# The Effect of Early Bilingualism on Executive Functions: A Training Study with the Early Executive Functions Questionnaire

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A Thesis in The Department of

Psychology

Presented in Partial Fulfillment of the Requirements for the Degree of

Master of Arts (Psychology)

Concordia University

Montreal, Quebec, Canada

August 2024

**CONCORDIA UNIVERSITY**

**School of Graduate Studies**

This is to certify that the thesis prepared

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Entitled: The Effect of Early Bilingualism on Executive Functions: A Training Study with the Early Executive Functions Questionnaire

and submitted in partial fulfillment of the requirements for the degree of

**Master of Arts (Psychology – Research and Clinical Training Option)**

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Abstract

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The bilingual cognitive advantage states that bilinguals exhibit greater executive function (EF) abilities than monolinguals. This advantage has been reported in children as young as 6 months old yet has failed to be consistently replicated. Given that the bulk of the literature has used correlational designs, the present study adopted a training design which aimed to determine whether teaching monolingual children a second language will lead to greater increases in EF than if taught words in their native language. Two groups of children completed a 12-week online training program during which 9 translation equivalents (TEs; experimental condition) or 9 novel words in their native language (control condition) were taught weekly. Participants' EF was compared pre- and post-intervention using the Early Executive Functions Questionnaire, which assesses working memory (WM), flexibility (FX), inhibitory control (IC), regulation, and cognitive executive function (CEF, which is a factor that loads onto WM, FX, and IC). Word learning was assessed weekly with a forced choice task based on pointing or touch. Results suggest that learning TEs is more difficult than learning new words in one's native vocabulary. Results also indicate that although the total sample significantly increased in IC, FX, WM, and CEF from pre- to post-intervention there was no time by condition interaction indicating that the groups EF skills grew equivalently. Finally, only learning TEs was associated with improvement in working memory. To conclude, our results do not support a bilingual advantage at 25 months but suggest a link between second language acquisition and WM.

Acknowledgements

This research was supported by a grant awarded to Dr. Diane Poulin-Dubois by the Natural Sciences and Engineering Research Council of Canada as well as scholarships awarded to Victoria Fratino (SSHRC Canada Graduate Scholarship Master's Program). Finally, I would like to acknowledge Concordia University for awarding me with an entrance award.

I would like to thank Dr. Diane Poulin-Dubois for her direction and counsel throughout my entire degree, and for entrusting me with this project. Your guidance was a key to my success. I would also like to thank Mihaela Zlatanovska, Nicolas Laporte, Ella Telio and Evangelia Zaharakis for their time and effort with data collection. Thank you to my committee members Dr. Norman Segalowitz, and Dr. Erin Barker for their time, insight, and interest in my project. Thank you to my previous supervisors Dr. Jelena Ristic, Dr. Francesca Capozzi, Dr. Clara Colombatto, and Dr. Sarah McCrackin for fostering my interest in research and believing in my abilities and passion to attend graduate school. Thank you to my laboratory mates for their constant help and support, knowing that you all had my back and were ready to brainstorm encouraged me more than you know. Thank you to my wonderful friends Alicia, Alyssa, Laetizia, and Isaura for your constant encouragement and excitement in my research. You have all had a huge impact on my life and I am so grateful for you all. To my parents and siblings thank you for always believing in me and offering an ear to listen when I needed it, you always pushed me to go as far as I can. To Milo, Zizi, Nonna, my gang of Fratino's and all my extended family thank you for always being excited for me and for your constant encouragement and support. Finally, to my Alex, I would not be who I am today or where I am today without you, your never-ending support and love was vital these last two years, you always gave me what I needed when I had doubts about whether I could do this.

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## Introduction

### Bilingualism

It is estimated that 50% of the world's population has some degree of bilingual proficiency (Hammer, 2012; Mendis et al., 2021) and that 70% of languages worldwide can be located within about 20 nation-states, thus creating many communities of coexisting monolingual and bilingual populations (Romaine, 2006). Bilingualism has been traditionally defined as the consistent use/exposure of at least two languages (Ianco-Worral, 1972; Kremin & Byers-Heinlein, 2021). However, the operational definition of bilingualism has shifted away from being categorical (Luk & Bialystok., 2013), to adopt a perspective in which it is conceptualized on a continuum (Rothman et al., 2023), in terms of a degree of proficiency and exposure to a second language (Kremin & Byers-Heinlein, 2021). When bilingualism is studied in infancy, researchers consider the percentage of exposure to a second language (e.g., at least 10% exposure; Bosch & Sebastián-Gallés, 1997; Byers-Heinlein, 2015; Byers-Heinlein & Lew-Williams 2013; Hoff et al., 2012).

Over the past decades many benefits of multilingualism have been uncovered, known as the bilingual cognitive advantage (BCA). For instance, bilingualism is protective not only against the onset of Alzheimer's disease but against the cognitive decline typically seen in those diagnosed as well (Diamond, 2010; Gollan et al., 2011). Moreover, bilingualism has been associated with greater creativity and social cognition (i.e., not expecting foreign speakers to speak the language(s) that you do; Byers-Heinlein et al., 2014; Leikin, 2013; Sebastian-Galles & Santolin, 2020). More importantly, there is evidence that bilingualism also benefits executive functions (Bialystok, et al., 2014).

## Executive Functions

Executive functions (EF) refer to a set of cognitive processes that are essential to achieve goals (Arizmendi et al. 2018; Miyake et al., 2000; Salehinejad et al., 2021). A model of EF proposed by Miyake and colleagues (2000) explains that EF is composed of the three following subcomponents: inhibition, updating, and shifting (Arizmendi et al., 2018; Miyake et al., 2000) The umbrella term of EF can be further subdivided into hot or cold functions (Salehinejad et al., 2021). Hot EF encompasses skills that involve an emotional, affective, or motivational component (Beaudin & Poulin-Dubois, 2022; Salehinejad et al., 2021). For instance, emotion regulation (ER), the ability to cope with and regulate one's emotions and mood is an example of hot EF and can be identified through behavior in children as young as 5 months of age (Eisenberg et al., 2007; Hendry et al., 2016; Salehinejad et al., 2021; Stifter & Braungart, 1995). Moreover, individual differences in emotion related regulation appear to be stable after one to two years of age (Hendry et al., 2016). Response inhibition, or the ability to control or inhibit one's behavior is another example of a hot EF skill that is often measured using delay of gratification tasks and has been previously tested in 22-month-old children (Luo & Pattankul, 2020; Mischel et al., 1989).

Cold EF refers to abilities that are purely cognitively based (e.g., inhibition, updating, and shifting; Salehinejad et al., 2021). In infancy, specifically before the age of three, updating and shifting are difficult to separate (Hendry et al., 2016). Updating (also referred to as working memory (WM)) is the ability to hold and manipulate/update information held within one's memory (Arizmendi et al. 2018; Baddeley, 2000; Miyake et al., 2000). Shifting, or flexibility (FX) is the ability to shift one's attention, tasks or state of mind (Arizmendi et al. 2018; Calcott & Berkman, 2015; Miyake et al., 2000). Although difficult to differentiate in young children, they both are believed to emerge between the age of five to eight months (Hendry et al., 2016). Attentional inhibition, a cold EF skill, refers to the ability to control for attentional interference and is often measured using conflict tasks (e,g., the Flanker or Stroop task) and is believed to be present to some degree in children as young as 9 months of age (Arizmendi et al., 2018; Beaudin & Poulin-Dubois, 2022; Hendry et al., 2016; Holmboe et al., 2008; Lowe et al., 2021; Miyake et al., 2000).

**The Bilingual Cognitive Advantage**

The EF's defined above are main variables of interest when discussing the BCA. As mentioned before, this theory posits that multilinguals exhibit a cognitive advantage in EF compared to their monolingual peers in both adults and children (Bialystok, 2010; Bialystok et al., 2009; Guo & Yao, 2022; Kroll & Bialystok, 2013). Although it has been argued that this advantage exists in both children and adults, results of work with children are typically more consistent (Poulin-Dubois, 2023). EF is believed to reach a plateau in adulthood and thus may hinder researchers' ability to identify any advantage if one does so exist (Bialystok, 2017). However, the rapid development of EF in childhood suggests that it might be a critical developmental period to investigate this phenomenon, as confounding variables may be more easily controlled (Bialystok, 2017). Similarly, it has been suggested that bilingual children may temporarily exhibit stronger EF skills as their cognitive skills may simply develop more quickly than monolinguals (Planckaert et al., 2023). As a result, although a bilingual benefit may be seen in younger infants, it is believed that monolinguals eventually catch up (Planckaert et al., 2023).

A plethora of studies within the recent decades have investigated the BCA in children as well as its age of emergence. The youngest age in which a bilingual advantage in EF has been reported has been in infants at 7 months of age. In a groundbreaking study, Kovács and Mehler

(2009) reported that infants who were raised bilingually since birth showed stronger EF abilities than their matched monolingual counterparts. More specifically, bilingual infants were better at shifting their attention during an anticipatory looking task compared to monolingual infants (Kovács & Mehler, 2009). There have been both failures (D'Souza et al., 2020; Kalashnikova et al., 2021; Spit et al., 2023) and successes (Comishen et al., 2019; Dal Ben et al., 2022) in replications of that original experiment with children younger than 24 months (D'Souza et al., 2020; Kalashnikova et al., 2021; Spit et al., 2023). For example, the BCA was not observed in 17-month-old children, when using in-person, interactive tasks designed to test executive functions in toddlers (Poulin-Dubois et al., 2022). Interestingly, a BCA has been reported a few months later, at 23 months, where bilingual toddlers not only exhibited greater response inhibition when using a parent-report questionnaire of EF (Beaudin & Poulin-Dubois, 2022) but also exhibited stronger attentional inhibition than their monolingual peers on in-laboratory conflict tasks (Crivello et al., 2016; Poulin-Dubois et al., 2011). Taken together, these patterns of results raise the possibility that a BCA emerges by the end of the second year.

