# How is language knowledge related to verbal working memory among preschool children? Evidence from bilinguals and monolinguals

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**Abstract:** The typical language development in bilingual children, which shows some similarities with atypical language development in monolinguals, displays unique characteristics when compared to monolingual counterparts. In order for clinicians to correctly diagnose bilingual children with atypical language development, it is important to have access to diagnostic tools that distinguish typical from atypical development. Measures of children's verbal working memory, such as digit span and nonword repetition, may be just such diagnostic tools. However, some previous studies have suggested that measures of verbal working memory could be related to language-specific knowledge, such as vocabulary. The purpose of the present study was to test whether bilingual children's performance on two verbal working memory tasks were related to their within- language vocabulary scores. Forty French-English bilingual preschoolers and 40 age- matched English monolingual children were administered a standardized vocabulary test in English, a nonword repetition task (NWR), and digit span tasks (both forward and backward). The results showed that the bilingual children scored significantly lower than the monolingual children on the vocabulary test, but not on the nonword repetition task nor on the digit span tasks. Moreover, vocabulary scores were not correlated with the verbal working memory tasks for monolingual children. For bilingual children the NWR was not correlated with vocabulary. NWR seems to be relatively free of language-specific knowledge, at least within this age group. We discuss the clinical implications of these results.

**Keywords:** phonological working memory; nonword repetition; bilingual advantage; preschool language development

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## Introduction

The number of children who learn a second language has been increasing across the world, including in both Canada and the United States (Statistics Canada, 2016; U.S. Census Bureau, 2013). In Canada, for instance, the proportion of English-French bilinguals increased by 3% in 2016 and 2021. As of 2021, 4.6 million Canadians speak a language other than English or French at home (Statistics Canada, 2016). Likewise, in the United States, more than 18% of the population consists of individuals who are over the age of 5 and speak a language other than English in the home (U.S. Census Bureau, 2000). Bilingual children may appear to lag behind in language development, particularly in within-language vocabulary, when compared to same-aged monolinguals in that language (Gross et al., 2014; Meir et al., 2017; Oller et al., 2007; Smithson et al., 2014; Sullivan et al., 2018). However, this perspective is rooted in a monolingual-centered view of language development. Bilinguals' reduced exposure to each language compared to monolinguals does not necessarily lead to developmental delays but rather reflects a different trajectory of language acquisition that may involve weaker connections between lexical items in each language (Bialystok et al., 2010; Thordardottir et al., 2006).

Typical bilingual development can often resemble atypical language development seen in monolinguals, making the assessment and diagnosis of language impairment among bi-multilingual children challenging (Gollan & Ferreira, 2009; Oetting, 2018; Williams & McLeod, 2012). There is a risk of both over- and under-identification of language impairment in bilinguals and multilinguals (Antonijevic-Elliott et al., 2020; Genessee et al., 2004, Paradis et al., 2013), which can be due to the lack of standardized assessment tools in non-English languages and culturally appropriate resources.

One key area where this challenge becomes evident is in vocabulary size evaluation. De Houwer et al. (2014) demonstrated that when bilingual children are evaluated in both their languages, they can exhibit comparable vocabulary sizes to monolingual children in both comprehension and production. This is in contrast to a common misunderstanding that bilingual children may have smaller vocabulary. This finding underscores the importance of considering a bilingual child's abilities in all their languages when making assessments. Therefore, it is critical for speech-language pathologists to utilize different assessment tools and protocols to more accurately identify language development and disorders in bilingual children. Some studies have suggested that bi-multilingual children should be assessed in all of their languages (American Speech-Language-Hearing Association, 2004; Armon-Lotem et al., 2015). However, this is not always feasible due to various reasons including time restrictions, lack of linguistically and culturally appropriate resources, and a dearth of skilled interpreters and bilingual speech and language therapists (Boerma & Blom, 2017).

