# A Test of the Cognitive Benefits of Bilingualism with the Early Childhood Inhibitory Touchscreen Task

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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, Research and Clinical Training Option)

Concordia University

Montréal, Québec, Canada

July 2025

**CONCORDIA UNIVERSITY**
**School of Graduate Studies**

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Entitled: A Test of the Cognitive Benefits of Bilingualism in Toddlers with the Early Childhood Inhibitory Touchscreen Task

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

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

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

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The bilingual cognitive advantage hypothesis posits that bilingual children exhibit stronger executive functioning, particularly in inhibitory control, compared to monolingual children. While several studies have provided support for this hypothesis, most research has focused on school-age children. The present study examined whether this advantage is present early in life with the Early Childhood Inhibitory Touchscreen Task (ECITT). This task offers a reliable method for measuring response inhibition in infants, requiring them to shift their responses from a previously rewarded location to a new one. It minimizes language and memory demands while engaging infants through animations, making it an ideal measure for very young children. A sample of 60 infants (aged 16-24 months) was tested, with language exposure measured on a continuum using the Language Exposure Assessment Tool (LEAT). Vocabulary was assessed using the McArthur-Bates Communicative Development Inventory (MCDI), and a range of executive functions were assessed using the Early Executive Functions Questionnaire (EEFQ), including inhibitory control. The ECITT data replicate previous research, showing that overall performance on this task improves with age. However, inhibition control skills did not vary as a function of the amount of second language exposure nor age. Finally, vocabulary size was positively correlated with inhibition control. The current results suggest that a bilingual cognitive advantage may not develop until the end of the second year.

Acknowledgements

I want to thank Dr. Diane Poulin-Dubois for entrusting me with this project and for her guidance and supervision throughout my degree. Your counsel was instrumental in my success, and I am incredibly grateful for the opportunity you provided me. I would also like to thank my committee members, Dr. Norman Segalowitz and Dr. Krista Byers-Heinlein, for their time, counsel, and interest in my project. Thank you to Chloe Akiki and Sayde Jennings for their time, effort, and dedication in data collection and scoring. 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 Alexandra Piuze (SSHRC Canada Graduate Scholarship Master's Program). Finally, I would like to acknowledge Concordia University for awarding me with a merit scholarship.

Thank you to my previous supervisor, Dr. Andra Smith, for fostering my research interests and for believing in my abilities and passion for attending graduate school. Thank you to my laboratory mates, Elizabeth, Marilyne, and Victoria, for their constant support and guidance. Knowing I could always come to you with questions and ideas helped me more than you know. Thank you to the impeccable research coordinators of the CLD laboratory, Mihaela Zlatanovska and Isadora de Oliveira Silva. Thank you to my wonderful friends Eve, Fred, and Anthony, who always offered a listening ear, comfort, and many board game nights. Thank you to all my extended family for always showing excitement and encouragement during my project. I'm grateful for Paolo, Braya, Poppy and Bella, the best and cutest cats ever. To Jeremy, you are my rock and best friend. Thank you for always being there for me. Finally, to my parents and siblings, Andrew and Johnathan, I wouldn't be where I am today without you. Thank you for always being my biggest support, believing in me, and pushing me to do my best.

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# Introduction

## *Bilingualism*

Bilingualism is currently more prevalent than ever, with an estimated 50% of the world's population possessing some degree of bilingualism (Grosjean, 2010; Mendis et al., 2021). Bilingualism is commonly defined as the everyday use of and exposure to more than one language, which, for the current study, will also include those who are considered multilingual (Grosjean, 2010, 2014). In preverbal infants, one is considered monolingual or bilingual based on the amount of exposure rather than use or proficiency (De Houwer, 1990; Byers-Heinlein et al., 2019). Once children develop a vocabulary, the proportion of doublets (or translation equivalents) is also considered when identifying bilingual individuals as an index of proficiency. Although there is no current consensus on what the ideal percentage of exposure is deemed essential to be considered bilingual (Byers-Heinlein et al., 2019), the current project used 25% as the cutoff amount of combined exposure to their non-dominant language, which has been a common criterion in previous research (Werker & Gervain, 2013). Importantly, although much of past research has treated bilingualism as a dichotomous trait, placing someone in the bilingual or monolingual category (Hoff et al., 2012), the bilingual experience is dynamic and thus should not be considered a categorical variable but instead should be studied on a continuum (Kremin & Byers-Heinlein, 2021; Luk & Bialystok, 2013). According to this approach, although the minimum amount of exposure to a second language needs to be considered when defining bilingualism, the amount of exposure to a second language can vary. For example, an infant with 25% exposure to a second language and an infant with 50% exposure to a non-dominant language will both be considered bilingual. However, the variation in exposure may impact how much bilingualism influences cognition. This approach will also be considered in the present study.