What are the cognitive mechanisms that could account for a BCA, particularly in young children? Green (1998) suggested that top-down processes allow for languages to be inhibited when not being used and that these inhibition processes may influence inhibitory control abilities in other domains. As a result, the act of inhibiting language(s) was theorized to be the driving force of the BCA (Bialystok, 2017; Bialystok et al., 2009). However, Bialystok & Craik (2022) suggest that the BCA is unlikely to be specific to inhibition but rather any cognitive advantages would likely fall under the umbrella of attentional control which will be later discussed in further detail. In principle, inhibition becomes possible as soon as children acquire translation equivalents (TEs), which refer to representations of the same concept in two languages (e.g., the word apple and pomme refer to the same concept in both English and French) and allow toddlers to practice code-switching, which is the act of switching between language systems throughout one's day to day (Crivello et al., 2016; Patterson & Pearson, 2004). Code-switching as a result is theorized to enhance both inhibition and selective attention skills (Beaudin & Poulin-Dubois, 2022; Patterson & Pearson, 2004). Specifically, bilinguals practice of inhibiting one or more language systems and altering which is/are inhibited translate to greater skills in cognition like inhibition (Prior & Gollan, 2011). In fact, research has shown that bilingual toddlers who gained a larger number of TEs over a 7-month period performed better on a task measuring inhibition (Crivello et al., 2016). Thus, it seems that 24 months may be the earliest age where a bilingual advantage can be observed because children need to acquire a sufficient number of TEs and/or a certain amount of practice code-switching in order for a BCA to arise, hence explaining the failure to replicate significant results at both 6 and 17 months of age .

Regarding which components of EF might be impacted by early bilingualism, recent meta-analyses based on data collected in children aged 18 months to 17 years, when combined, have concluded that the BCA is not domain general (Gunnerud et al., 2020) but rather domain specific, specifically response inhibition (Lowe et al., 2021). Recent work by Wimmer et al., (2021) also concluded that 3–5-year-old bilinguals exhibit stronger inhibitory control. Importantly, these meta-analyses suggest that confounds like socioeconomic status (SES), and publication bias may be driving a small effect (Lowe et al., 2021). More generally, it has been suggested that when advantages in EF are found, these may be driven by group differences in more general memory skills and demographics in young adults (Antón et al., 2019). In line with these conclusions, others have also concluded that bilingual benefits to EF are unlikely to exist or are driven by extenuating variables like SES once again or may be in part task-specific (Paap et al., 2016; Van den Noort et al., 2019; Ware et al., 2020).

Since these meta-analyses were published, a study using a parent-report questionnaire to measure EF in 24-month-old monolingual and bilingual toddlers found a statistically significant BCA in response inhibition when controlling for SES (Beaudin & Poulin-Dubois, 2022). However, studies using in-laboratory measures have typically not found this effect in response inhibition (Carlson & Meltzoff, 2008; Crivello et al., 2016; Poulin-Dubois et al., 2011). Thus, suggesting that in-laboratory measures may not be suitable to grasp a full picture of very young children's inhibition skills (e.g., a lack of ecological validity; Beaudin & Poulin-Dubois, 2022). Rather, in-person studies have typically found stronger attentional inhibition abilities in 24-month-olds (Poulin-Dubois et al., 2011), 31-month-old (Crivello et al., 2016), 6-year-old (Carlson & Meltzoff, 2008), and 9-year-old (Sorge et al., 2017). Recent reviews have also supported a bilingual benefit in inhibition in children and adolescents (Giovannoli et al., 2020). However, these benefits have not been replicated before the age of 24 months (Poulin-Dubois et al., 2022). Furthermore, work with elementary school aged children found no such effect of attentional inhibition (Antón et al., 2014; Duñabeitia et al., 2014; Salwei & Diego-Lazaro, 2021).

When reviewing the literature on FX, two studies have found a bilingual advantage in shifting attention when using an in-laboratory habituation paradigm at 7 months of age (Comishen et al., 2019; Kovács & Mehler, 2009). A recent review has concluded greater FX abilities in children and adolescents (Giovannoli et al., 2020). Moreover, a 2020 meta-analysis concluded that a bilingual benefit in shifting remains statistically significant even after controlling for publication bias (Gunnerud et al., 2020). However, authors interpreted these effects with caution as the effect was small and thus concluded that this finding was insufficient to lend support to a BCA in EF globally (Gunnerud et al., 2020). Additionally, this advantage has not only failed to be replicated at this exact age (D'Souza et al., 2020; Kalashnikova et al., 2021; Spit et al., 2023) but in 17-month-old and 24-month-old as well (Beaudin & Poulin-Dubois, 2022; Poulin-Dubois et al., 2011; 2022). To conclude, there is a lack of evidence beyond meta-analyses at this point in time to suggest that there is a bilingual advantage in FX especially above the age of 7 months.

In terms of WM, results appear to be even more contradictory across studies. Some researchers have concluded a bilingual advantage in WM in preschool/kindergarten aged children (Blom et al., 2014; Marini et al., 2019; Morales et al., 2013) and concluded that this advantage is larger in childhood than in adulthood (Grundy & Timer, 2017). Moreover, one study found a bilingual advantage in more difficult WM tasks when using groups matched on age, IQ, SES, education etc. in young adults (Antón et al., 2019). However, many studies have failed to find bilingual benefits in WM specifically below the age of five (Beaudin & Poulin-Dubois, 2022; Brito et al., 2014; 2021; Crivello et al., 2016; Poulin-Dubois et al., 2011; 2022) and between the age of 5 to 17 in a recent review (Giovannoli et al., 2020). Although many have failed to find a bilingual benefit in WM, work by Brito and colleagues have found benefits in memory generalization in bilingual benefits as young as 6 months of age (Brito & Barr, 2014), 18 months of age (Brito & Barr, 2012; Brito et al., 2021), and 24 months of age (Brito et al., 2014). Although these results seem promising, they have failed to be replicated on multiple occasions when testing children (Bonifacci et al., 2011; Engel De Abreu, 2011; Namazi & Thordardottir, 2010). Some have suggested that any bilingual benefit to WM is likely domain-specific (e.g., to verbal WM; Espi-Sanchis & Cockcroft, 2022). In addition, it is hypothesized this lack of consensus among researchers may be in part due to task-specificity (Beaudin &

Poulin-Dubois, 2022). To explain, many studies that have found a BCA in WM used visuospatial WM tasks (Beaudin & Poulin-Dubois, 2022). Moreover, it is suggested that the tasks being used to measure WM may be mapping onto other cognitive skills that may drive an advantageous effect (Beaudin & Poulin-Dubois, 2022).

A fourth and final subcomponent of EF whose association with bilingualism has been less commonly studied is emotion regulation (ER). There is a lack of general consensus across researchers as studies have shown both a statistically insignificant and statistically significant difference between bilingual and monolingual children on ER skills (Barker & Bialystok, 2019; Beaudin & Poulin-Dubois 2022).

More recently, in order to explain the conflicting results discussed above as well as a potential benefit in preverbal infants, a new BCA account has emerged. It has been suggested that bilinguals exhibit greater attentional control (Bialystok & Craik, 2022), an umbrella term that encompasses various skills and components of different domains of EF like inhibition and WM (Bialystok & Craik, 2022). For instance, attentional control encompasses skills like response inhibition and information manipulation (a component of WM; Bialystok & Craik, 2022). It is hypothesized that not all tasks assessing inhibition and that not all tasks assessing WM etc. tap into the specific cognitive skills embedded within attentional control that are benefitted by bilingualism (Bialystok & Craik, 2022). As a result, this may explain the inconsistency of findings when using different tasks. Moreover, Bialystok & Craik (2022) suggest that in order for a BCA to arise, tasks must require a high degree of attentional control that exceeds the abilities of monolinguals. To conclude, not all tasks may require a high enough demand of attentional control nor do all tasks assess the specific cognitive skills of attentional control (Bialystok & Craik, 2022).

It is important to point out that the bulk of the research on the BCA is mostly correlational. As the BCA is currently hotly debated (i.e., whether it exists and which areas of EF are specifically benefitted), training studies are crucial as they allow for further insight into the direct effect of second language learning on EF's. Fortunately, in recent years, research on bilingualism and EF has started to investigate the influence of language training with language immersion designs. For example, Nicolay & Poncelet (2013) matched eight-year-old children attending a unilingual or immersion school for three years on verbal and nonverbal intelligence, and SES. Results suggested that the immersion group showed greater attentional abilities, and FX but not inhibition skills (Nicolay & Poncelet, 2013). These results were then replicated with groups of children who were equivalent in executive skills at the start of school (Nicolay & Poncelet, 2015). Work by Purić et al. (2017) examined how exposure to a second language for either 0-hour, 1.5 hour or 5 hours, over a period of a year, would influence EF in age-matched children. Their results suggest that 2nd grade children who experienced the most time in second language exposure exhibited the greatest increase in WM abilities (Purić et al., 2017). Similarly, researchers who compared performance on EF tasks between children (matched on age, SES, intelligence, receptive vocabulary and gender) who were enrolled or not in an immersion school program for the last one, two, three or six years found a bilingual advantage in FX and WM only in the sixth year (Gillet et al., 2020). In another study, Santillán & Khurana (2018) compared the change in EF abilities across three groups of low SES four-year-old children. The groups consisted of a group of monolingual children who remained monolingual, a group of monolingual children who began attending a bilingual Head Start program (pre-k), and a group of already bilingual children who reminaed bilingual (Santillán & Khurana, 2018). All three groups of children were followed for 18 months and results indicated that the newly bilingual children had a greater increase in attentional inhibition skills on a Stroop-like task compared to those who remained monolingual (Santillán & Khurana, 2018). In addition, at time two (18 months after beginning school) the inhibition growth of the children who became bilingual was equivalent to that of native bilinguals (Santillán & Khurana, 2018). Finally, Neveu et al (2021) investigated differences in EF in nine-year-old children, both four and five years after they began attending a monolingual or a bilingual school. Researchers found that monolingual children who had been attending a bilingual school for four years exhibited greater inhibition abilities than children who had continued attending a monolingual school (Neveu et al., 2021). However, this advantage was no longer present one year later (Neveu et al., 2021). The authors interpreted these results as suggesting that although the cognitive skills of bilingual children may develop more quickly, both groups eventually exhibited equivalent skills (Neveu et al., 2021). Although these results are promising, work by Simonis et al (2020) found no significant effect of second-language acquisition/proficiency on EF.

