al. 2020). For instance, Talli and Stavrakaki (2020) found that VSTM skills as well as CE skills predicted syntactic abilities (as measured by sentence repetition and syntactic comprehension tasks).

To summarize, considering the current state of research and the limited number of studies investigating working memory in bilingual children with DLD, it remains unclear whether the two effects with contrasting outcomes (a negative effect of DLD and a potential positive effect of bilingualism) would balance out in bilingual individuals with DLD or whether the positive effect of growing up with two languages in the input would prevail. This in turn would lead to positive effects of dual language exposure in children with DLD.

The aim of the present study is to specifically explore the effects of bilingual experience on different components of working memory (VSTM and CE) in children with DLD compared to monolingual children with and without DLD. Therefore, the main research question is whether bilingual children with DLD differ from monolinguals with DLD regarding VSTM and CE. Following the proposal of a bilingual advantage, as evidenced by Boerma and Blom (2020), our hypotheses concerning various group comparisons are the following.

**Hypothesis 1.** *In bilingual children with DLD, the positive effect of bilingualism outweighs the disadvantage of DLD such that bilingual children with DLD demonstrate higher performances on the two tested components than monolingual children with DLD. Likewise, in unimpaired children, bilingual TD children outperform monolingual TDs. Based on previous studies, we expect that potential positive effects might differ depending on the task. Specifically, we anticipate that positive effects might be weaker or even absent in a nonword repetition task due to a higher linguistic load as opposed to a digit span task.*

**Hypothesis 2.** *The positive effect of bilingualism on working memory measures is more pronounced in children with TD than in children with DLD. Therefore, the effect size is larger for bilingual children with TD when compared to their monolingual peers than for bilingual children with DLD when compared to monolinguals with DLD.*

The remainder of this article will present the materials and methods of this study in Section 2, the results in Section 3, and the discussion in Section 4. Besides, we will also briefly address the practical implications of our findings for parents of bilingual children.

## 2. Materials and Methods

### *2.1. Participants*

In line with Armon-Lotem's (2012) suggestion of informative between-group comparisons in a two-by-two design, we investigated four groups of children, monolingual and bilingual children with and without DLD, in order to be able to answer the research questions with respect to the effect of DLD and the effect of bilingualism. To disentangle these effects, four groups of children are needed, manipulating the variables 'language acquisition status' (mono- vs. bilingual) and 'impairment' (DLD vs. TD).

A total of $n = 42$ children aged 6 to 8 years participated in the present study. This study was part of a larger project (Title: Linguistic markers in bilingual DLD, PI: Scherger). This project's goal was to evaluate assessment tests specifically developed to disentangle bilingual TD and DLD children, the so-called Language Impairment Testing in Multilingual Settings tools (LITMUS, COST Action IS0804, Armon-Lotem et al. 2015). For a participant overview see Table 1. For reasons of group homogeneity with respect to the type of bilingualism and group matching, two children with DLD (from a previous total of $n = 44$ children) were excluded from further analysis because they were raised simultaneously with two languages in their input from birth. Both clinical groups were diagnosed through clinical assessment and referred to speech-language pathologists (SLPs) by pediatricians. Note in this respect that mono- as well as bilingual children with DLD showed prototypical grammatical impairments as evidenced by a subject-verb-agreement task and performed similarly with respect to this linguistic task (TD: $U = 44$, $p = 0.468$; DLD: $U = 44$, $p = 0.792$; for further details on assessment and reassurance regarding DLD diagnosis, see Scherger (2022) on the same sample). At the time of recording, the children with DLD had had at least one-and-a-half years of regular therapy in German. Their input in German was rated by means of a parental questionnaire within a score (PaBiQ, Tuller 2015) which allows for quantification of the amount of L2 exposure at home. The children's German input was categorized as coming from the (a) mother, (b) father, (c) other regular care-givers of the child and (d) siblings. Parents rated the use of German within (a), (b), (c) and (d) within the scale: 0 = never, 1 = rarely, 2 = sometimes, 3 = mostly and 4 = very often/always. A ratio was calculated for the amount of overall German exposure at home by adding the score of input given by mother, father and siblings and dividing it by three (since category (c) was never ticked). As Table 1 illustrates, the amount of L2 exposure at home is comparable between both bilingual groups investigated here.