Over the past few decades, many benefits have been discovered to be linked with bilingualism (Bialystok, 2017). This phenomenon is known as the bilingual cognitive advantage (BCA). The current paper will focus on an important component associated with the BCA: frequent exposure to more than one language has been associated with greater executive functioning skills (Bialystok, 2017). Executive functions (EF) are often defined as the use of higher cognitive processes to coordinate and integrate other cognitive processes to achieve a goal, particularly when faced with a choice or motivated to behave in a particular manner, especially in non-routine situations (Arizmendi et al., 2018; Miyake et al., 2000). EFs are multidimensional, and thus, many different models exist concerning the components and processes of EF. The current paper will follow the model proposed by Miyake and colleagues (2000), which suggests that executive functions can be narrowed down to three core functions: Updating, shifting, and inhibition (Arizmendi et al., 2018; Miyake et al., 2000). Updating, also called working memory, is the ability to hold and manipulate information during cognitive processing (Arizmendi et al., 2018; Beaudin & Poulin-Dubois, 2022). Shifting, or attentional flexibility, allows individuals to shift their focus from one stimulus to another (Beaudin & Poulin-Dubois, 2022; Calcott & Berkman, 2015). Finally, inhibition refers to the ability to override automatic or impulsive responses and instead respond through reasoning (Kang et al., 2022). This paper will also incorporate regulation when studying executive function (EF). Regulation is the ability to cope and control one's emotions and is considered a hot EF. Regulation is commonly thought to emerge in infants as young as 5 months of age (Hendry et al., 2016; Salehinejad et al., 2021)

***The Bilingual Cognitive Advantage***

As previously mentioned, one of the primary variables of interest when studying the BCA is how bilingualism affects EF skills. According to the BCA transfer theory, improvement occurs when skills developed in one domain transfer to a related but non-linguistic task, a phenomenon known as far transfer. In the case of bilingualism, the frequent need to suppress one language while selecting another enhances the brain's inhibitory control mechanisms (Arizmendi et al., 2018). This strengthened inhibition can improve performance on tasks that require executive control, such as the Stroop task, where managing interference is crucial. Given the parallel activation of multiple language systems in the bilingual brain, bilingual individuals may develop more efficient EF skills through continuous language suppression, ultimately refining their inhibitory control processes (Bialystok et al., 2010; Noble et al., 2012). Results from meta-analyses (Gunnerud et al., 2020; Lowe et al., 2021) suggest that any advantage bilinguals may have in EF skills is not domain-general, meaning that the advantage is not observed across all EF components. Instead, research suggests a domain-specific advantage that might arise from the need for bilinguals to constantly monitor both languages, manage lexical interference, and inhibit conflicting information (e.g., Colomé, 2001; Kaushanskaya & Marian, 2007; Kroll & Stewart, 1994; Thierry & Wu, 2007). Both child and adult populations have been studied for the benefits in EF, with differing results in both population groups.

A bilingual cognitive advantage in working memory has been suggested by previous research on the role of working memory, which plays a significant role in language comprehension. In children, the results are ambiguous. Morales and colleagues (2012) state that children between 5 and 7 years old exhibit greater working memory and visuospatial skills than their monolingual counterparts. However, this advantage could have been due to other EF skills since the task was not solely measuring working memory. Many studies have failed to replicate this finding, showing that working memory skills do not differ between bilingual and monolingual children (Bialystok, 2017; Poulin-Dubois et al., 2022).

Attentional flexibility may be an example of BCA due to its link with the ability to manage multiple language systems and switch between two or more. However, previous studies have shown ambiguous results when comparing flexibility skills between monolingual and bilingual children. Meta-analyses have also failed to show an advantage in attentional flexibility throughout childhood (Gunnerund et al., 2020; Lowe et al., 2021).

As with the previous EF skills, emotion regulation has shown inconclusive results regarding whether a BCA exists in this subcomponent. A study by Melo and colleagues (2024) suggests that bilingual preschoolers achieve greater gains in self-regulatory skills than their monolingual peers when there is high-quality teacher-child interaction. However, this finding was not replicated in 23-month-olds with a parental questionnaire, the Early Executive Functions Questionnaire (EEFQ) (Beaudin & Poulin-Dubois, 2022), possibly due to developmental immaturity.

When examining the advantage of inhibition control, findings differ between hot and cold inhibition. When looking at cold inhibition, most research has shown that attentional inhibition may be more potent in bilingual children. For example, Poulin-Dubois and colleagues (2011) found that 24-month-old bilingual infants performed better on an age-appropriate Stroop task than their monolingual counterparts. Bilingual preschool children outperform monolinguals on other conflict tasks, such as the Flanker task (Carlson & Meltzoff, 2008; Sorge et al., 2016). However, many of these tasks can be challenging for young children due to their complexity (Bialystok & Craik, 2022). Interestingly, infants as young as 7 months old have been shown to have enhanced attentional control compared to monolinguals with an eye-tracking cueing task in which they saw centrally presented stimuli followed by a target appearing on either the left or right side of the screen (Comishen et al, 2019; Kovacs & Mehler, 2009). The first half of the trials consisted of centrally presented cues that predicted targets' locations; in the second half, the cue-target location relation was switched. However, many studies have been unable to replicate these findings in partial or conceptual replications, including a multi-center exact replication failure of the original experiment (e.g., D’Souza et al., 2020; Kalashnikova et al., 2020; Dal Ben et al., 2022; Spit et al, 2023). calling into question the robustness of the claim that bilingual preverbal infants have enhanced attentional control. However, Poulin-Dubois and colleagues (2022) did not find such an advantage in inhibitory control in children at 17 months of age with a detour task. This developmental pattern might be due to the challenges of testing infants. Many tasks used to test inhibitory control often have language and working memory demands that are too high for younger children to handle. For example, a common task, the Go/No-Go task, is too complex for children younger than 3 years of age (Holmboe et al., 2021). There is also a need for more reliable tasks that researchers can use across the lifespan to increase the clarity, replicability, and generalizability of previous findings on a bilingual cognitive advantage in inhibition control.