**The Present Study**

To conclude, it remains unclear whether bilingual infants and toddlers truly hold stronger inhibition abilities compared to monolinguals. As most studies have focused on correlational links between bilingualism and EF skills, a causal link has not yet been established. Specifically, although many have published on the influence of language immersion on EF, to our knowledge, no study directly trained second language learning and observed its effects on EF. Moreover, promising work suggests that seven- to 33-month-old infants are capable of learning a second language via play interventions (Ferjan Ramirez & Kuhl, 2017; Ramírez & Kuhl, 2020). The present study aims to fill this gap in the literature by establishing whether a causal link between second language acquisition and EF growth in 24-month-old children is present. The main goal of the present study is therefore to determine whether teaching monolingual toddlers' words in a second language (experimental condition) will lead to a larger increase in EF abilities compared to monolingual children who are taught words in their native language (control condition). As most typically, a BCA in inhibition has been observed in children 24 months of age, we hypothesize that toddlers assigned to the experimental condition will exhibit a larger growth in inhibition skills in comparison to the control group of children.

# Methods

## Participants

Participants were recruited across Canada through advertising in social media, and from the laboratory database of past participants. Parents received either a recruitment email for a 14 weeklong study where children would be taught new words in their native language or be taught new words in a second language, to understand whether training improves cognition. Recruitment emails also indicated all of the eligibility requirements. In order to be eligible to participate in this training study, participants had to be between 20 and 27 months of age at the time of the first session, had to have been born full-term, with no visual, auditory, or development delays, and considered monolingual (i.e., less than 10% exposure to a non-dominant language; Hoff et al., 2012; Place & Hoff, 2011). An a priori G*Power analysis (Faul, Erdfelder, Lang, & Buchner, 2007) was conducted to determine the sample size required for a 2 x 2 fixed effects ANCOVA with .8 power, an effect size of .36 (Beaudin & Poulin-Dubois, 2022) at a standard .05 alpha error probability. The analysis resulted in a minimum sample size of 63 participants (32 per group). A total of 110 participants were tested however, 44 participants were excluded from analysis if they did not meet the criteria of monolingualism (i.e., less than 10% exposure to a non-dominant language; Hoff et al., 2012; Place & Hoff, 2011) either before the start of the study or after its end (*N* = 15), did not complete the EEFQ questionnaire at the beginning or end of the study (*N* = 2), dropped out of the study (*N* = 20), had no access to technical equipment needed to participate (*N* = 1) and/or were born prematurely ((*N* = 6) i.e., prior to 37 weeks of gestation; World Health Organization, 2023).

The sample was randomly assigned to an experimental or control condition ($N_{experimental}$ = 34; $N_{control}$ = 31). The average age of participants at the time of the first session was 21.93 months in the experimental group and 22.24 months in the control group. The experimental group was comprised of 17 males, 16 females and one unknown, while the control group included 17 males and 13 females and one unknown. On average children were exposed to their native mother tongue 99.03% in the experimental group and 98.84% in the control group. Moreover, 30 participants were English speaking, and 4 participants were French speaking in the experimental group while 26 participants were English speaking, and 5 participants were French speaking in the control group. Participants in both conditions were predominantly identified as of European descent by their guardians. Specifically, 61.76% participants were identified as European by their parents, 2.94% as Indigenous, 5.88% as Asian, 8.82% as other, and 20.59% parents indicated that their child identified with two or more ethnic groups. In the control group, 54.84% participants were identified as European by their parents, 9.68% as Asian, 3.23% as Indigenous, 19.35% as other, and 12.90% parents indicated that their child identified with two or more ethnic groups. Finally, most participants reported an average household income between 100, 000 to 150, 000 in the experimental group and most participants reported an average household income above 150, 000 in the control group. Two participants in the control group opted out of responding to the question regarding household income.

**Measures**

## Language Exposure Assessment Tool (LEAT)

The Language Exposure Assessment Tool (LEAT; DeAnda et al., 2016) was used to obtain a measure of language exposure. It is a validated tool used to measure early language exposure and has been used with children aged 4 months to 5 years of age (Beaudin & Poulin-Dubois, 2022; Kalashnikova et al., 2024; Kuzyk et al., 2020; Marcet et al., 2024). It is an Excel-based tool that calculates participants time of exposure to one or more languages per day, week and overall (DeAnda et al., 2016). Interviews using the LEAT ask parents to reflect on the individuals who interact with their child at least once a week, which languages these individuals speak, how much time everyone spends with their child, and at what age they began to do so (DeAnda et al., 2016). We used the LEAT and the overall exposure to the child's dominant language to determine whether participants were considered monolingual (i.e., less than 10% exposure to non-dominant languages) prior to training. Finally, the details of participants' LEAT at Session 1 were confirmed during the last session in order to confirm that participants had remained unexposed to a second language outside the training sessions.

## Demographics Questionnaire

This questionnaire assessed basic demographic-related questions including gender, healthy history of the child, ethnic background, household income, occupational and marriage status etc.

## MacArthur-Bates Communicative Development Inventories: Words and Sentences (MCDI:WS)

The MCDI:WS is a parent-report checklist that assesses the expressive vocabulary size of children between the ages of 16 and 30 months (Fenson et al., 1993). For the purpose of this study, the Canadian-English long form and the French-Canadian long form (Trudeau et al., 1999) were assigned to participants parents using the Web CDI (Frank et al., 2017) depending on whether the child was a monolingual English or French speaker. The results of this inventory were used to assess participants' vocabulary size at the beginning of the training and at the end of the intervention. Thus, difference scores were also computed to calculate participants' vocabulary growth that occurred over the length of the study. In addition, data from Wordbank (Frank et al., 2017) were consulted to select the words to be taught to each group. In order to increase the likelihood that children in the experimental condition would learn translation equivalents (TEs) or doublets we chose to teach them nouns known by at least 50% of 24-month-old children based on Wordbank by-word summary data (Frank et al., 2017). To maximize the likelihood that children in the control group would not already know the new words being taught, we chose to teach them nouns known by less than 50% of 24-month-old children once again based on Wordbank by-word summary data (Frank et al., 2017). In order to determine the total number of words to be taught, the average vocabulary size for 24-month-old children using Wordbank normative data of the American English and the French-Canadian MCDI:WS was calculated. As previous work has reported that native 24-month-old bilinguals have on average 34% to 47% translation equivalents in their vocabulary (Beaudin & Poulin-Dubois, 2022; Crivello et al., 2016; Poulin-Dubois et al., 2011) we used 37% of 24-month-old children's average vocabulary size as our target number of translation equivalents, which resulted in a total of 108 words to be taught in each group.

**Early Executive Functions Questionnaire (EEFQ)**

The Early Executive Functions Questionnaire (EEFQ), a well validated 31-item parent-report questionnaire that assesses a range of executive functions in children between the age of 9 and 30 months (Hendry & Holmboe, 2021), was used to measure executive functions. It has been successfully used in identifying a BCA in response inhibition in 23-month-old children (Beaudin & Poulin-Dubois, 2022). This questionnaire assesses inhibitory control (IC), working memory (WM), flexibility (FX), regulation (RG), and cognitive executive function (CEF) which is a factor onto which IC, WM, and FX load onto. The first three items of the EEFQ are games that parents are asked to complete with their children. In the first game (the waiting game), which measures IC, children are placed in front of a snack that they like and are asked to wait (up to 30 seconds). Parents then indicate how long their child waited before eating the snack. In the second game (the finding game), which measures WM, parents are asked to place a small toy under one of two differing and non-transparent containers while their child is watching. The child is then asked to find the toy. Parents are asked to repeat this game four times alternating each time the location of the toy and to indicate how often their child chose the correct container. In the third game (the sorting game), which measures FX, parents are asked to place five small spoons, five large spoons, and two bowls of different sizes in front of their child. Children asked to place the small spoons in the smaller bowl and to place the larger spoons in the larger bowl. Once this game is completed, children are told that they are playing a silly game and must now place the small spoons in the large bowl and the large spoons in the small bowl. Parents are then asked to indicate their child's performance on these tasks. Once these games are completed, parents are then asked to answer 28 questions assessing the domains of EF listed above. These questions ask parents about their child's behaviour during the last two weeks and parents respond using a 7-point Likert scale range from never to always.

The EEFQ was administered in English or in Quebec-French depending on the mother tongue of the participants and their parent(s) via GoogleForms and both written and video instructions were directly embedded into the online survey. This questionnaire was completed both pre and post training, in order to assess EF growth in both conditions.