**Table 1.** Participant characteristics.

| Groups | Monolingual (Mo)/ Bilingual (Bi) | Number (Sex) | Mean Age (Range) | Age of Onset | Length of Exposure | Amount of L2 Exposure at Home |
|---|---|---|---|---|---|---|
| TD | MoTD | *N* = 11 (*N* = 6 female) | 7;1 (6;1–8;6) | – | – | – |
| | BiTD | *N* = 10 (*N* = 4 female) | 7;10 (6;11–8;6) | 2;11 (2;10–4;3) | 54.2 (45–66) | 2.63 (*SD* = 0.6) |
| DLD | MoDLD | *N* = 8 (*N* = 2 female) | 7;8 (6;1–8;5) | – | – | – |
| | BiDLD | *N* = 13 (*N* = 7 female) | 7;6 (6;3–8;3) | 3;1 (2;0–4;0) | 53.1 (45–60) | 2.29 (*SD* = 1.0) |

Participants were recruited from kindergartens, schools, speech and language therapy practices, and schools for children with special educational needs in Lower Saxony, Germany. The data collection took place in a quiet room within the institution from which the child was recruited and was video-recorded after parents had given their written informed consent. TD children participated in 2 × 45 min sessions, children with DLD participated in 3 × 30 min sessions; this constituted the whole data collection process.

### 2.2. Methodology

Children were investigated with respect to three working memory tasks: nonword repetition (NWR) and digit span forward (DS-FW) which are commonly used to measure VSTM in the populations under study (Archibald 2018; Blom and Boerma 2017; Tuller et al. 2018) and digit span backward (DS-BW) which is associated with CE skills (Blom and Boerma 2017; Archibald 2018).

The participating children were tested with the short version of the German LIT-MUS-QU-NWR (see Grimm and Hübner, forthcoming; Grimm 2022). NWR-tasks are said to avoid disadvantages for bilingual children with potentially smaller lexical knowledge than their monolingual peers. NWR tasks are culturally fair, do not discriminate against bilingual children and are considered to be independent of socio-economic status (Chiat 2015; Chiat and Polišenská 2016; Engel et al. 2008). As children with DLD often have difficulties with phonological complexity (cf. de Almeida et al. 2019) that could potentially affect the repetition of nonwords, we chose this newly developed tool (LITMUS-QU-NWR) which systematically varies phonological complexity. Although it was not developed to measure working memory capacities in the first place, word lengths differ between one and three syllables in this test and therefore should have different effects on working memory. To investigate a potential influence of word length, we analyzed the whole word accuracy of children's nonword repetitions (see Section 3.2).

The short version of the LITMUS-QU-NWR used in the present study contains a language-dependent (LD) and a (quasi-)language-independent (LI) part. In both parts, the base was formed of a trochaic ‘CVCV shape which was varied systematically with regard to phonological complexity. For the LI part consisting of 20 items, the ‘CVCV shape is expanded by an additional syllable and/or one or more consonants. The nonwords contained the consonants /p/, /k/, /f/, and /l/ as well as the vowels /a/, /i/, /u/. Since the representation of /s/ or /ʃ/ in onset and coda position varies cross-linguistically (see Grimm and Hübner, forthcoming; Grimm and Schulz 2021 for more details), the items of the LD part were constructed according to the same principles as the LI part, with the addition of /s/ or /ʃ/ in word-initial and word-final position (e.g., ‘sCCVCV; ‘CCVCVCs). The LD part contains another 20 items resulting in a total of 40 items for the complete test. The nonwords are presented auditorily in a standardized way via a PowerPoint presentation from a laptop. Children wear headphones while listening to a small alien in the presentation prompting the nonwords. Table 2 presents examples of mono-, bi- and trisyllabic nonwords.