Regarding hot inhibition, a meta-analysis by Lowe and colleagues (2021) reported greater response inhibition in children aged between 3 and 17 years. This result could be partially explained by the small effect of confounding variables, such as socioeconomic status (SES). Indeed, as Naeem and colleagues (2018) point out, SES is a vital mediator and must be considered when studying the BCA. While most studies researching the BCA have focused on school-aged children and adults, an interesting pattern has emerged when studying EF and the

BCA in very young children. Crivello and colleagues (2016) found no advantage in response inhibition but did find an advantage in attentional control in a longitudinal study of children aged 24 to 31 months. However, Beaudin & Poulin-Dubois (2022) found that increased exposure to a second language was associated with greater response inhibition when using the Early Executive Functions Questionnaire (EEFQ).

Traditional measures often lack developmental appropriateness for infants and toddlers, making it challenging to assess early executive function reliably. Holmboe and colleagues (2021) recently introduced the Early Childhood Inhibitory Touchscreen Task (ECITT) to address a longstanding gap in measuring cold inhibition in very young children. The ECITT was designed as an age-appropriate inhibition control task administered via touchscreen and has demonstrated applicability across an extensive age range from as young as 10 months to as old as 84 years (Fiske et al., 2022; Fiske et al., 2025; Hendry et al., 2021; Holmboe et al., 2021; Lui et al., 2021; Rico-Picó et al., 2025). In this new task, participants have to overcome a tendency to respond to a frequently rewarded location on a touchscreen and instead make an alternative response. This innovation provides researchers with a valuable tool for investigating cognitive processes during early developmental stages.

### *Present Study*

The recent introduction of the ECITT presents a unique opportunity to investigate the impact of bilingual exposure on attentional control during infancy. The current study leverages this measure to examine potential cognitive differences between monolingual and bilingual children aged 16 to 24 months. We hypothesized that greater exposure to a second language would be associated with enhanced attentional inhibition. Given past findings, increased bilingual exposure would unlikely impact cognitive flexibility or regulatory abilities.

Furthermore, we predicted that infants categorized as bilingual would exhibit better attentional control compared to their monolingual peers. The study aims to contribute to the growing body of literature on early bilingualism and executive function through this multidimensional approach.

## Methods

The target sample size, included variables, hypotheses, and planned analyses were preregistered on Open Science Framework (https://doi.org/10.17605/OSF.IO/6ANC9) before any data were collected.

### *Participants*

Participants were recruited across a large Canadian city through a laboratory database of past participants and advertising in local daycares and libraries. Parents received a recruitment email for a study on the impact of bilingualism on cognition, which involved one online interview and one in-person session.  To be eligible to participate in this study, participants had to be 16 to 24 months of age. They had to have been born full-term without visual, auditory, or developmental delays. An a priori G*Power analysis (Faul et al., 2007) was conducted to determine the sample size required for linear multiple regression with 0.8 power, assuming an effect size of 0.15 at a standard α error probability of 0.05. The analysis resulted in the required sample size of 55 participants.

A total of 64 children were tested, with four being entirely excluded due to being too fussy to participate in any of the tasks ($N = 4$). Regarding the ECITT analyses, other participants were partially excluded from the ECITT analyses. This exclusion was due to having fewer than 60% of prepotent trials correct ($N = 4$), resulting in complete exclusion from the ECITT analyses. If participants had less than 60% correct prepotent trials, it indicates that they did not develop a prepotent response, which would mean that their performance is unlikely to reflect response inhibition (Holmboe et al., 2021). Participants who improperly executed the ECITT task ($N = 3$) (i.e., failing all inhibition trials) were excluded from the reaction time analyses but included in the accuracy analyses. Regarding the EEFQ, one participant was excluded due to experimenter error ($N = 1$). No participant was excluded for other reasons.