One measure that could help clinicians differentiate typically developing bilinguals from language- disordered bilinguals is Verbal Working Memory (VWM) (Campbell et al. 1997; Ellis Weismer & Evans, 2002; Ellis Weismer et al., 2000; Engel et al., 2008). VWM refers to the ability of maintaining speech stimuli, such as words and numbers, for a short period of time (van Dun & Mariën, 2016). One example of VWM would be keeping a phone number in mind for a short time until it is dialed. VWM has been shown to be important in language learning (Martin & He, 2004; Shallice & Papagno, 2019). There are different models of working memory (e.g., Engle et al., 1992; Gray et al., 2017). One prominent model of WM has been suggested by Baddeley and Hitch (1974). This model consists of three components: central executive, phonological loop (for verbal and auditory information) and visuospatial sketchpad (for visuospatial information). Baddeley (2000) added another component to this model: the episodic buffer which connects verbal and visual memory. This model draws a distinction between short-term (STM) and working memory (WM). STM refers to memory stored as the stimuli were experienced (as in the phone number example) while WM refers to memory that is manipulated and processed, such as recalling stimuli in the reverse order. WM critically involves the central executive, while STM does not. This model critically assumes a distinction between VWM and STM. However, Buchsbaum and D'Esposito (2019) have proposed that the VWM refers to both keeping and processing information, as the transformation of the stimulus is always in terms of goal-directed behavior. In other words, they do not draw a sharp distinction between VWM and STM. In the present study, we have followed their lead and include measures of both STM and WM under the umbrella of VWM.

These memory stores are important predictors of children's learning new words in both first and second languages (e.g., Gathercole, 1995; Gathercole & Baddeley, 1990; Juffs & Harrington, 2011; Kohonen, 1995; Service, 1992) and in foreign languages (Masoura & Gathercole, 2005). This relationship holds both contemporaneously and longitudinally (Gathercole et al., 1992; 1997; 1999; 2008).

There is also some evidence supporting a causal association between impairments of VWM and learning difficulties (Alloway et al., 2005; Swanson & Siegel, 2001). For these reasons, a valid and reliable measure of VWM could aid clinicians in the assessment of children with communication difficulties. Processing measures, such as VWM tasks, may be less biased tasks for assessing language development since they involve language-general cognitive processes, compared to a more language-specific task such as vocabulary, which are influenced by a child's exposure to a specific language (Campbell et al., 1997; Ellis Weismer & Evans, 2002; Ellis Weismer et al., 2000). It is particularly important when considering bilingual children, who may exhibit uneven language proficiency across their languages. Therefore, VWM tasks enable a more equitable evaluation of a child's potential to learn a foreign language, without relying on the size of vocabulary specific to a particular language. However, one challenge in using VWM measures in the assessment of bilingual children is that it is not entirely clear how previous experience of a particular language plays a role in VWM ability.

The purpose of the present study is to test whether language knowledge is related to VWM performance in bilingual and monolingual children. From a clinical point of view, it is critical to determine how these tasks can be used as an appropriate assessment for bilingual children. In this study, we expected bilingual children to perform worse on an English vocabulary test than monolinguals, as has often been found in prior research (Gross et al., 2014; Meir et al., 2017; Oller et al., 2007; Smithson et al., 2014; Sullivan et al., 2018).

However, bilingual lexical development suggests it is inappropriate to have monolingual-centered expectations for bilingual children (Fennell & Lew-Williams, 2017). If language knowledge is associated with VWM performance, then the bilingual children should perform worse than same-aged monolingual children. In both groups of children, VWM scores should be correlated with vocabulary scores.

To the extent that forward DS and NWR are both measures of STM, performance on the two tasks should be highly correlated. Indeed, Gathercole et al. (1999) investigated the association between verbal memory measuring by DS and NWR, and vocabulary knowledge in monolingual children 4 to 13 years of age. The results of this study indicated a significant correlation between DS and NWR. As noted earlier, some models of VWM assume a distinction between VWM and STM (Schwering & MacDonald, 2020). However, Alloway and Alloway (2010) found that forward and backward DS are highly correlated. This result is consistent with models assuming that VWM and STM are related (Davidson et al., 2006; Jensen et al., 2007; Miller et al., 1960).