**Training and Word Learning Task**

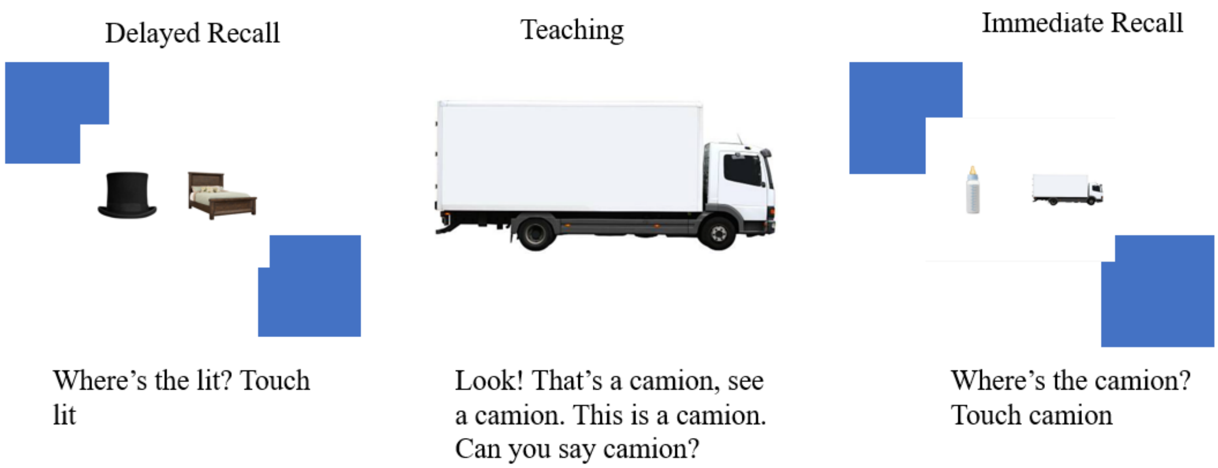
To maximize word learning, children were trained on nine new words each session. Each word was presented using a real-life image of the noun being taught on a white background and was presented full screen. Experimenters taught the word by using an adaptation of Koenig & Woodward (2012) teaching script. Our script was as follows; “Look! That’s a chapeau [hat]. See? A chapeau [hat]. This is a chapeau [hat]. Can you say chapeau [hat]?” We chose to use this script as it had been previously used to teach children novel labels (Koenig & Woodward, 2012).

To assess children’s word learning, we chose to test both their immediate recall and delayed recall. Thus, children’s word recognition was assessed on each set of nine words both immediately after they were taught and a week later at the start of the next session. To design the word learning task, we took as model the Computerized Comprehension Task (CCT) by Friend and Keplinger (2008). The CCT is a forced-choice computerized measure of vocabulary comprehension and has been used previously with children aged 16 to 26 months (Friend et al., 2012; Legacy et al., 2016; Poulin-Dubois et al., 2013; 2018). The CCT presents two side-by-side images simultaneously on the left and right centers of the screen, for a 7s display window, where children are verbally prompted to touch the referent of a target word and test trials are interleaved with blue screens (Friend et al., 2012).

To create our immediate recall task, we first matched target nouns with a distractor. To choose a distractor image, the word that followed the target noun (according to the order of the words when they were taught) was paired with the target as the distractor. Once each target was paired to a distractor the order of word testing was randomized once again. This process was then repeated a second time using the presentation order of the immediate recall task to generate the pairings for the delayed retention task. Therefore, this resulted in a total of 12 immediate recall tasks and 12 delayed recall tasks. Each task contained nine test trials, each of which were presented for 7 seconds and were interleaved with blue screens. The two real-life images (distractor and target) were presented on a white background at the center of the left side of the screen and at the center of the right side of the screen simultaneously (see Figure 1). Finally, four targets were randomly selected to be presented on the right side of the screen while the five other targets were presented on the left side of the screen. Each trial was paired with a verbal prompt adapted from the CCT (Friend et al., 2012) (e.g., where's the chapeau [hat]? Touch chapeau [hat]."). Vertical images were maximized to be 2.05 inches in height and horizontal images were maximized to be 3.04 inches in width, in order to match the presentation size of both images as much as possible and to leave at least 0.5 inches of blank space to the left, right, top and bottom of each image. Real life images were obtained from google images and Getty images in order to create the tasks. To create the final task that participants completed during their last session, we randomly selected two to three words from each set in order to obtain a total of 27 words (25% of 108 words). Their presentation order was randomized. Target images were then randomly paired with distractor images. This task was once again modelled after the CCT (Friend et al., 2012).

**Figure 1**

*Session Procedure*




This task was scored using a binary point system based on the CTT scoring convention (Friend et al., 2012). Recordings of the sessions, which included recordings of the children pointing, were used to score word learning (see Figure 2). Both delayed recall and immediate recall tasks were scored. Participants obtained a score of 1 if their first touch/point was directed at the target image. Any ambiguous touch (e.g., touch to the center of the screen), no touch, or first touch/point to a distractor image was scored as 0. Trials where parents or siblings pointed to the images during a test trial, where an iPhone was used, where the child failed to look during the trial, technical difficulties (e.g., minimizing/maximizing the screen during a test trial, mic cutting out etc.), experimenter error (e.g., asking for a target that is not present on the screen etc.), and/or missing footage were excluded. In addition, words and sessions were excluded if experimenters tested the child on the wrong set of words or accidentally repeated a session (i.e., words for which the child was never exposed to or were tested on twice). As a result, the final test of three participants in the experimental group were missing, a range of 0 to 7 sessions were missing for the immediate recall task ($M$ = .77, $SD$ = 1.28, 95% CI = [.45, 1.09]), and a range of 0 to 5 sessions were missing for the delayed recall task (*M* = .57, *SD* = 1.02, 95% CI = [.32, .82]) for the entire sample.

**Figure 2**

*Still Frame of a Session Recording*

Two different coders scored the data. A coder blind to the hypothesis of the study then scored 25% of the total amount scored by each individual coder. Specifically, this blind coder scored 25% of what coder 1 scored (k = .79) and 25% of what coder 2 scored (k = .92).

**Procedure**

Because of the longitudinal nature of this study and the challenge of recruiting monolingual children in the Montreal area, the training was conducted online in fourteen sessions on the Zoom videoconference platform. Before the first session, parents were sent the links to the consent form, demographics questionnaire, MCDI:WS, and EEFQ along with a PowerPoint presentation containing instructions and information about the questionnaires. If parents did not complete the consent form before the first session, they did so during the first Zoom session used to confirm eligibility. At the start of the session, parents gave verbal consent and were asked to let the experimenter know if ever their child becomes exposed to another language throughout the study. Once this was completed, parents were administered the LEAT, and the date and time of the next session was confirmed with them. Participants were asked to complete the MCDI and EEFQ before the third session (i.e., two weeks). Four participants completed the EEFQ, and two participants completed the MCDI after the third session but before the fourth. If children did not meet the study's eligibility requirements (born full term and monolingual), the follow up session was cancelled, participants received compensation for their time, and were sent a debriefing form.

Session two was the start of the training. Parents were informed about a practice video shared with them via google drive, which they were asked to watch 5 times a week between sessions. The practice videos were recordings of the experimenter reteaching the nine words that the child was assigned that week. Each child was assigned a randomized order in which they would be taught all 12 sets of words. Parents were asked to use a computer or tablet (at least 10 inches), to use the same device across all sessions if possible, and to limit interference/distraction. Any sessions that were completed on an iPhone were excluded from the final analyses. Parents were asked at the start of each session whether there was any change to their child's language environment in the last week. In addition, they were asked to ensure that their device was in full screen mode and that their self-view was hidden. Children were typically seated on their own in front of their electronic device, often in a highchair. However, children had the option to sit on a parent's lap if fussy. The second session began with a familiarization task where children were asked to touch four different images (none of the words being taught) in order to familiarize them with this behaviour. Participants were then taught nine words and were later tested on their immediate word learning using the immediate recall task described above. Once both tasks were completed, the time and day of the next session were confirmed. Once the second session took place, participants had access to the practice video that corresponded to the set of words that they were being taught that week, along with a word document allowing them to keep track of how many times their child watched the practice video that week. This word document also contained instructions regarding how to fill out the document and how many times the practice video should be watched by the child.

Session three to thirteen followed the same procedure. Parents were asked at the start of each session whether there was any change to their child's language environment in the last week, to confirm that they were using the same device, that they were in full screen, and that their self-view was hidden. If necessary, parents were reminded to keep distractions and interference as minimal as possible. Each session began with a delayed recall task where children were tested on their learning of the nine words they had learnt the previous week. Once completed, children were taught nine new words and were tested on their immediate recall of those same nine words. Finally, the session ended with a confirmation of the next appointment. If children ever became too fussy to complete the session, parents had the right to end the appointment early. Once participants completed the seventh session (halfway through the study) they received the first half of their compensation, which was a $50 gift card to a local bookstore.

Session fourteen was the final testing session. This session began as the previous sessions, with children tested on their delayed recall of the words they had learnt the previous week. However, rather than learning another set of words, children completed a final test where they were tested on 25% of all words taught using the same forced-choice task described above.