Our final sample consisted of 60 participants (30 females, 28 males; 2 prefer not to say) with a mean age of 20.21 months, and a range of 16.30- 24.96 months (see Table 1 for descriptive statistics). Responses from the demographic questionnaire indicated that a majority had an annual net income of more than $150,000 (N = 25). Parents predominantly reported their child's ethnic background as European (61.67%), with 40% of participants reporting a mix of ethnic backgrounds. Four parents did not complete the demographics questionnaire, so their demographic data could not be included. Our sample was relatively balanced between monolingual ($N = 35$; 58.33%) and bilingual ($N = 25$; 41.67%) infants, with 25% exposure to a second (or multiple) language(s) used as the cutoff. 36.67% of the children had English as their first language, 40% had French as their first language, and the remaining children spoke either Spanish, Portuguese, Vietnamese, Italian, or Armenian. Furthermore, 46.67% of participants had English as one of their non-dominant languages, and 53.33% had French as one of their non-dominant languages. 60% of children had exposure to more than one non-dominant language. The mean amount of exposure to a second language was 24.27%.

**Table 1**

*Descriptive Statistics of the total sample*

| | N | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|---|
| | | Total Sample | | | |
| Age (months) | 60 | 16.30 | 24.96 | 20.21 | .34 |
| ND %* | 60 | 0 | 64 | 24.27 | 2.36 |
| SES** | 56 | $22,000 - $35,000 | >$150,000 | $100 000 - $150 000 | 1.24 |
| Vocab*** | 30 | 4.00 | 446.00 | 128.53 | 117.95 |

*ND % refers to the percentage of non-dominant language exposure
** SES refers to socioeconomic status based on annual income
***Vocab refers to vocabulary size in the dominant language

***Measures***

*Demographics Questionnaire*

This questionnaire assessed basic demographic-related questions, including the child's gender, health history, ethnic background of the parents and child, household income, occupation, and civil status. This questionnaire also inquired about the parents' and children's language status and the time spent with screens.

*Language Exposure Assessment Tool (LEAT)*

The Language Exposure Assessment Tool (LEAT; DeAnda et al., 2016), a validated measure of early language exposure, was used to assess language input. This Excel-based tool has been used with children aged 4 months to 5 years old (Kalashnikova et al., 2023; Beaudin & Poulin-Dubois, 2022; Poulin-Dubois et al., 2022). By interviewing parents on who interacts with the child at least once a week, how much time each person spends with the child, at what age they began to interact with the child, and which languages each individual speaks, the LEAT tool calculates each participant's time of exposure to one or more languages per day, week, and throughout their life (DeAnda et al., 2016). The LEAT was used in this study to determine overall exposure to the participants' dominant and non-dominant languages and to classify participants as monolingual, bilingual, or multilingual. The LEAT interview was conducted with one or both participants' parents via a video conference on the Zoom platform.

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

The MacArthur-Bates Communicative Development Inventories: Words and Sentences (MCDI: WS) is a parent-report checklist that measures expressive vocabulary and productive grammatical complexity for children between 16 and 30 months of age (Fenson et al., 1993). For this study, participants were assigned to the Canadian-English long form and the French-Canadian long form (Trudeau & Poulin-Dubois, 1999) based on their exposure to English or French, as determined by the Web CDI (Frank et al., 2017), following the administration of the LEAT interview. Those considered bilingual in English and French were assigned the MCDI: WS in both languages. Participants were assigned the English version, the French-Canadian version, or both, depending on their reported exposure to the languages. The results of this inventory were used to assess participants’ vocabulary size at the time of testing.

*Early Executive Functions Questionnaire (EEFQ)*

The Early Executive Functions Questionnaire (EEFQ) is a 31-item parent-report questionnaire used to assess executive functions in children aged 9 to 30 months (Hendry & Holmboe, 2021). This tool was used to assess inhibitory control (IC), working memory (WM), flexibility (FX), regulation (RG) and cognitive executive function (CEF), which is a factor comprising IC, WM, FX and RG. The first three items of the assessment include games that the parents completed during the in-person session. The first game, *The Waiting Game*, measures IC and requires the parent to put a snack the child enjoys in front of them and ask the child to wait for up to thirty seconds. The time elapsed before the child reaches for the snack is used as a measure of IC. The second game, *The Finding Game*, measures WM and asks parents to place a small toy under one of two non-transparent containers while their child watches. The child is then asked to find the toy. This action is repeated four times, alternating between the containers. The number of times the child correctly locates the toy is used as a measure of WM. The third game, *The Sorting Game,* measures FX and asks parents to place five large spoons, five small spoons, and two bowls of different sizes in front of the child. The child is then asked to put the small spoons in the small bowl and the large spoons in the large bowl. If the child succeeds in placing the spoons in the correct bowl, the parent then says they will play a silly game where they put the small spoons in the large bowl and the large spoons in the small bowl. The child's ability to switch between instructions is used as a measure of FX. All three games were filmed using a video recorder mounted on a tripod for scoring. Both written and video instructions were shown to the parent before each game was completed.