Since the DS involves existing words and the NWR does not, one might expect that language knowledge would be more strongly related to DS performance than NWR performance. Alternatively, since the non-words in a NWR task reflect the phonotactics of a particular language, performance on the NWR could be strongly related to language knowledge. Indeed, as predicted, some studies have shown that NWR performance is less dependent on language knowledge than DS tasks among children aged 4 to 9 (Boerma et al., 2015; Chiat & Polišenská, 2016; Windsor et al., 2010). Similarly, some studies have found that DS performance is related to vocabulary for both monolingual (Gathercole et al., 1999) and bilingual (Haman et al., 2017) children. And some studies have shown no relationship between language abilities and NWR performance (Botting & Conti-Ramsden, 2001; Pigdon et al., 2019).

However, a number of studies have shown that performance on NWR tasks is related to language abilities for typically developing monolingual children (Gathercole, 2006; Gathercole et al., 1999). Similarly, some studies show that children with language difficulty often performed this task less accurately, especially for longer nonwords (Adams & Gathercole, 1995; Estes et al., 2007; Munson et al., 2005), With respect to bilinguals, studies have shown that performance on NWR tasks is related to language knowledge in which the task was performed (Ebert et al., 2014; Lee & Gorman, 2012; Parra et al., 2011; Peña et al., 2002; Summers et al., 2010; Thorn & Gathercole, 1999). Other studies have shown that NWR is one of the tasks that best discriminates between bilingual children with and without language difficulties (e.g., Schwob et al., 2021). In sum, the weight of the evidence suggests that there is a relationship between language knowledge and VWM performance for both bilingual and monolingual children as measured by both DS and by NWR. Another way of testing for possible links between linguistic knowledge and VWM is to compare bilingual and monolingual children. If VWM performance involves language-specific knowledge, one prediction is that monolingual children should outperform bilingual children. Language-specific knowledge refers to the grasp and comprehension of linguistic features unique to a particular language, which could lead to differing task performance between monolinguals and bilinguals due to their exposure to different language systems. Indeed, some studies have shown a monolingual advantage on DS performance, both forward (Blom & Boerma, 2017; Fernandes et al. 2007; Wodniecka et al., 2010) and backward (Bialystok, 2010; Bialystok et al., 2008; Blom & Boerma, 2017). However, other studies have shown equivalent performance on DS tasks in monolinguals and bilinguals (Gutiérrez-Clellen et al., 2004; Luo et al., 2010; Martin-Rhee & Bialystok, 2008; Shokrkon & Nicoladis, 2021).

Similarly, with NWR tasks, some studies have shown that monolinguals outperform bilinguals (Engel de Abreu 2011; Kohnert et al., 2006; Windsor et al. 2010). Whereas other studies have found no difference between monolinguals and bilinguals (Lee et al., 2013; Thorn & Gathercole, 1999). Taken together, these studies have shown mixed results about VWM performance between bilinguals and monolinguals. Further studies are needed to understand the contribution of language knowledge to VWM tasks. The purpose of the current study was to test whether language knowledge underlies performance on two VWM tasks: NWR and DS. Since both tasks are thought to measure VWM, we hypothesized that performance would be highly correlated on the NWR and the DS. We predicted that the bilinguals would score lower than monolinguals on an English vocabulary task and therefore lower on VWM tasks. We also tested whether the English vocabulary score is correlated with DS and NWR in both groups.