**Table 2.** Examples of the nonwords contained in LITMUS-QU-NWR.

| Word Length | Nonword Examples |
|---|---|
| monosyllabic ($N$ = 2) | *pli*, *kip* |
| bisyllabic ($N$ = 13) | *pukif*, *fluka*, *klifak*, *kafip* |
| trisyllabic ($N$ = 17) | *sklipafu*, *kuflapi*, *kufiski*, *pifakup* |

Digit span forward (DS-FW) and digit span backward (DS-BW) tasks were also administered, taken from the WISC-V (Petermann 2017). In the DS-FW task, a series of numbers are given to the child with the request to correctly repeat the numbers heard. Number series range from two numbers (e.g., 2-9) up to potentially ten numbers (e.g., 6-2-5-3-1-9-8-5-4-7). In each case, there are two number sets with the same amount of numbers, that is the child hears, for example, two number sets consisting of three numbers before hearing two sets of four numbers. If one of the two sets is repeated correctly, the test conductor moves on to the next number set. The test is terminated if the test person gets 0 points in both attempts of a task, i.e., after giving a wrong answer, a “don’t know” or 30 s of silence. In the DS-BW task, the child is requested to repeat the numbers heard in the reverse order (e.g., 2-3-6 would be 6-3-2).

## 3. Results

### *3.1. Overall Results on Working Memory Measures*

Results regarding the performance of the four groups on the three measures of working memory are provided in Table 3. Mann–Whitney U tests were conducted to compare monolinguals with DLD (MoDLD) with bilingual children with DLD (BiDLD) and mono- with bilingual children with TD (MoTD, BiTD). We used non-parametric tests as the data are not normally distributed (Shapiro–Wilk test for NWR: $W = 0.95$, $p = 0.049$; for DS forward: $W = 0.84$, $p < 0.001$; for DS backward: $W = 0.81$, $p < 0.001$).

As can be seen in Table 3, our findings do not show differences between monolingual and bilingual children, neither in the TD population nor in the DLD population.

Bilingual children with DLD did not differ from monolingual children with DLD in NWR ($U = 43$, $p = 0.547$), in DS-FW ($U = 25.5$, $p = 0.054$) and in DS-BW ($U = 39.5$, $p = 0.374$).

Likewise, bilingual TD children did not outperform monolingual TD children in NWR ($U = 33.5$, $p = 0.132$), in DS-FW ($U = 53.5$, $p = 0.917$) and in DS-BW ($U = 48.5$, $p = 0.940$). However, it is important to note that bilinguals did not lag behind their monolingual peers (neither in the DLD nor in the TD population).

**Table 3.** Results of the tests investigating working memory components across all four groups (MoTD, BiTD, MoDLD, BiDLD).

| | TD | | DLD | |
|---|---|---|---|---|
| | **MoTD** | **BiTD** | **MoDLD** | **BiDLD** |
| **NWR** | | | | |
| *M* | 75.6% | 81.0% | 30.9% | 35.8% |
| *SD* | 9.1 | 18.1 | 18.6 | 22.9 |
| *range* | 59.4–93.8 | 34.4–100 | 3.1–53.1 | 3.1–68.8 |
| **DS forward** | | | | |
| *M* | 4.27 | 4.30 | 3.88 | 3.23 |
| *SD* | 0.62 | 0.64 | 0.33 | 0.70 |
| *range* | 3–5 | 3–4 | 3–4 | 2–4 |
| **DS backward** | | | | |
| *M* | 2.91 | 2.78 | 2.63 | 2.00 |
| *SD* | 0.79 | 0.42 | 0.86 | 0.96 |
| *range* | 2–5 | 2–3 | 2–4 | 0–3 |

Comparing children with TD and DLD in the NWR task, children with TD (monolinguals and bilinguals: $M = 78.1\%$, $SD = 14.4$) outperformed children with DLD ($U = 16.5$, $p < 0.001$, Cohen's $d = 0.77$). Likewise, TD children outperformed DLD groups with respect to the DS-FW ($U = 97$, $p = 0.002$, Cohen's $d = 0.53$) and DS-BW ($U = 128$, $p = 0.032$, Cohen's $d = 0.35$).