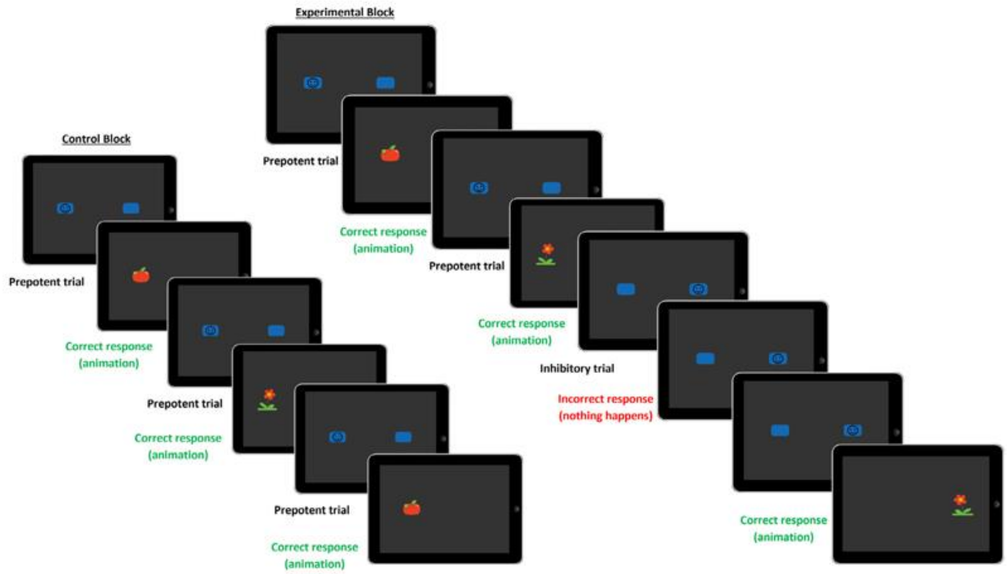
Once the games were completed, the parents answered 28 questions assessing the EF domains. These questions ask about the child's behaviour in the past two weeks, and parents reply using a 7-point Likert scale ranging from "Never" to "Always." The questionnaire section of the EEFQ was administered via SurveyMonkey in English or Quebec-French, depending on the parents' preferred language. Each subscale consisted of seven or eight items, and each game was considered a single item.

*Early Childhood Inhibitory Touchscreen Task (ECITT)*

The Early Childhood Inhibitory Touchscreen Task (ECITT) measures the ability to inhibit a prepotent response. This task has multiple versions suitable for individuals aged 10 months to 84 years (Holmboe et al., 2021). It is administered as an iPad game for children whose goal is to press one of two buttons, depending on which one has a ‘happy face’ on it. Instructions are straightforward and require little verbal ability and working memory skills, with the only instruction being to press on the smiley face. A short animation is played once the correct button is pressed to maintain motivation and attention and promote understanding of the task requirements. The stimuli were presented on an iPad tablet with an 11-inch screen size. The experimenter controlled the ECITT stimuli via their smartphone. The iPad was in the landscape orientation, with two 24 x 17 mm blue rectangular touchscreen buttons positioned 81 mm apart horizontally. A 14 mm simple “smiley face” icon was presented on either the left or right button, and the stimuli were presented against a dark grey background (see Figure 1 for a visual representation). During one demonstration and practice trial, a single blue button with the smiley face icon, in the same dimensions as previously described, was displayed in the center of the screen. The touch-sensitive area included the rectangular buttons and a small area around each one, totalling 44 x 44 mm on each side. This slightly larger response area was designed to accommodate the motor skills of young children. The participant’s behaviour was recorded using a video camera placed on a tripod behind the participant. This was done to allow for manual coding after the session. After each correct response, a short cartoon animation combined with sound effects was played. The iPad recorded the accuracy and reaction times of each response. These recorded responses were later manually checked and corrected using the recording. Corrections included overriding the response time if the iPad did not detect the first touch, accounting for experimenter error, and accounting for caregiver interference. Software access was granted by the team that designed the test at the University of Oxford, and data was saved on their server.

**Figure 1**

*ECITT Schematic Structure*




Note. Figure from Fiske et al. (2022)

***Procedure***

The testing was completed in two steps: one online call and one in-person testing session. When participants first signed up, they were sent an email containing the demographics and consent forms, along with a link to the Zoom video conference platform. The meetings and study materials were offered in either English or French. The parent(s) then met online with an experimenter to complete the LEAT and schedule the in-person session, which was recorded for scoring purposes. The LEAT was scored manually by the experimenter after the meeting. The proportion of second language exposure was recorded, and participants were considered monolingual (i.e., less than 10% exposure to a non-dominant language; Hoff et al., 2012) or bilingual (i.e. more than 25% exposure to a non-dominant language; Hoff et al., 2012). Participants who were trilingual or multilingual were included in the bilingual category. Between the Zoom and in-person sessions, the caregiver was sent one or two weblinks to complete the MCDI-WS in the language(s) to which their child was exposed. During the in-person session, the participant either started by completing the ECITT or the EEFQ games. The order of the tasks was counterbalanced between participants.