## Method

### Participants

The sample of this study included 40 (*M* age = 62.02 months, *SD* = 8.26), English-speaking monolinguals and 40 French-English (*M* age = 61.62 months, *SD* = 8.19) simultaneous bilingual children who were exposed to both languages from birth. The characterization of the bilingual children as simultaneous bilinguals was based on parental reports indicating that the children had been exposed to both French and English from birth. The monolingual children were chosen from a database of 79 children as the closest age matches the bilingual children. We did not have measures of the socioeconomic status (SES) of the children's families, although our recruitment approaches likely targeted high SES families (e.g., we recruited in university area daycares, known to target the children of graduate students and faculty members). To evaluate language dominance among the bilingual children, their parents were asked to best describe their child's French and English language proficiencies. The options were as follows: (a) My child speaks French far better than English, (b) My child speaks French a bit better than English, (c) My child speaks both languages about equally well, (d) My child speaks English a bit better than French, and (e) My child speaks English far better than French. There was no difference between the two groups on age $U = 771.00$, $n1 = 40$, $n2 = 40$, $p = .78$. All the children lived in the same western Canadian city.

Analyses in G-Power (Faul et al., 2009) revealed that the total sample size of 29 participants gave us power ($1-\beta = .80$) enough to find at least medium effect size ($d = .50$). We included 40 participants in each group, which not only exceeds the minimum required by the power analysis but also helps account for potential dropouts and provides a more comprehensive analysis of the research questions.

## Materials

### *Receptive vocabulary*

The Peabody Picture Vocabulary Test III (PPVT; Dunn & Dunn, 1997), version A, was used to assess the children's receptive vocabulary in English. A high reliability of .92 was reported for this test (Community-University Partnership for the Study of Children, Youth, and Families, 2011). To assess the vocabulary of the children in French, the Échelle de vocabulaire en images Peabody (EVIP; Dunn et al., 1993) was used. This is a standardized instrument tailored for Canadian French that evaluates receptive vocabulary.

### *Verbal Working Memory*

We included two measures of the children's VWM: Digit Span (DS; Richardson, 2007) and Nonword Repetition (NWR; Gathercole & Baddeley, 1996). Under the Baddeley (2000) model, forward DS is thought to tap STM. Backward DS is thought to tap VWM, since it has greater executive function involvement than forward DS (Gerton et al., 2004). In the NWR task, which is thought to tap STM, children repeat some nonsense words with the phonotactics of the target language (Coady & Aslin 2004; Munson et al., 2005, Rispens & Parriger, 2010; Zamuner et al., 2004). These nonwords are often different in length between 2 to 5 syllables (e.g., *ballop, bannifer, blonterstaping* and *altupatory*; Gathercole & Baddeley, 1996). According to Roy and Chiat (2004), NWR tasks are independent of culture and intelligence quotient (IQ).

### *Digit Span Task*

To measure digit span (DS), we used the Wechsler Intelligence Scale for Children (WISC-R; Weschler, 2003), digit span subscale. In this task, children are given a series of digits, and they were asked to recall and repeat the string of digits in the same way (i.e. the participants should repeat 2,4,6 as they heard 2,4,6) and reverse order (backward digit span, they need to repeat 4,7,5, as they heard 5,7,4). For the first trial, participants were given a series of two digits. For every subsequent correct trial, the experimenter added one digit (to a maximum of nine digits). They were given one trial at each string-length until they made an error and if they responded correctly, they were given a longer string. So, scores represent the highest level of error-free performance. A good psychometric property has been reported for forward and backward DS tasks, .89 and .86, respectively (Alloway & Passolunghi, 2011).

### *Nonword Repetition Task*

To measure nonword repetition skills in English, the children's test of nonword repetition (NWR) was used (Gathercole & Baddeley, 1996). This test consists of 40 pseudowords of two to five syllables and each syllable category involves 10 nonwords. Participants were asked to listen to pre-recorded nonwords, spoken by a female native speaker of Canadian English and repeat afterwards. The performance of children taped for scoring and the raw scores were used for analysis. The scoring was based on the procedure of Dollaghan and Campbell (1998), in which, the responses were considered as correct if they made all phonetics correctly, and if they did any insertion, substitution or omission, the response was considered as incorrect. Each correct response scored 1, with the maximum score of 40. For internal consistency, we calculated Cronbach's alpha, which was .81 and showed good reliability.