### 3.2. *Specific Measures of VSTM*

As has been shown in the previous section, we found similar outcomes for both measures of VSTM, namely DS-FW and NWR. Both are vulnerable in children with DLD, but no differences could be found between monolingual and bilingual children regarding these measures (see Figures 2 and 3 for illustration).

The particular NWR task we used here (a LITMUS tool) was constructed with a focus on phonological complexity rather than on VSTM. As both measures of VSTM used in the present study highly correlate (Spearman's *rho* = 0.49, $p = 0.001$), the role and influence of VSTM in this new kind of NWR task is of further explorative interest here.

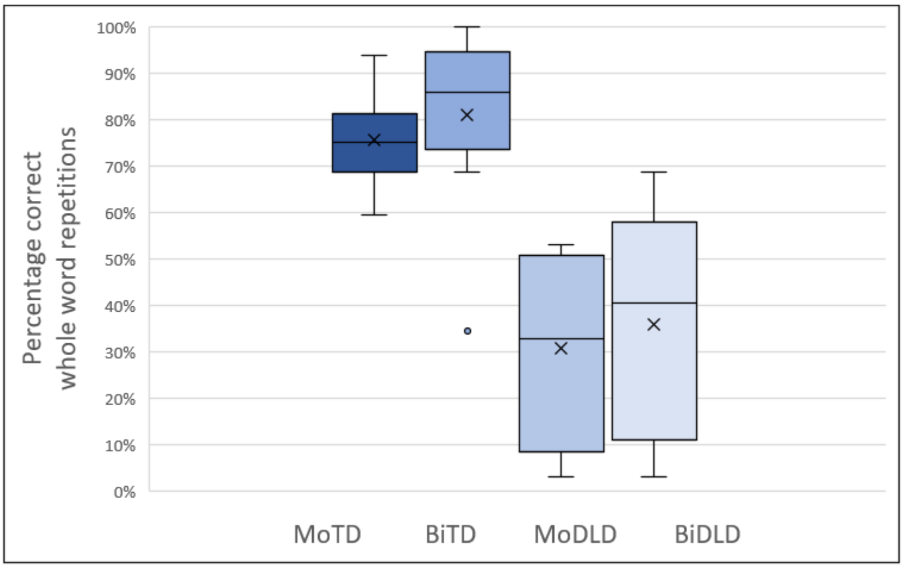


**Figure 2.** Boxplots representing the NWR results for whole word accuracy in MoTD, BiTD, MoDLD and BiDLD groups (vertical line = *Mdn*, x = *M*; circle = outlier).