The words included in this final test of word learning were randomly chosen and thus a total of 27 of 108 words were assessed. Once children completed this last task, details of the LEAT that the parents completed the first session was confirmed with them in order to ensure that the children remained monolingual throughout the length of the study. Finally, parents were debriefed. Once the zoom call ended, parents received the MCDI:WS and EEFQ to complete for a second time, now post-training. Importantly, parents did not have access to their previous EEFQ responses when completing the questionnaire post-intervention. Parents once again had two weeks to complete these questionnaires. One participant completed the EEFQ 6 days late, one participant completed the EEFQ five days late and three participants completed the EEFQ one day late. Regarding the MCDI, one participant completed the questionnaire 6 days after the initial two-week deadline, one participant completed the questionnaire one day after the deadline, and one participant completed the questionnaire 13 days after the deadline. Once all questionnaires were received, parents received the debriefing letter via email and were mailed out the second half of their compensation, which was a $50 gift card to a local bookstore and a Certificate of Merit for the child. See Figure 3 for a visual representation of the study timeline.

**Figure 3**

*Training Timeline*


**Results**

**Data Cleaning**

Data analyses were completed using SPSS 28 (IBM Corp., 2021). Prior to conducting the main analyses, the assumptions for all main analyses were run and checked. One participant from the control group was excluded from the analyses as their MCDI data revealed that they already knew all of the target words. Thus, a total of 65 participants were included in the final analysis. In addition, one participant was excluded from the analyses on the EEFQ data due to indications of additional EF training throughout the length of the study. First, participants' z-scores were examined for univariate outliers. Although a total of 6 scores +/- 3 standard deviations from the mean (Raykov & Marcoulides, 2008) were identified for some of the main variables (flexibility at time 1, regulation at time 2, regulation difference score, inhibitory control difference score, cognitive executive function difference score, flexibility difference score) participants were included as the presence of these scores were not judged to be a sufficient cause for deletion. In other words, we retained these scores because the information was important and being flagged as a univariate outlier did not render the score meaningless or invalid. No multivariate outliers were identified using Mahalanobis distance. Finally, all variables were assessed for normality both as a sample and within each group. All skewness values were within recommended values i.e., below +/- 3 and all kurtosis values were below +/- 10 (Kline, 2011) except for the following variable: number of data points included in the average practice video watching in the experimental group (skewness = -3.57., kurtosis = 12.35).

**Group differences on control variables**

A series of one-way analyses of variance revealed that participants in both the experimental and control condition were equivalent in all key variables at the onset of the study: age ($F(1,63) = .3$, $p = .586$), vocabulary size ($F(1,63) = .045$, $p = .832$), IC ($F(1,62) = .661$, $p = .419$), FX ($F(1,62) = .106$, $p = .746$), WM ($F(1,62) = .073$, $p = .789$), RG ($F(1,62) = .890$, $p = .349$), and CEF ($F(1,62) = .264$, $p = .609$; see Table 1 and Table 2 for all mean values). Although 2 participants had less than 70% of questions answered at time one included in the flexibility subscale (62.5 and 37.5%) and one participant answered less than 70% of the questions included in the CEF subscale at time 1 (69.6%), we opted to retain their scores in order to prioritize sample size, as EF scores were equivalent across groups. In addition, both groups were equivalent in SES ($F(1,61) = .940$, $p = .336$) and in percent of exposure to their mother tongue ($F(1,63) = .161$, $p = .690$). At the end of the study, groups were equivalent in age ($F(1,63) = .13$, $p = .719$), the length of time to complete the study ($F(1,63) = .032$, $p = .858$), and in the average number of times they watched the practice video between sessions ($F(1,56) = .986$, $p = .325$). As the number of data points used to calculate the average number of times participants watched the practice video was not normally distributed in the experimental group, a Kruskal-Wallis Test was used to compare the mean between groups. Results indicated that children in the experimental group had significantly more data points (H(1) = 9.569, $p$ = .002). Finally, groups were equivalent in the number of words to be excluded based on their MCDI data ($F$(1,63) = .001, $p$ = .981). More specifically, words excluded from the word learning trials for children in the experimental group were those that they did not know in their mother tongue, as a translation equivalent could not be learned ($M$ = 18.06, $SD$ = 21.29, 95% CI = [10.63,25.49]). In the case of the control group, words were excluded if their initial MCDI data indicated that they already knew the words to be taught ($M$= 18.19, $SD$ = 23.69, 95% CI = [9.51, 26.88]).

**Group differences in Word Learning**

A one-way analysis of variance was used to investigate the differences in the percentage of words learned between groups. When comparing the performance of both groups on the final test assessing 25% of all words taught, participants in the control group ($M$ = .61, $SD$ = .260, 95% CI = [.516, .707]) scored higher than those in the experimental group ($M$ = .42, $SD$ = .248, 95% CI = [.331, .513]), and this difference was statistically significant ($F$(1,60) = 8.606, $p$ = .005)

A Kruskal-Wallis Test was used to compare immediate recall performance between groups as this variable violated homogeneity of variance. When comparing the performance of both groups on their average immediate recall score across all 14 sessions, participants in the control group ($M$ = .52, $SD$ = .264, 95% CI = [.427, .621]) scored higher than those in the experimental group ($M$ = .39, $SD$ = .185, 95% CI = [.322, .451]), and this difference was statistically significant (H(1) = 4.416, $p$ = .036).

When comparing the performance of both groups on their average delayed recall score across all 14 sessions, participants in the control group (*M*= .61, *SD* = .276, 95% CI = [.509, .712]) also scored higher than those in the experimental group (*M* = 0.48, *SD* = 0.233, 95% CI = [.401, .564]), and this difference was statistically significant ($F(1,63) = 4.099$, $p = .047$).

A one-sample t-test was run for chance analysis on the final test, immediate recall, and delayed recall scores of both groups. Participants in the control group scored significantly above chance (0.5) on the final test ($t(30) = 2.385$, $p = .024$) and their average delayed recall score across all 14 sessions was also statistically above chance ($t(30) = 2.234$, $p = .033$). However, the immediate recall score across all 14 sessions was not statistically above chance in the control group ($t(30) = .506$, $p = .617$). Participants in the experimental group had an average immediate recall score across all 14 sessions that was statistically below chance ($t(33) = -3.579$, $p = .001$) but their average delayed recall score across all 14 sessions was not statistically above/below chance ($t(33) = -.432$, $p = .668$). Participants in the experimental group also did not significantly score above/below chance on the final test ($t(30) = -1.75$, $p = .09$). See Figure 4 for a visual representation of word learning accuracy across groups.

**Table 1**

*Mean Values for all Variables*

| Variable | Experimental | | | Control | | |
|---|---|---|---|---|---|---|
| | *N* | *M* | *SD* | *N* | *M* | *SD* |
| Age T1 (months) | 34 | 21.93 | 2.02 | 31 | 22.24 | 2.54 |
| Age T2 (months) | 34 | 25.37 | 2.10 | 31 | 25.59 | 2.71 |
| Length of Study (days) | 34 | 104.56 | 11.53 | 31 | 104.06 | 10.6 |
| MCDI:WS T1 | 34 | 222.68 | 170.97 | 31 | 231.77 | 174.04 |
| MCD:WS T2 | 34 | 386.32 | 194.01 | 31 | 412 | 175.02 |
| Vocabulary Growth | 34 | 163.65 | 91.56 | 31 | 180.23 | 132.97 |
| % Exposure L1 | 34 | 99.03 | 1.68 | 31 | 98.84 | 2.15 |
| Final Test Accuracy (%) | 31 | 42.21 | 24.8 | 31 | 61.14 | 26.01 |
| Delayed Recall Accuracy (%) | 34 | 48.27 | 23.32 | 31 | 61.05 | 27.55 |
| Immediate Recall Accuracy (%) | 34 | 38.66 | 18.48 | 31 | 52.4 | 26.41 |
| Number of Words Included | 34 | 89.94 | 21.29 | 31 | 89.81 | 23.69 |
| Number of Weekly Practice (out of 5) | 33 | 4.26 | 1.19 | 25 | 3.92 | 1.42 |
| Number of Sessions with Practice Data (out of 12) | 34 | 11.12 | 2.68 | 31 | 8.03 | 4.95 |