## Procedure

Research ethics approval was obtained from the institutional research ethics board for this study. Informed consent forms were signed by the parents, allowing us to conduct the test on their children. The data for this study come from a larger study that included a battery of language and cognitive tasks with both bilingual and monolingual children (Nicoladis & Mimovic, 2022). The analyses in the current study, however, are distinct and have not been published elsewhere.

In this paper, we report only the results connected to our research questions. The bilingual children participated in two separate language sessions. The English sessions were conducted by a native English speaker and the French sessions by a native French speaker. The order of the two language sessions were counter balanced and the two sessions were separated by about a week.

All children were asked for their verbal consent before any task was undertaken. Within a language session, the order of the tasks was at the discretion of the experimenter, based on the child's engagement. The sessions usually started with the more passive tasks, like the PPVT, which only requires children to point to a picture. Tasks requiring children to speak, like the NWR and the DS were usually administered later in the session. Two bilingual and monolingual children did not speak when asked to repeat non-words on the NWR repetition task. Five bilingual children (three FDS and two BDS) and one monolingual child did not perform the DS tasks. Three bilingual children and one monolingual child did not complete the PPVT. Consistent with guidelines suggested by Allison (2001), we have responsibly managed the incomplete data from the three bilingual children and one monolingual child who did not complete the PPVT, incorporating their results only in analyses where the absence of PPVT data would not compromise the reliability of the findings.

## Results

We devised our results section based on best practices in the field and considered the specifics of our dataset. Our use of non-parametric statistical techniques, like the Mann–Whitney U test and Spearman nonparametric correlations, was necessitated by significant deviations from normality in our data, as indicated by the Shapiro-Wilk test results. We looked to relevant studies, such as (Blom et al., 2014; Czapka et al., 2019), for methodological guidance. Although their study used a combination of t-tests and mixed effects models rather than non-parametric tests, their approach to analyzing data separately for each language group was similar to ours and provided us with useful insights into the potential relationships between variables in our own data. The descriptive statistics associated with PPVT, DS and NWR scores across monolingual and bilingual groups, are summarized in Table 1. We tested the normality of all variables, prior to the analyses, by conducting the Shapiro-Wilk test. The results indicated significant deviations from normality for FDS ($W = .86$, $p < .001$) and BDS ($W = .82$, $p < .001$) tests. Therefore, we conducted Mann–Whitney U as a nonparametric test to examine the differences between groups. As expected, the monolingual children had significantly higher PPVT scores than the bilingual children, $U = 443.50$, $n1 = 39$, $n2 = 39$, $p = .004$. However, the results indicated no significant difference for any of the VWM tasks: FDS: $U = 612.50$, $n1 = 39$, $n2 = 38$, $p = .16$; BDS: $U = 738.00$, $n1 = 39$, $n2 = 38$, $p = .97$; and NWR: $U = 721.50$, $n1 = 36$, $n2 = 40$, $p = .70$.

**Table 1.** ***Descriptive statistics for monolinguals and the bilinguals.***

| Measure | Group | N | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|---|
| Age | Monolingual | 40 | 62.02 | 8.26 | 47 | 83 |
| | Bilingual | 40 | 61.62 | 8.19 | 48 | 82 |
| PPVT | Monolingual | 39 | 86.30 | 24.83 | 39 | 137 |
| | Bilingual | 37 | 68.37 | 20.33 | 20 | 101 |
| FDS | Monolingual | 39 | 4.32 | .72 | 3 | 6 |
| | Bilingual | 37 | 4.51 | .93 | 3 | 7 |
| BDS | Monolingual | 39 | 1.61 | 1.61 | 0 | 6 |
| | Bilingual | 38 | 1.40 | 1.23 | 0 | 3 |
| NWR | Monolingual | 38 | 31.02 | 4.76 | 21 | 40 |
| | Bilingual | 38 | 29.78 | 5.98 | 14 | 40 |