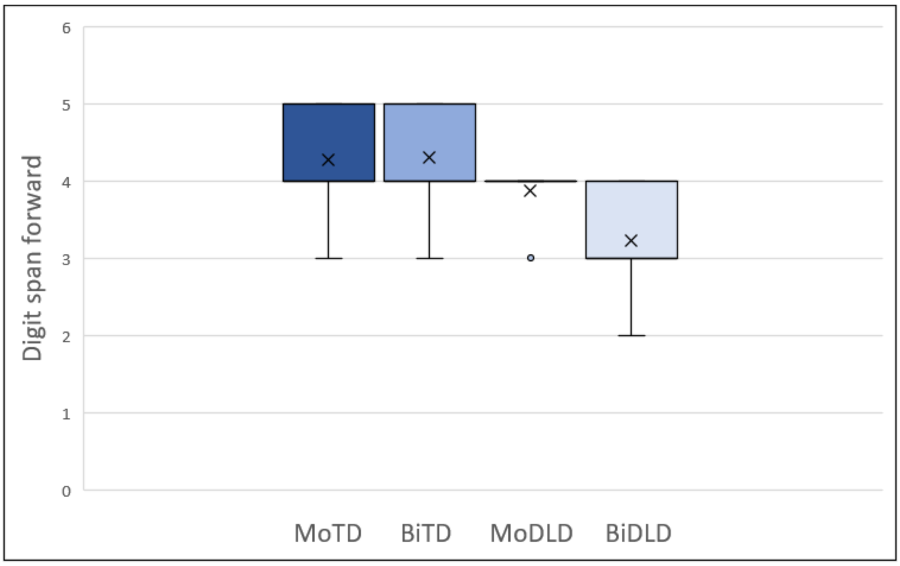


**Figure 3.** Boxplots representing the DS-FW results for MoTD, BiTD, MoDLD and BiDLD groups (x = *M*, circle = outlier).

We therefore analyzed this task to examine a possible word length effect that would mirror problems with VSTM. We compared the accuracy of the repetition of mono- and bisyllabic nonwords with that of trisyllabic nonwords and found a significant difference: For all participants, trisyllabic words were harder to repeat than mono- or bisyllabic words (paired sample *t*-test: $t = 2.897$, $p = 0.002$, see Figure 4). As illustrated in the figure, this difference seems to be equally pronounced across all groups. However, the differences between shorter and longer nonwords were only significant in both TD populations, not in the children with DLD (see descriptive statistics in Table 4). No group-related differences emerged, neither between mono- and bilingual children nor between children with TD and DLD (Mann–Whitney *U* test comparing the difference values of accuracies between shorter and longer words: monolinguals vs. bilinguals; $U = 217.5$, $p = 0.980$; TD vs. DLD: $U = 202.5$, $p = 0.654$).

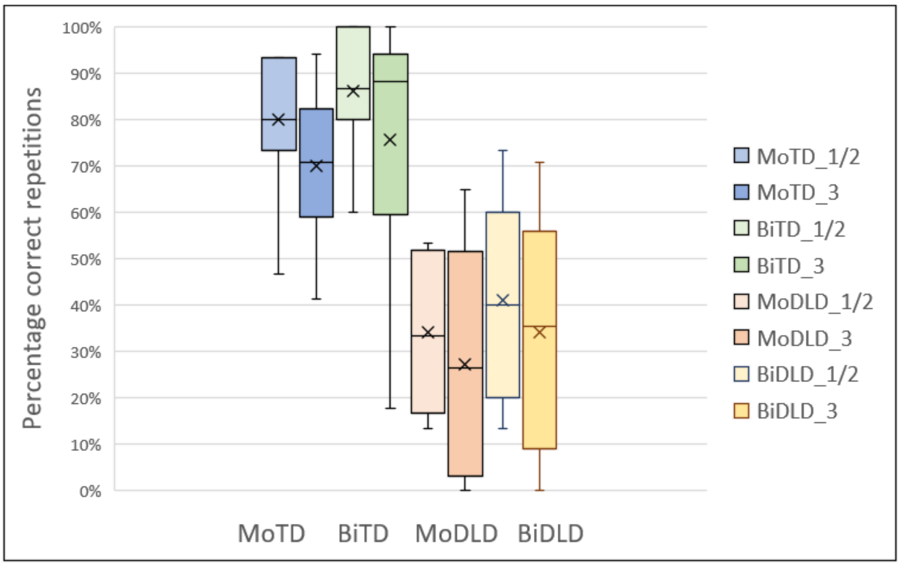


**Figure 4.** Boxplots representing the word length differences across all groups (vertical line = *Mdn*, x = *M*, 1/2 = mono- and bisyllabic nonwords, 3 = trisyllabic nonwords).