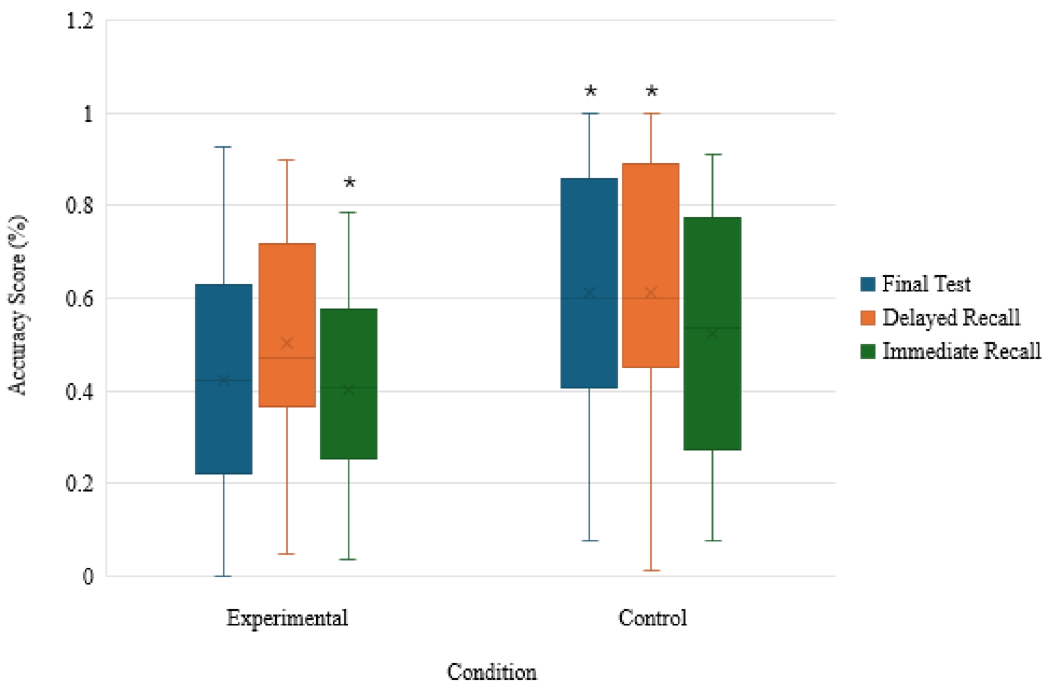
**Table 2**

*Mean Executive Function Values*

| Variable | Experimental | | | Control | | |
|---|---|---|---|---|---|---|
| | *N* | *M* | *SD* | *N* | *M* | *SD* |
| Inhibition Average T1 | 34 | 4.55 | .76 | 30 | 4.71 | .86 |
| Flexibility Average T1 | 34 | 4.7 | .75 | 30 | 4.75 | .63 |
| Working Memory Average T1 | 34 | 5.59 | .58 | 30 | 5.55 | .68 |
| Regulation Average T1 | 34 | 4.76 | 1 | 30 | 4.99 | .90 |
| Cognitive Executive Function Average T1 | 34 | 4.91 | .51 | 30 | 4.99 | .59 |
| Inhibition Average T2 | 34 | 4.92 | .78 | 30 | 4.98 | .65 |
| Flexibility Average T2 | 34 | 4.97 | .60 | 30 | 5.16 | .63 |
| Working Memory Average T2 | 34 | 5.76 | .63 | 30 | 5.67 | .72 |
| Regulation Average T2 | 34 | 4.90 | .85 | 30 | 4.75 | 1.15 |
| Cognitive Executive Function Average T2 | 34 | 5.19 | .49 | 30 | 5.25 | .51 |
| Inhibition Growth | 34 | .37 | .92 | 30 | .27 | .63 |
| Flexibility Growth | 34 | .27 | .62 | 30 | .41 | .50 |
| Working Memory Growth | 34 | .17 | .55 | 30 | .12 | .50 |
| Regulation Growth | 34 | .14 | 1.06 | 30 | -.23 | .99 |
| Cognitive Executive Function Growth | 34 | .27 | .49 | 30 | .27 | .35 |

**Figure 4**

*Boxplots of Word Learning Variables by Condition*




*Note*. An asterisk (*) indicates that the score was statistically below or above chance. $N_{\text{experimental}} = 31$; $N_{\text{control}} = 31$.

**Group differences in EEFQ growth**

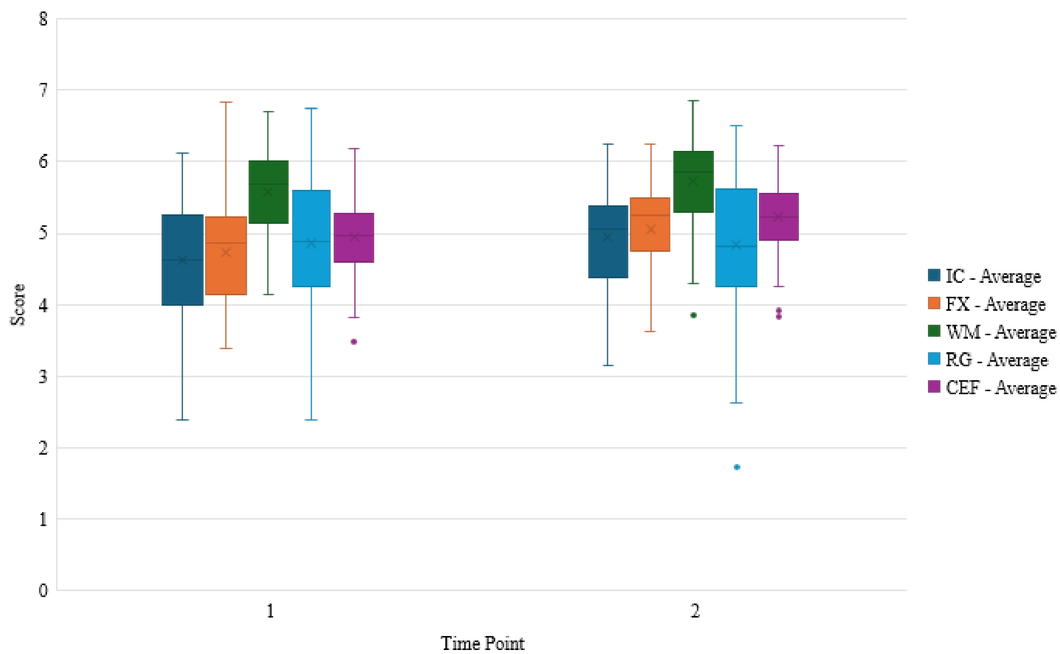
As participants were equivalent on age at time one, vocabulary growth and SES, a series of mixed-design repeated measures ANOVA's with wave (Session 1 vs Session 14) as a within-subject factor and group (control, experimental) as a between-subject factor was conducted in order to investigate the effect of condition on EF changes across all subscales of the EEFQ. The results indicated a statistically significant main effect of time on IC ($F(1,62) = 10.308$, $p = .002$), FX ($F(1,62) = 22.394$, $p < .001$), WM ($F(1,62) = 4.773$, $p = .033$), and CEF ($F(1,62) = 25.687$, $p$

< .001) indicating that both groups showed a significant increase across four domains of EF from time one to time two (see Figure 5). However, results indicated that there was not a statistically significant main effect of condition on IC ($F(1,62) = .508$, $p = .479$), FX ($F(1,62) = .709$, $p = .403$), WM ($F(1,62) = .199$, $p = .657$), CEF ($F(1,62) = .326$, $p = .570$). Moreover, results indicated that there was not a statistically significant interaction effect between time and condition on IC ($F(1,62) = .229$, $p = .634$), FX ($F(1,62) = .905$, $p = .345$), WM ($F(1,62) = .133$, $p = .717$) or CEF ($F(1,62) = .001$, $p = .970$) growth between the experimental and control group.

As the assumption homogeneity of variance was violated for RG scores at time two, a one sample t-test was used to investigate whether the sample grew in RG skills across the length of the study and a Kruskal-Wallis test was used to investigate the difference in RG growth between groups. Results indicated that there was not a statistically significant difference in RG growth from zero ($t(63) = -.265$, $p = .792$), suggesting no effect of time across the entire sample. Results also indicated that there was no statistically significant difference in RG growth between the experimental and control group ($H(1) = 2.061$, $p = .151$).

**Figure 5**

*Boxplots of Time 1 and Time 2 Scores for each Executive Function Ability*




**Word learning and EEFQ growth**

A series of bivariate correlation coefficients were computed to assess the relationship between word learning performance (final test, delayed recall, immediate recall) and difference scores on the EEFQ from time one to time two. A positive correlation between change in WM and delayed recall scores was identified $r(32) = .487$, $p = .003$ and between change in WM and immediate recall scores $r(32) = .516$, $p = .002$ in the experimental group only (see Table 3 and 4).

**Table 3**

*Bivariate Pearson Correlations between Word Learning and Executive Function change for the Experimental Group*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. Delayed Recall | 1 | .94** | .653** | -.179 | .247 | .487** | -.171 | .153 |
| 2. Immediate Recall | | 1 | .662** | -.217 | .125 | .516** | -.163 | .08 |
| 3. Final Test | | | 1 | .022 | -.029 | .13 | -.213 | .054 |
| 4. Inhibitory Control Difference Score | | | | 1 | .206 | .092 | .158 | .801** |
| 5. Flexibility Difference Score | | | | | 1 | .302 | .221 | .646** |
| 6. Working Memory Difference Score | | | | | | 1 | .214 | .535** |
| 7. Regulation Difference Score | | | | | | | 1 | .262 |
| 8. Cognitive Executive Function Difference Score | | | | | | | | 1 |

*Note*. $N = 34$ except for correlations except for those including Final Test score where $N = 31$.
** $p < .01$

**Table 4**

*Bivariate Pearson Correlations between Word Learning and Executive Function change for the Control Group*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. Delayed Recall | 1 | .922** | .686** | .063 | .227 | -.155 | .143 | .092 |
| 2. Immediate Recall | | 1 | .712** | .004 | .222 | -.136 | .098 | .058 |
| 3. Final Test | | | 1 | -.035 | .230 | -.038 | .189 | .091 |
| 4. Inhibitory Control Difference Score | | | | 1 | .283 | -.022 | .031 | .776** |
| 5. Flexibility Difference Score | | | | | 1 | -.101 | .315 | .648** |
| 6. Working Memory Difference Score | | | | | | 1 | -.318 | .378* |
| 7. Regulation Difference Score | | | | | | | 1 | .062 |
| 8. Cognitive Executive Function Difference Score | | | | | | | | 1 |

*Note*. $N = 30$

** $p < .01$; * $p < .05$

## Discussion

The main goal of the present study was to test the bilingual cognitive advantage in very young children through a training design. We investigated whether teaching monolingual toddlers' words in a second language would lead to greater executive functions benefits, particularly inhibitory control, compared to monolinguals who were taught words in their native language. In very young children, many studies have failed to find a bilingual cognitive advantage in working memory (Brito et al., 2014; 2021), and regulation (Beaudin & Poulin-Dubois, 2022). In addition, many have failed to replicate a bilingual advantage in flexibility before 24 months of age (D'Souza et al., 2020; Spit et al., 2023). In contrast, research with toddlers has more consistently identified a bilingual advantage in inhibition (Beaudin & Poulin-Dubois, 2022; Crivello et al., 2016; Poulin-Dubois et al., 2011). Recently the bilingual cognitive advantage has been challenged due to a very small effect often driven by confounds like SES (Lowe et al., 2021; Paap et al., 2016). Thus, it remains unclear whether the bilingual cognitive advantage (BCA) truly exists. As a result, the present study offers a unique contribution to the field as it is one of the first longitudinal language training studies testing the BCA with very young children. Paap and colleagues (2016) noted that although bilingual advantages in EF are unlikely to exist, it is possible that we simply lack the necessary conditions to find this benefit. In addition, it is hypothesized that if such an advantage does exist, it is likely to be specific to certain components of EF and driven by specific aspects of bilingualism, which has not yet been determined (Paap et al., 2015). Therefore, this study is one of the first to offer insight into which domains of EF are specifically improved by second language word acquisition at 25 months of age. We hypothesized that toddlers who learned new words in a second language across a 14-

week period would show a greater increase in inhibitory control skills in comparison to those who learned new words in their mother tongue across the same time period.