PPVT = Peabody Picture Vocabulary Test; FDS = forward digit span; BDS = backward digit span; NWR = non-word repetition

***Relationship between language ability, digit span and nonword repetition***

To examine relations between the verbal working memory, nonword repetition and vocabulary (PPVT scores), Spearman nonparametric correlations were conducted. We present these correlations in the Appendix. As can be seen in the Table A1, age was highly correlated with VWM measures for both monolingual and bilingual children. We therefore partialled out age to test for the relationship between VWM and vocabulary. For the monolinguals, there was no significant correlation between vocabulary scores and FDS, $r_{partial}(33) = .286$, $p = .10$, BDS, $r_{partial}(33) = .076$, $p = .67$, or NWR, $r_{partial}(33) = .225$, $p = .20$. For the bilinguals, there was no significant correlation between vocabulary scores and FDS, $r_{partial}(32) = .288$, $p = .09$, BDS, $r_{partial}(32) = .243$, $p = .12$, or NWR, $r_{partial}(32) = .071$, $p = .69$.

Given how little difference there was between the bilinguals and the monolinguals on the VWM measures, to test for significant partial correlations (controlling for age) between measures of VWM, we combined the groups. The results indicated that forward and backward DS were significantly correlated, $r_{partial}(76) = .253$, $p = .02$, and NWR was correlated with FDS, $r_{partial}(75) = .232$, $p = .04$ and with BDS, $r_{partial}(75) = .381$, $p < .001$. For partial correlations between VWM tasks for each group separately, see Table A2 in the Appendix.

## Discussion

The purpose of this study was to test whether VWM, which is assessed by DS and NWR tasks, is linked to English language ability in monolingual and bilingual preschoolers. As expected, in line with many previous studies (Bialystok et al., 2010; Gollan et al.

2007; Namazi & Thordardottir, 2010), the bilinguals scored lower than the monolinguals on English receptive vocabulary. If VWM performance were related to language experience and knowledge, bilinguals would perform worse on VWM tasks than monolinguals. However, our results did not support a bilingual disadvantage on VWM tests: there was no significant difference between monolinguals and bilinguals on either a DS task or a NWR task. Moreover, vocabulary scores were not significantly correlated with performance on either the DS or the NWR tasks, for either bilingual or monolingual children, after we controlled for age. These results are surprising given that some previous research has shown a bilingual disadvantage in VWM measures relative to monolinguals (Bialystok et al. 2010; Thordardottir et al. 2006, Liu & Liu, 2021). However, it is important to keep in mind that other previous studies have also shown no difference between bilinguals and monolinguals on VWM measures (Cockcroft, 2016; Engel de Abreu, 2011; Engel de Abreu et al., 2012).

The inconsistent results across studies examining children's VWM performance could be due to a multitude of factors, including potential differences in methodological tools, such as variations in tasks used to measure VWM, participant characteristics, and operational definitions of bilingualism. Considering the developmental nature of VWM, age and language proficiency of participants may also influence the performance, underscoring the need for consistent and reliable measures when studying VWM (e.g., Bouffier et al., 2020). Moreover, some studies have shown a potential bilingual advantage in executive function, which may extend to WM and VWM (Adi-Japha et al., 2010; Bialystok, 2010; Carlson & Meltzoff, 2008; Prior & MacWhinney, 2010; Yoshida et al., 2011). Previous studies provided evidence that bilingual's higher executive functioning might extend to WM in general and VWM in particular (e.g., Blom et al., 2014; Delcenserie & Genesee, 2016; Kaushanskaya, 2012; Kroll et al., 2002). This advantage might be contingent on the amount of language exposure (Pierce et al., 2017). The bilingual children in this study, despite having lower vocabulary scores than monolinguals, had strong English proficiency due to their extensive exposure to English from an early age. Future longitudinal studies may shed more light on the relationship between the degree of language proficiency and VWM performance. Furthermore, it's noteworthy that the implications of bilingualism may extend to cognitive resilience in later life, potentially delaying cognitive decline and the onset of dementia (van den Noort et al., 2019), underscoring the lifelong impact of bilingualism on cognitive functions. The point that our bilingual children were possibly developing equivalent VWM skills to the monolinguals deserves careful consideration, especially given the influence of age on VWM. As noted, our study engaged children who were around five years old, unlike some other studies that involved older children (for instance, Lee and Gorman, 2012, worked with seven-year-olds). We acknowledge that the two-year difference is significant in early childhood development, potentially influencing not just language acquisition but also other skills like reading.