**Table 4.** Correct repetition of mono- and bisyllabic as well as trisyllabic words (means, standard deviations, and ranges per group).

| Groups | Mono-/Bisyllabic | Trisyllabic | Wilcoxon Signed Rank Test |
|---|---|---|---|
| **MoTD** | | | |
| *M* | 80.0% | 70.1% | $W = 6.0$ |
| *SD* | 12.7 | 16.3 | $p = 0.008$ |
| *range* | 46.7–93.3 | 41.2–94.1 | |
| **BiTD** | | | |
| *M* | 86.0% | 75.6% | $W = 9.0$ |
| *SD* | 11.7 | 25.6 | $p = 0.045$ |
| *range* | 60.0–100 | 17.6–100 | |
| **MoDLD** | | | |
| *M* | 34.2% | 27.2% | $W = 7.0$ |
| *SD* | 15.1 | 22.8 | $p = 0.938$ |
| *range* | 13.3–53.3 | 0.0–64.7 | |
| **BiDLD** | | | |
| *M* | 41.0% | 33.9% | $W = 20.5$ |
| *SD* | 20.1 | 24.0 | $p = 0.959$ |
| *range* | 13.3–73.3 | 0.0–70.6 | |

## 4. Discussion

Previous research investigating effects of bilingualism in children with DLD has revealed conflicting results since both positive and negative effects have been found. The aim of our study was to contribute to the literature on this topic that is scarce and elucidate the effects of bilingual experience on different components of working memory in children with DLD. Using a four-group design, we contrasted mono- and bilingual children with and without DLD. In the following, we will summarize and explain the most important findings of our study by referring to our research question, hypotheses, and predictions.

### *4.1. No Differences Were Found between Monolingual and Bilingual Children with DLD with Respect to the Working Memory Components VSTM and CE*

Overall, our results do not show any differences between monolingual and bilingual children with respect to these two relevant working memory components that have been identified as being critical for language acquisition and vulnerable domains in children with DLD. The results from the two tasks measuring VSTM (DS-FW and NWR) show that performance in the group of bilingual children did not significantly differ from that of monolingual children. This holds for children with DLD as well as for children with TD. No significant group differences were found with respect to CE skills either, as measured by the DS-BW task. Regarding our first hypothesis, we thus could not confirm a cognitive advantage for bilingual children as found by Boerma and Blom (2020), neither for the group of children with DLD nor for the group of children with TD. Concerning children with DLD, our results confirm previous studies that failed to find differences between monolingual and bilingual performances on working memory measures (Talli and Stavrakaki 2020; Thordardottir and Brandeker 2013; Ziethe et al. 2013). However, the findings also indicate that there are no additive effects in the sense of a double delay, an idea put forward by Orgassa and Weerman (2008), as the bilingual children with DLD in our study did not perform worse than the monolingual children with DLD. However, the lack of a bilingual advantage in both the DLD and TD groups might not necessarily mean that such an advantage is not present at all. The missing effect could be due to the small sample size of the study. Alternatively, it might be the case that a bilingual advantage in children and adults only shows up in tasks that tap into other cognitive functions or more specific facets of the CE, such as shifting and inhibition (e.g., Bialystok et al. 2004). Those skills might be enhanced when bilingual persons use both languages in daily communication.

Further evidence of such strengthened attentional control processes comes from studies investigating brainstem and cortical responses in bilinguals (Krizman et al. 2014). Results for bilingual children and adults with DLD would be interesting in this respect.

With regard to our second hypothesis, we expected that a potential positive effect of bilingualism on working memory measures would be more pronounced in children with TD than in children with DLD. We therefore expected the effect size to be larger for bilingual children with TD when compared to their monolingual peers than for bilingual children with DLD when compared to monolinguals with DLD. As we have not found positive effects of bilingualism on cognitive tasks tapping into working memory at all, we cannot take a position or make any statements on this matter.