During the ECITT task, the participant sat on their caregiver's lap, in a highchair, or on a children's chair. If the participant preferred to sit on their caregiver's lap, the caregiver was asked to wear blackout glasses to avoid interference. The caregiver was asked not to point to or label the buttons if the child was sitting in a high chair or a children's chair. The ECITT is comprised of three sets of trials. During the demonstration trial, the experimenter demonstrated pressing a blue button with a smiley face in the centre of the screen. A short animation was then played. During the practice trial, another button with a smiley face was shown in the middle of the screen. The child was then encouraged to press the button. If the child was reluctant to press the button, the practice trial was repeated until the child was comfortable pressing the button without encouragement. After the practice trial, a block of 32 experimental trials was administered. Two buttons were presented on the screen, and the child was instructed to press the button with the smiley face. A short cartoon animation, lasting between 3.75 and 4 seconds, was played if the correct button was pressed. After the animation, the screen immediately started the subsequent trial. If the child pressed the incorrect button, the screen remained unchanged until the correct button was pressed by either the experimenter or the participant. The smiley face appeared on one side of the screen for 75% of the trials (24 trials) to build a prepotent response. The other 25% of the trials (8 trials) were shown on the other side and were considered inhibition trials. The goal of the inhibition trials was to require the participant to inhibit their prepotent response and press the other location to see the animation. The experimental block always started with at least three prepotent trials to establish a prepotent response. The order of trial presentation was automatically randomized at the start of the experimental block. However, the randomization was constrained to five prepotent and two inhibition trials in a row. Whether the prepotent trials appeared on the left or right side of the screen was counterbalanced between participants.

When administering the EEFQ, the experimenter showed each instructional video to the caregiver before playing each game with their child. Parents were encouraged to play each game in a setting where their child would be most comfortable, either on the floor or at a children-sized table and chair. The experimenter remained in the room to answer any questions the parent might have during the game. Once both the ECITT and the EEFQ games were completed, the parent was given the EEFQ questionnaire to complete. Upon completion of the study, participants were compensated with a Certificate of Merit and a 25$ gift card to a local bookstore.

## Results

### *Data Processing*

Data analyses were completed using SPSS 28 (IBM Corp., 2021). Before conducting the primary analyses, the assumptions for all main analyses were run and checked. Based on the exclusion criteria discussed above, 60 participants were included in the final analysis. An alpha level of $p < .05$ was used as the threshold for statistical significance. In analyses, all tests of significance were two-tailed.

### *Coding Scores*

When coding the ECITT responses, coders manually compared the video footage with the scores recorded by the software installed on the iPad to ensure that the scores were as accurate as possible. A total of 1682 trials were recorded across all participants. Corrections most frequently occurred because the iPad failed to detect the child's touch, requiring coders to manually time the response using a millisecond timer. This occurred in 25 trials, representing

1.49% of all trials. Additionally, a set of exclusion criteria was applied to each trial to exclude those that would not accurately reflect their performance. For example, if a participant's parent interfered with a trial by providing the answer, that trial would be excluded from analyses, as it would not accurately reflect the child's actual performance. This occurred for 0.06% of all trials. As previously mentioned, at least 60% of prepotent trials had to be correct, confirming the presence of a prepotent reaction.

Additionally, all trials with a reaction time of less than 300ms were treated as invalid and excluded from the analyses, which accounted for 4.4% of the trials. This criterion is applied due to the young age of the participants, as many exhibit very short reaction times, either through repetitive tapping during the animation or by having their finger close to the target location, which would render the trial invalid. Trials were also excluded if the parent or experimenter interfered with or pressed the button, which occurred if the participant disengaged from the task. This happened for a total of 38 trials (2.26%). While encouragement to touch the screen was acceptable, trials were invalid and, therefore, excluded if the experimenter or parents verbally indicated the correct response. Accidental touches were also excluded from analyses. A touch was considered accidental if the child brushed their hand on one of the buttons while clearly reaching for the other, as evidenced by the child looking at one button but brushing another, resulting in the software recording the accidental touch instead of the child's intention. This occurred in six trials (0.36%). According to Cohen's Kappa, all ECITT scores showed excellent intercoder reliability (ECITT prepotent accuracy $\kappa = .735$, ECITT inhibition accuracy $\kappa = .872$, ECITT prepotent reaction time $\kappa = .738$, ECITT inhibition reaction time $\kappa = .868$).

Additionally, participants who did not complete at least 20 trials were excluded from the analysis ($N = 4$). Participants were also required to have at least two valid inhibitory trials to be included in ECITT analyses. No participants were excluded due to this criterion. Finally, trials with reaction times above 5000 ms were excluded from the reaction time analyses, as they often indicated that the child was distracted by an external stimulus. However, they were still included for accuracy analyses. Accuracy analyses were conducted on the percentages of correct responses for each participant, separately for the prepotent and inhibition trials. The reaction time analyses used the median reaction time of the correct responses for prepotent and inhibition trials separately (Holmboe et al., 2021). The median score was used, as is typical in developmental research, since it is less susceptible to distortion by outliers (Holmboe et al., 2021). See Table 2 for ECITT descriptive statistics.