It's crucial to recognize that this study did not intend to make direct comparisons with studies involving different age groups. Instead, our goal was to provide a snapshot of VWM and language performance among bilingual and monolingual children at this particular stage of development. The statement about bilingual children potentially developing equivalent VWM skills to the monolinguals was speculative and meant to hint at potential trajectories of development, rather than provide definitive conclusions.

Future studies could focus on longitudinal designs, tracing the development of VWM and language proficiency over time. Such work could provide more definitive insights into the rate and pattern of VWM development among bilingual and monolingual children. Furthermore, it might help in better understanding the interaction between language proficiency and VWM performance.

With respect to the NWR task, our results add more evidence to the debate about the extent to which NWR is related to language knowledge or as a language-free task (Alloway & Archibald 2008; Gathercole et al. 1999; Kohnert et al., 2006). Our findings suggest that NWR has little connection to language knowledge among both monolingual and bilingual children of this age, as there were nonsignificant correlations between language knowledge and this task. These results are in line with previous study describing no relation between NWR and language exposure in five-year-olds French-English bilinguals (Thordardottir & Brandeker, 2013). These results, however, conflict with other studies showing the relationship between vocabulary size and NWR performance. Lee and Gorman (2012), for example, found that vocabulary scores and NWR performance were correlated in all bilingual children with various first languages (e.g., Korean, Chinese, Spanish). One plausible explanation for these differences is the similarity and close relationship between the first and second languages of our bilinguals. Some studies, especially studies with French-English bilinguals in Canada, showed that some bilinguals performed on par with monolinguals in their first and second language (Smithson et al., 2014; Thordardottir, 2011). Previous studies have found that NWR highly depends on language proficiency both vocabulary and grammar (Archibald & Gathercole, 2006; Ellis Weismer et al., 2000; Thordardottir et al., 2010). Favoring this explanation, many studies suggested that although NWR are not related to long-term lexical knowledge, nonword recall is linked to familiarity with the phonotactic properties of the language in which NWR are performed (Gathercole, 1995; Gathercole et al., 1999; Kovács & Racsmány, 2008; Roodenrys & Hinton, 2002; van Bon & van der Pijl, 1997). That is the similarity between L1 and the language in which NWR is tested may be considered as an advantage. Another possible explanation for the mixed results in terms of its connection to language abilities is that there are different types of NWR measurements which are different in the rate of wordlikeliness and therefore to what extent the nonwords are related to real vocabulary (Thordardottir & Brandeker, 2013).

The results of this study showed strong intercorrelations between FDS, BDS, and NWR, suggesting that these tasks may tap on similar underlying abilities. These results are in line with some studies that have found that NWR is moderately to strongly associated with BDS and/or visuospatial working memory (Baniqued et al. 2013, Cleary et al. 2001). In the other words, our results suggested that the distinction between STM and WM is not in place at least among preschool children. This finding has been well established and supported in the previous studies (Davidson et al., 2006; Jensen et al., 2007; Krumm et al., 2009; Martinez et al., 2011). Likewise, a number of studies provided empirical evidence that STM and WM could possibly represent the same latent construct (Colom, Rebollo et al., 2006; Colom, Shih et al., 2006; Unsworth & Engle, 2006). Unsworth and Engle (2007), for instance, proposed simple and complex tasks measure the same cognitive process showing STM and WM are indistinguishable.