### *4.2. Children with TD Outperformed Children with DLD on All Measures of Working Memory with the Highest Effect Size Obtained for NWR*

Looking at the extent to which working memory skills are affected in children with DLD, our study revealed that all working memory components (and all tasks) differentiated between TD and DLD. This effect was highest in NWR with a medium effect size, followed by DS-FW with a medium effect size as well. The task testing CE, i.e., DS-BW, was related to the lowest and small effect size when comparing TD and DLD children. Thus, even though some children with DLD (both bilinguals and monolinguals), as with unimpaired children, managed to repeat four- or five-digit series forward, there were huge group differences when children were asked to accurately repeat nonwords. That is, children with TD achieved mean accuracy scores of about 76% (monolinguals) and 81% (bilinguals), while the mean averages of mono- and bilingual children with DLD were below 36%. These results indicate a severe deficit concerning the temporal storage of phonological material that is particularly associated with NWR. As NWR carries the highest linguistic load among short-term memory tasks (Archibald 2018) and deficits in this task have been described as core markers of DLD, this finding confirms our predictions and corroborates previous research with mono- and bilingual children with DLD (Tuller et al. 2018). It is important to highlight that there were children with DLD who performed well on one measure of VSTM (namely DS-FW) and very low on the other measure of VSTM (namely NWR). For instance, a monolingual boy with DLD was able to repeat four digits forward but could only repeat one out of 32 nonwords correctly. Likewise, a bilingual girl with DLD repeated four digits forward correctly, but only three out of 32 nonwords. Therefore, we have to be cautious in interpreting poor NWR performance as a pure deficit in VSTM and instead take into account the interrelation with linguistic (in this case phonological) load that we find in this task that is often considered a good operationalization of VSTM.

Additionally, we were able to show a word length effect in this task that did not, however, yield significance regarding mono- or bilingual children with DLD in contrast to the two TD subgroups. One reason for this result could be that accuracies in this task were generally low (perhaps most likely due to consonant clusters) and most of the DLD children struggled to repeat even shorter words. Moreover, the LITMUS test encompasses only words up to three syllables and a word-length effect might therefore have been observed only when contrasted with four- or five-syllabic words. Similarly, in the study by Thordardottir and Brandeker (2013), there was no significant difference in the accuracy of repetitions between nonwords of two and three syllables in children with DLD and TD (regardless of being mono- or bilingual) in contrast to comparisons with four or five syllables. As noted in Pratt et al. (2021) and as is highlighted by the two cases of dissociation between one VSTM measure and the other in our sample, it is difficult to determine whether the important diagnostic contribution of VSTM skills measured by a NWR task is due to its *linguistic nature* as it is the most linguistically loaded task of the simple span short-term memory tasks (Archibald 2018; Pratt et al. 2021, p. 316). This confounding factor in using verbal stimuli in tasks designed for measuring working memory skills has also been subject to debate in the context of developmental disorders (see Marshall 2020). However, in a recent study with monolingual children with DLD (Delage and Frauenfelder 2020) it was shown that those simple span tasks (testing VSTM) in which verbal/linguistic effects are minimized (in this case, a serial-order reconstruction task) particularly explained a significant part of the variance in the grammatical tasks of these studies. We therefore suggest that future studies examining the interplay between working memory skills and grammar skills in bilinguals with DLD should ideally also contrast verbal and non-verbal tasks testing VSTM and CE skills.

Besides the group differences in the NWR task, we also found differences between children with TD and DLD with respect to CE. However, the effect size was rather small ($d$ = 0.35) in this comparison concerning the DS-BW task. Likewise, Boerma and Blom (2020) reported decreasing effect sizes in their study regarding the effect of the group (DLD-TD) on the CE performance with rising ages, i.e., only medium effect sizes at testing points two and three (6–8 years, corresponding to the children's age in our study). Although our study did not aim to evaluate the accuracy of diagnostic tasks, such findings call for further studies that examine the diagnostic value of different tasks including NWR and sentence repetition in bilingual children with and without DLD (for discussion, see Klem et al. 2015; Tuller et al. 2018; Zebib et al. 2020) and in other developmental disorders that display grammatical as well as working memory deficits (e.g., Penke and Wimmer 2020; Wimmer et al. 2021).