Our findings indicate that executive functions improved equivalently over the 14-week period across both groups. Thus, our hypothesis that inhibitory control skills would increase most in the experimental group was not supported. However, we observed an association between WM growth and word learning in the experimental group only.  To conclude, although our results do not support our hypothesis of a bilingual cognitive advantage at 25 months of age, they suggest a link between second language acquisition and WM.

Participants in the control group showed a significantly greater word learning performance on immediate recall, delayed recall, and final test tasks, confirming that it is more difficult for monolingual children to learn words in a new language in comparison to learning new words in their native tongue. This result may be explained by the mutual exclusivity bias (Markman & Wachtel, 1988), where it has been shown that toddlers 24 months of age exhibit a resistance to accept a new label for a concept, they already have a label for (Byers-Heinlein et al., 2014). Consequently, it is likely that participants in the experimental condition were not easily able to learn a label in a foreign language for an object/concept that already had a label in their dominant language. Anecdotally, parents had reported that their children corrected the second language label given to a familiar noun by labelling the object in their mother tongue when watching practice videos.

Although some studies have found bilingual benefits in attentional and/or response inhibition (Beaudin & Poulin-Dubois, 2022; Carlson & Meltzoff, 2008; Crivello et al., 2016; Lowe et al., 2021; Poulin-Dubois et al., 2011; Sorge et al., 2017), we did not find a bilingual advantage for the inhibition component of the EEFQ after 12 weeks of second language acquisition training. Thus, our hypothesis was not confirmed. One explanation as to why we failed to observe the expected effect could be that children in the experimental condition did not learn a sufficient number of TEs to facilitate code-switching. As previously explained, the BCA is theorized to be driven by code-switching, where the greater the increase in TEs in one's vocabulary, the greater the cognitive benefits in inhibition (Crivello et al., 2016). Unfortunately, based on the limited number of TEs that could be learned per child based on the child's knowledge of the words and the average delayed recall performance of children in the experimental group, the participants only gained on average a total of 43 TEs (on average 89.94 words included in the experimental group times 0.4827 delayed recall accuracy score). As the vocabulary of native 24-month-old bilinguals is composed on average of 34-47% (Beaudin & Poulin-Dubois, 2022; Crivello et al., 2016; Poulin-Dubois et al., 2011) translation equivalents , it is unlikely that this was a sufficient number of TEs to provide the sufficient amount of code-switching for a BCA in inhibition to arise. Because all participants came from monolingual language environments, it is unlikely that they had the opportunity to use the words in their second language in their day-to-day life when interacting with their family members. Thus, once again, it is highly likely that participants lacked sufficient practice with code-switching. To conclude, it is possible that a BCA in inhibition were to arise if toddlers gained more TEs throughout the length of the study and thus future research should aim to investigate this.

The experimental condition yielded a similar growth in flexibility abilities in comparison to the control group, suggesting that second language acquisition and the acquisition of new words in one's mother tongue equally benefit flexibility. Thus, our results align with previous work, confirming that bilingualism does not benefit attentional flexibility (Beaudin & Poulin-Dubois, 2022; D'Souza et al., 2020; Poulin-Dubois et al., 2011; Spit et al., 2023). Beaudin &

Poulin-Dubois (2022) suggested that the task assessing FX on the EEFQ may require skills of other EF domains (i.e., working memory and response inhibition skills), thus making it difficult to assess attentional flexibility specifically. Thus, lending to the hypothesis that any BCA is likely specific to certain skills of EF (Paap et al., 2015). However, before three years of age, it is difficult to parse shifting (FX) and updating (WM) abilities (Hendry et al., 2016). Although the FX subscale of the EEFQ assesses shifting and the WM subscale assesses updating, it is possible that the tasks measuring each domain map onto other EF skills. Thus, it is possible that our results do not necessarily mean a complete lack of a BCA in attentional flexibility and that an advantage may arise with other tasks that measure FX via a different avenue like anticipatory looking (Beaudin & Poulin-Dubois, 2022; Comishen et al., 2019; Kovács & Mehler, 2009). However, as many studies have failed to replicate the BCA using anticipatory looking, it is more likely that our results further solidify the claim that FX is not benefited by bilingualism.

In line with previous work, we found that second language acquisition does not greatly benefit WM. Although previous work has identified a bilingual advantage in memory generalization, most do not find a benefit in WM (Brito et al., 2014; 2021) until children are of preschool/kindergarten age (Blom et al., 2014; Gillet al., 2020; Marini et al., 2019; Morales et al., 2013; Purić et al., 2017). Interestingly, a positive association between word learning and WM growth was only found in the experimental condition, suggesting that learning words in a second language practices one's updating skills. We hypothesize that this may also be linked to the finding that second language acquisition is more difficult than learning new words in one's mother tongue. Specifically, we believe that the act of updating the link between a label and a concept in the testing session is advantageous to WM. With these results, we thus hypothesize that it is possible for a BCA in WM to exist, however due to various circumstances may only be significant in older children. As shifting and updating skills are difficult to separate before the age of three (Hendry et al., 2016), it is possible that the intertwined nature of these EF skills is what is driving the difficulty in identifying a BCA specifically in WM at such a young age. However, there is also a second possibility; although WM growth and word learning are associated in the experimental group only, participants did not acquire a sufficient number of TEs for their WM growth to be significantly greater than those increasing the vocabulary size of their mother tongue. In sum, the highly related nature of shifting and updating before the age of three and a possible lack of TEs may make it difficult to identify a BCA in WM. Thus, future research should investigate the effect of longer second language training on WM at an older age.

In line with previous work by Beaudin & Poulin-Dubois (2022), participants in both conditions showed a lack of significant regulation growth. Emotion regulation (ER) is a core component of temperament and is believed to tap into WM (Liew, 2012). Furthermore, ER is correlated with effortful control in children 18 to 24 months of age (Gago Galvagno et al., 2019). It is also suggested that attentional shifting, attentional focusing and inhibitory control are all elements of effortful control (Rothbart et al., 2001; Rothbart & Rueda, 2005). As a result, it is unsurprising that a large growth in ER did not arise in the experimental condition after failing to find a benefit in inhibition, WM, and FX. However, Beaudin & Poulin-Dubois (2022) previously suggested that 24 months of age may be too early to identify individual differences in ER as these skills are likely underdeveloped at this age, as children below the age of three fail to easily control their behavioural responses (Carlson et al., 2002; Diamond, 2002; Zelazo et al., 2003). As a result, although we conclude that a BCA in ER does not exist at 25 months, it is possible for a bilingual benefit in ER to arise in older samples and may co-occur with bilingual benefits in inhibition, FX, and WM.

One main strength of this study is the word learning training program, as it was specifically designed for children of this age based on normative data (i.e., Wordbank; Frank et al., 2017) and our word learning task was based off of a validated measure of vocabulary comprehension (e.g., the CCT; Friend & Keplinger, 2008). Specifically, the word learning task was modeled after a widely used forced-choice touch task that has been shown to be a reliable measure of word knowledge and vocabulary (Friend & Keplinger, 2008; Friend et al., 2012). In addition, the scripts used were all adapted from studies that successfully taught children of the same age new words (Koenig & Woodward, 2012). Finally, the number of words to be chosen was based on normative data about the vocabulary size of 24-month-old children and the average number of TEs in native bilinguals at this age, in order to allow the participants in the experimental group's second language vocabulary to be as similar to that of native bilinguals. Finally, the training experience of experimental and control group children only differed by the kind of words that they were learning, thus allowing us to conclude that our results directly speak to the difference in second language versus first language acquisition on EF.

As is the case for all studies, there are also limitations to this study. First, our sample was not diverse as many children were considered European and of a higher SES compared to the average Canadian. Specifically, most participants fell between the $100, 000 to $150, 000 range for household income whereas the average Canadian household income in 2021 was approximately $68, 000 (Statistics Canada, 2023). A second limitation is constraint in testing sessions related to working with children and when completing a longitudinal study. In order to maximize the attentiveness of participants, we opted for short sessions and also had to avoid placing a high demand of time on the participant's parents by conducting weekly sessions. Unfortunately, the results suggest that children learnt on average a little less than half of the words taught to them, suggesting that participants may require more sessions and more words to be taught for an effect to arise. Specifically, children likely lacked experience practicing the second language words that they were being taught outside of their sessions (i.e., code-switching). To date, most longitudinal work completed to test the bilingual advantage typically compare the EF abilities of older children after a year or more of exposure to a second language (Gillet et al., 2020; Neveu et al., 2021; Nicolay & Poncelet, 2013; Purić et al., 2017; Santillán & Khurana, 2018), suggesting that three months of training is simply not enough time for a bilingual benefit in inhibition to arise. A similar design should be adopted in toddlers that would include a comparison of children enrolled in a daycare in a second language to children exposed to same language since birth over a long period of time.