Naturally, the present study has a number of limitations. One of the main limitations is the close relationship between French and English languages. Moreover, our simultaneous bilinguals were exposed to their both languages in a sociocultural context that supported bilingualism. Therefore, more studies with different language groups and larger sample sizes are needed to expand the generalizability of these findings. Another limitation of this study is that our participants were likely from high-SES families. Although we did not measure SES directly, our recruitment approach likely targeted high-SES families. Previous studies have shown a significant association between SES and WM functioning (Noble et al., 2005; 2007). Thus, an interesting avenue for further research is investigating how SES might influence the relationship between VWM and language.

In conclusion, the results of this study suggest that bilingual preschoolers, despite their lower vocabulary scores in English, performed equivalently to monolinguals on two measures of verbal working memory (VWM). The notion of a critical threshold of language exposure before performing well on VWM tasks, as also suggested by Thordardottir (2020), emerges as a central theme in our discussion. However, our findings contribute additional nuances to this idea by shedding light on the comparable performance of bilinguals and monolinguals in VWM tasks despite differing vocabulary proficiency.

In terms of clinical implications, the understanding of a critical language exposure threshold could have significant ramifications for the design and interpretation of cognitive and language assessments for bilingual children. If language exposure proves to be a pivotal factor in determining VWM performance, clinicians might need to incorporate measures of language exposure when evaluating bilingual children. Furthermore, it's important to consider that the bilingual children in this study, despite their lower English vocabulary scores, were frequently exposed to English either from birth or very early on. This suggests that the age, volume and quality of language exposure, rather than simply the number of languages spoken, might play a crucial role in VWM performance.

More research is undoubtedly required to further elucidate these links and inform clinical practice. Specifically, longitudinal studies that monitor language exposure and VWM performance over time would be beneficial. Meanwhile, clinicians and researchers should remain cautious in interpreting the results of VWM tasks, particularly when comparing bilingual and monolingual children.

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## Data, Code and Materials Availability Statement

The raw data and analysis syntax are available on the Open Science Framework at https://osf.io/dhj39/

## Ethics Statement

Ethics approval was obtained from the ethics committee of the University of Alberta. All participants gave informed written consent before taking part in the study.

## Authorship and Contributorship Statement

**Farzaneh Anjomshoae** conceived of the study, designed the study, analyzed the data and wrote the first draft of the manuscript. **Elena Nicoladis** contributed to the design of the study, collected the data, and revised the manuscript. **Anahita Shokrkon** revised the manuscript. All authors approved the final version of the manuscript.

## Appendix

**Table A1.** ***Spearman correlations between Peabody Picture Vocabulary Test Scores, forward and backward digit span, and nonword repetition.***

| | Age | PPVT | FDS | BDS | NWR |
|---|---|---|---|---|---|
| Age | – | .296 | .120 | .468** | .392* |
| PPVT | .553** | – | .285 | .070 | .300 |
| FDS | .352* | .431** | – | .112 | .099 |
| BDS | .528** | .499** | .437** | – | .406* |
| NWR | .326* | .112 | .296 | .340* | – |

*Note:* Top of matrix above diagonal indicates correlations for monolinguals, bottom of matrix below diagonal indicates correlations for bilinguals; PPVT = Peabody Picture Vocabulary Test; FDS = forward digit span; BDS = backward digit span; NWR = non-word repetition; $^{**}p < .01$, $^{*}p < .05$

**Table A2.** ***Partial correlations (controlling for age) between verbal working memory tasks in monolinguals and bilinguals.***

| | FDS | BDS | NWR |
|---|---|---|---|
| FDS | – | .027 | .277 |
| BDS | .300 | – | .340* |
| NWR | .151 | .205 | – |

*Note:* Top of matrix above diagonal indicates correlations for monolinguals, bottom of matrix below diagonal indicates correlations for bilinguals; FDS = forward digit span; BDS = backward digit span; NWR = non-word repetition; *$p < .05$

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