### *4.3. Limitations of the Study*

There are some limitations of the study to be mentioned. Firstly, we want to raise some methodological issues. As a consequence of extensive data collection procedures (two to three sessions per child) and careful selection criteria, the study sample is relatively small. Thus, due to limited power, we cannot fully exclude the possibility that there might indeed have been a group effect between mono- and bilingual children with and without DLD. The second issue concerns the choice of the NWR test. We intentionally chose the LITMUS-QU-NWR tool, which was constructed for use with bilinguals as one of the VSTM measures, since the nonword items in other common NWR tests often contain real morphemes of the respective language (e.g., the German test battery for working memory skills by Hasselhorn et al. 2012). This might disadvantage bilingual children who may have weaker lexical skills concerning their L2. However, a limitation of the NWR task chosen for the present study might be that it focuses on phonological complexity (by including consonant clusters) instead of phonological memory skills as the nonwords used contain maximally three syllables. This test might therefore be more of a linguistic measure than other VSTM tasks as it may depend more on children's phonological representation skills (as also noted by Hamann 2017). Nevertheless, the observed word length effect (in the TD groups) suggests that this task also taps into working memory. Alternatively, as described above, short-term memory tasks or CE tasks which do not depend on language representations could be applied for comparison. Additionally, as working memory skills, in particular VSTM, develop considerably between preschool age and adolescence (Gathercole et al. 2004; Hasselhorn et al. 2012), longitudinal studies are needed to investigate developmental trajectories in bilingual children with DLD to further examine a potential bilingual advantage which could also be relevant for clinical purposes (see below).

### *4.4. Implications for Practice and Research*

Regarding the practical implications of our findings, we suggest informing parents about study results like these to allow evidence-based decisions. In our case, the most important outcome is that bilingual children experience no disadvantage in cognitive functions. Raising a child with DLD bilingually aggravates neither their linguistic nor cognitive difficulties. This insight might be helpful in reducing parents' worries that bilingualism might hamper language acquisition in their child with DLD. However, at least in our cases, and based on a small sample size, it does not lead to cognitive advantages concerning working memory either. With respect to future research directions, we stand with Hulk and Unsworth (2010) on there being no "one size fits all" solution: the path to successful bilingual acquisition is a complex one depending on several relevant factors that have to be disentangled both within and across groups in further research (Hulk and Unsworth 2010). Regarding clinical practice, future research must further examine which tasks differentiate most between bilingual children with TD and bilingual children with DLD, so that language impairment can be reliably attested. Studies on bilingual children should also focus more on working memory functions and the extent to which different working memory functions are affected. Insights from those studies could be helpful for the development of new intervention materials for children with DLD that take weak working memory skills into account or train them directly. The efficacy of such working memory programs suggested by recent, promising therapy studies (Delage et al. 2021; Henry et al. 2022; Stanford et al. 2019, but see the review by Melby-Lervåg and Hulme 2013) is, however, left to future research.

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**Data Availability Statement:** The data are available via a cloud service and can be shared by the authors on request.

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## Notes

1 Note that such latter CE functions (i.e., *shifting*, *inhibition* and *updating* of information) have also been discussed as specific facets of basal executive functions (EF) (cf. Miyake et al. 2000).

2 Note that verbal memory tasks proved to be more difficult than non-verbal tasks (for instance, visual-spatial) in children with DLD (cf. Vugs et al. 2013 for review of non-verbal memory skills and for studies including bilingual children cf. e.g., Engel de Abreu et al. 2014).

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