A final limitation is the testing environment of the study. As this was a longitudinal project with many weekly sessions, it would have been extremely difficult to conduct this study in-person. As a result, it was challenging to ensure that participants were truly being shown the practice video assigned to them each week, and to fully control the testing environment. In addition, as parents were not asked to film the completion of the 3 games included in the EEFQ this raises another possible limitation. Firstly, parents always had access to a self-report Word document with instructions regarding how many times their child should be shown the practice video (five) and with a table assigned to each week of the training where they could instantly update their tracking sheet after showing their child the video in order to decrease the chances of false memory ($M_{\text{sample}}$ = 4.11 practice video watches per week). Second, our coding system was created in order to account for distracting environments beyond our control where trials with clear interference and distraction were excluded from analysis. Thirdly, EEFQ instruction videos created by the developers of the EEFQ (Hendry & Holmboe, 2021) were embedded into the questionnaire given to parents and a PowerPoint containing instructions on how to complete the MCDI and EEFQ were emailed to parents as well.

Future research should aim to conduct a similar study with children of the same age. More specifically, a training study with a larger number of words taught and twice weekly sessions should be completed. A study as such would clarity whether second language training has no influence on EF or whether a critical mass of TEs must be acquired for this effect to arise. A second session should be added to each week, where the experimenter simply plays with the child in their second language using the words that they were taught that week, in order to facilitate the practice of code-switching. Moreover, a longitudinal second language training study should be completed with older children above the age of three, as it is difficult to separate FX and WM abilities and to truly measure ER before this age.

As discussed above, there have been some immersion studies, however limited work has been done with infants and toddlers. As the BCA is thought to arise in children as young as 24 months of age, it would be of great interest to investigate the effect of immersion daycare (i.e., a greater degree of exposure and language practice) on EF in children around 24 months of age. However, as the EEFQ is a parent report measure it would be important to conduct a longitudinal experiment as such with an in-person measure of inhibition like the early childhood inhibitory touchscreen task (ECITT; Holmboe et al., 2021) which is a validated measure of inhibition in children as young as 18 months of age. This would offer a greater insight into whether our results are better understood as a lack of sufficient code-switching practice, or whether the BCA may not arise as early as previously believed. Furthermore, it would be important to compare the results of our experimental and control condition to a third control group. More specifically, a group of children who are developing without intervention, and to track their EF growth over a period of 14 weeks. This data would allow for a greater understanding regarding the benefits of training more generally. For instance, whether both participant conditions show an equivalent benefit in EF growth in comparison to children developing without specific language training interventions.

In conclusion, our findings do not support the hypothesis that second language acquisition is associated with greater inhibition abilities. However, it is important to note that this advantage may arise in older children or with longer training. This study uniquely adds to the literature on the BCA in infancy as it is the first training study examining the direct benefits of second language acquisition on EF in 25-month-old children. Finally, our results suggest that second language acquisition is associated with WM growth and may benefit updating skills.

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## Appendix A

**Table A**

*List of Words Taught in the Experimental Condition*

| English | French |
|---|---|
| Elephant | Éléphant |
| Nose | Nez |
| Bubbles | Bulles |
| Hat | Chapeau |
| Water | Eau |
| Bottle | Bouteille |
| Truck | Camion |
| Bed | Lit |
| Car | Auto |
| Tooth | Dent |
| Bird | Oiseau |
| Tree | Arbre |
| Cheek | Joue |
| Keys | Clés |
| Flower | Fleur |
| Door | Porte |
| Bathtub | Bain |
| Bear | Ours |
| Toe | Orteil |
| Plate | Assiette |
| Orange | Orange |
| Yogurt | Yogourt |
| Boots | Bottes |
| Horse | Cheval |
| Butterfly | Papillon |
| Cereals | Céréales |
| Daddy | Papa |
| House | Maison |
| Grapes | Raisin |
| Block | Bloc |
| Mouth | Bouche |
| Sheep | Mouton |
| Head | Tête |
| Grandma | Grand-maman |
| Milk | Lait |
| Eyes | Yeux |
| Outside | Dehors |
| Duck | Canard |
| Chair | Chaise |
| Pizza | Pizza |

| | |
|---|---|
| Train | Train |
| Teddy bear | Nounours |
| Park | Parc |
| Booboo | Bobo |
| Dog | Chien |
| Juice | Jus |
| Fork | Fourchette |
| Cow | Vache |
| Ice cream | Crème glacée |
| Diaper | Couche |
| Ball | Balle |
| Ear | Oreille |
| Doll | Poupée |
| Bug | Bibitte |
| Glasses | Lunettes |
| Spoon | Cuillère |
| Moon | Lune |
| Chicken | Poulet |
| Tummy | Ventre |
| Shoe | Soulier |
| Fish | Poisson |
| Bib | Bavette |
| Hand | Main |
| Book | Livre |
| Banana | Banane |
| Strawberry | Fraise |
| Pool | Piscine |
| Toast | Toast |
| Sun | Soleil |
| Pig | Cochon |
| Cheese | Fromage |
| Carrot | Carotte |
| Bread | Pain |
| Airplane | Avion |
| Brush | Brosse |
| Apple | Pomme |
| Coat | Manteau |
| Sock | Bas |
| Frog | Grenouille |
| Crayon | Crayon |
| Mommy | Maman |
| Candy | Bonbon |
| Mouse | Souris |
| Boat | Bateau |
| Table | Table |
| Lion | Lion |

| | |
|---|---|
| Grandpa | Grand-papa |
| Tongue | Langue |
| TV | Télévision |
| Cat | Chat |
| Soap | Savon |
| Turtle | Tortue |
| Toothbrush | Brosse à dents |
| Pants | Pantalons |
| Pajamas | Pyjamas |
| Hair | Cheveux |
| Arm | Bras |
| Leg | Jambe |
| Foot | Pied |
| Bunny | Lapin |
| Baby | Bébé |
| Balloon | Ballon |
| Cookie | Biscuit |
| Finger | Doigt |
| Cake | Gâteau |
| Rain | Pluie |
| Telephone | Téléphone |
| Bus | Autobus |

## Appendix B

**Table B**

*List of Words Taught in the Control Condition*

| English | French |
|---|---|
| Tricycle | Tricycle |
| Donut | Beigne |
| Plant | Plante |
| Deer | Chevreuil |
| Lollipop | Suçon |
| Cowboy | Cowboy |
| Pudding | Pouding |
| Muffin | Muffin |
| Street | Rue |
| Garage | Garage |
| Shovel | Pelle |
| Tights | Collants |
| Living room | Salon |
| Underpants | Petite culotte |
| Goose | Oie |
| Church | Église |
| Donkey | Âne |
| Bench | Banc |
| Lips | Lèvres |
| Police | Police |
| Person | Personne |
| Penguin | Pingouin |
| Closet | Garde-robe |
| Garden | Jardin |
| Party | Fête |
| Lamb | Agneau |
| Purse | Sacoche |
| People | Gens |
| Popsicle | Popsicle |
| Stone | Pierre |
| Shoulder | Épaule |
| Sled | Traîneau |
| Wolf | Loup |
| Sofa | Divan |
| Picnic | Pique-nique |
| Coke | Coke |
| Meat | Viande |
| Snowsuit | Habit de neige |
| Vitamins | Vitamines |
| Lawn mower | Tondeuse |

| | |
|---|---|
| Crib | Berceau |
| Penny | Sou |
| Drawer | Tiroir |
| Yard | Cour |
| Roof | Toit |
| Game | Jeu |
| Pumpkin | Citrouille |
| Washing machine | Laveuse |
| Fireman | Pompier |
| Tuna | Thon |
| Hamburger | Hamburger |
| Radio | Radio |
| Pickle | Cornichon |
| Lamp | Lampe |
| Scissors | Ciseaux |
| Oven | Four |
| Hammer | Marteau |
| Flag | Drapeau |
| Beach | Plage |
| Circus | Cirque |
| Beads | Perles |
| Refrigerator | Frigidaire |
| Ladder | Échelle |
| Play pen | Parc d'enfant |
| Teacher | Professeur |
| Country | Campagne |
| Rocking chair | Chaise berçante |
| Stove | Poêle |
| Child | Enfant |
| Necklace | Collier |
| Farm | Ferme |
| Salt | Sel |
| Chalk | Craie |
| Gum | Gomme |
| Playground | Terrain de jeu |
| Melon | Melon |
| Turkey | Dinde |
| Tape | Ruban |
| Nuts | Noix |
| Jeans | Jeans |
| Sneaker | Espadrille |
| Snowman | Bonhomme de neige |
| Rooster | Coq |
| Jelly | Confiture |
| Sprinkler | Arrosoir |
| Moose | Orignal |

| | |
|---|---|
| Porch | Véranda |
| Dryer | Sécheuse |
| Highchair | Chaise haute |
| Playdough | Pâte à modeler |
| Gloves | Gants |
| Clown | Clown |
| Glue | Colle |
| Jell-O | Jello |
| Nail | Clou |
| Scarf | Foulard |
| Hose | Boyau |
| Dish | Plat |
| Alligator | Alligator |
| Mailman | Facteur |
| Jar | Pot |
| Belt | Ceinture |
| Sidewalk | Trottoir |
| Woods | Forêt |
| Bucket | Seau |
| Camping | Camping |
| Camera | Caméra |
| Basement | Sous-sol |