EEFQ scores were coded as the mean score for each executive function category (i.e. IC, FX, WM, REG, CEF) (See Table 3 for EEFQ Descriptive statistics). The experimenter scored the three games manually using a 7-point Likert scale. Interrater reliability was excellent when calculating Cohen's Kappa for all EEFQ scores (EEFQ IC, WM, FX, RG, CEF $\kappa = 1.000$).

The total number of words produced was extracted from the WEB: CDI website. Only scores from monolingual English, monolingual French, or bilingual French and English speakers were used, as scoring the MCDI questionnaire in languages other than English or French required speakers of these languages. CDIs were provided by a total of 30 participants: English monolingual participants (N = 6), French monolingual participants (N = 10), bilingual participants whose first language was English (N = 6), or bilingual participants whose first language was French (N = 8). Of the bilingual participants, only 4 completed both the French and English CDI. For these participants, the total vocabulary size was used as the measure. For the other 26 participants, only their L1 responses were collected and used in the analyses. L1 vocabulary was determined as being the language with the most exposure as assessed with the LEAT.

### ***Data Cleaning***

Participants' raw scores were examined for univariate outliers. Although one score, +/- 3 standard deviations from the mean (Raykov & Marcoulides, 2008), was identified for the variable Prepotent Reaction Time, the participant was included, as the score's presence was not considered a sufficient cause for deletion. No multivariate outliers were identified using Mahalanobis distance. Finally, all variables were assessed for normality in the sample. All skewness values were within the recommended range of +/- 3, and all kurtosis values were below +/- 10 (Kline, 2011).

**Table 2**

*Descriptive Statistics for the ECITT Task*

| | N | Min. | Max | Mean (SD)* | Skewness (SE)** | Kurtosis (SE) |
|---|---|---|---|---|---|---|
| ECITT Accuracy Prepotent | 55 | 0.61 | 1 | 0.88 (0.11) | −0.76 (0.32) | −0.19 (0.63) |
| ECITT Accuracy Inhibitory | 55 | 0 | 1 | 0.56 (0.30) | −0.22 (0.32) | −1.05 (0.63) |
| ECITT RT Prepotent | 52 | 1117 | 3620 | 1727.28 (483.02) | 1.93 (0.33) | 4.67 (0.65) |
| ECITT RT Inhibitory | 52 | 735 | 4261 | 2018.31 (799.98) | 1.28 (0.33) | 1.44 (0.65) |

* SD refers to standard deviation; ** SE refers to standard error; ***RT refers to reaction time in msc.

**Table 3**

*Descriptive Statistics for the EEFQ*

| | N | Min. | Max | Mean (SD)* | Skewness (SE)** | Kurtosis (SE) |
|---|---|---|---|---|---|---|
| Inhibition Control | 59 | 3.13 | 6.25 | 4.76 (0.79) | −0.18 (0.31) | −0.61 (0.61) |
| Working Memory | 59 | 4.0 | 6.57 | 5.61 (0.54) | −0.67 (0.31) | −0.31 (0.61) |
| Attentional Flexibility | 59 | 3.13 | 6.50 | 4.70 (0.67) | 0.10 (0.31) | −0.11 (0.61) |
| Regulation | 59 | 1.63 | 6.75 | 4.60 (1.15) | −0.43 (0.31) | 0.01 (0.61) |
| CEF*** | 59 | 3.83 | 6.0 | 4.99 (0.47) | −0.06 (0.31) | −0.24 (0.61) |

* SD refers to standard deviation; ** SE refers to standard error; *** CEF refers to Cognitive Executive Function. Maximum score=7

***Correlational Analyses***

Given that the key variables were either on an ordinal or a continuous scale, the first analyses used bivariate Spearman correlations between non-dominant language exposure and all executive functioning variables. These studies were conducted to test the first and second hypotheses. No statistically significant correlations were found between non-dominant language exposure and accuracy on ECITT Inhibitory trials, $r(53) = -.12$, $p = .38$, ECITT Prepotent trials, $r(53) = -.02$, $p = .89$, reaction time on ECITT Inhibitory trials, $r(50) = -.04$, $p = .77$, or ECITT Prepotent trials $r(50) = .11$, $p = .44$. Similarly, no statistically significant correlations emerged between non-dominant language exposure and all the EEFQ measures: IC, $r(57) = .14$, $p = .29$, FX, $r(57) = .06$, $p = .64$, REG, $r(57) = -.022$, $p = .87$, WM, $r(57) = -.01$, $p = .94$, or CEF, $r(57) = .123$, $p = .355$.

When conducting correlational analyses between age and those same executive function outcomes, we found a statistically significant positive correlation between age and ECITT INH accuracy, $r(53) = .35$ $p = .01$, as well as for age and ECITT PRPT accuracy, $r(53) = .28$, $p = .04$. This is consistent with our developmental expectations (Kang et al., 2022). Otherwise, no statistically significant correlations were found between age and our executive functioning variables.

Additionally, correlation analyses were conducted between vocabulary and the same executive function scores. The results showed a statistically significant positive correlation between vocabulary and accuracy on ECITT Inhibitory trials, $r(26) = .48$, $p = .01$. This suggests that as vocabulary increases, so does inhibitory control on the ECITT task. There was also a statistically significant positive correlation between EEFQ FX and vocabulary, $r(28) = .44$, $p = .02$.

Finally, correlational analyses were conducted to examine the relation between annual income and executive function outcomes. Annual revenue was included in the analyses due to its role as a moderator in the manifestation of the Bilingual Cognitive Advantage (Naeem et al., 2018). The results showed a statistically significant negative correlation between annual income and EEFQ FX, $r(54) = -.30$, $p = .02$. They also showed a statistically significant positive correlation with accuracy on ECITT Prepotent trials, $r(53) = -.32$, $p = .02$. All correlations are shown in table 4.

**Table 4**

*Zero-order Correlations between ECITT scores, EEFQ scores and non-dominant language exposure, Age, Vocabulary, and Annual Income*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. PRPT Accuracy | - | | | | | | | | |
| 2. INH Accuracy | .245 | - | | | | | | | |
| 3. PRPT RT | .065 | .033 | - | | | | | | |
| 4. INH RT | .293* | -.172 | .451** | - | | | | | |
| 5. INH Control | .166 | .092 | -.024 | -.162 | - | | | | |
| 6. Flexibility | .224 | .167 | .070 | -.034 | .274* | - | | | |
| 7. Regulation | .024 | -.125 | -.086 | .079 | .200 | .069 | - | | |
| 8. Working Memory | .018 | -.137 | -.003 | .063 | .221 | .122 | .185 | - | |
| 9. CEF | .216 | .092 | .018 | -.089 | .794** | .701** | .214 | .539** | - |
| 10. ND Exposure | -.019 | -.120 | .109 | -.043 | .139 | .063 | -.022 | -.011 | .123 |
| 11. Age | .283* | .347** | -.178 | -.228 | .038 | .042 | -.025 | .046 | .069 |
| 12. Vocab | .210 | .478* | -.162 | -.367 | .188 | .441* | .183 | .147 | .314 |
| 13. Annual Income | -.316* | -.145 | -.017 | .001 | -.030 | -.300** | -.053 | -.192 | -.214 |

* p<0.05 level (2-tailed), **p< 0.01 level (2-tailed)

***Hierarchical Regressions***

A series of hierarchical linear regressions was conducted to further analyze the effects of second language exposure, scored on a continuum, on executive functioning skills, with ECITT accuracy and reaction time scores as the dependent variables for both prepotent and inhibition trials. The predictors were age, non-dominant language exposure, and annual income. Model 1 included age. Model 2 consisted of non-dominant language exposure and age. Model 3 included age, non-dominant language exposure, and yearly income. Vocabulary was excluded due to the limited number of available scores.

For accuracy PRPT analyses, the first model was significant, $F(1,50) = 4.04$, $p= .05$, $R2=$ .08. Age was significantly associated with accuracy PRPT performance ($b=.27$, $t= 2.01$, $p= .05$). The second model ($F(2,49) = 1.99$, $p= .15$, $R2= .08$), which included non-dominant language percentage ($b= -.02$, $t= -.17$, $p= .87$), was not significant, and showed no significant improvement from the first model ($\Delta F(1,49) = .03$, p= 87, $\Delta R2= .001$). The third model ($F(3,48) = 2.41$, $p=$ .08, $R2= .13$), which included annual income ($b= -.24$, $t= -1.75$, $p= .09$), was nonsignificant and showed no significant improvement from the second model ($\Delta F(1,48) = 3.06$, $p= .09$, $\Delta R2= .06$). Overall, 7.5% of the variance in accuracy prepotent scores was accounted for by age.

For accuracy INH analyses, the first model was significant, $F(1,50) = 8.87$, $p= .004$, $R2=.15$. Age was significantly associated with accuracy INH performance ($b=.39$, $t= 2.98$, $p=$ .004). The second model ($F(2,49) = 5.29$, $p= .01$, $R2= .18$), which included non-dominant language percentage ($b= -.17$, $t= -1.27$, $p= .21$), was significant but showed no significant improvement from the first model ($\Delta F(1,49) = 1.60$, $p= .21$, $\Delta R2= .03$). The third model ($F(3,48)$ $= 3.64$, $p= .02$, $R2= .19$), which included annual income ($b= -.09$, $t= -.68$, $p= .50$) showed no significant improvement from the second model ($\Delta F(1,48) = .46$, $p= .50$, $\Delta R2= .01$). Overall, 15.1% of the variance was explained when age was included in the model.

No significant models were observed when conducting the regressions with Reaction Time PRPT and Reaction Time INH as outcome variables.

***Language and Age Group Analyses***

The third hypothesis, that executive function skills would be superior in bilingual children, was tested using a series of two-way mixed ANOVAs. The first two-way ANOVA was performed to evaluate the effects of Age (two groups split by the median: 20.31 months) on the Accuracy condition (prepotent accuracy vs. inhibitory accuracy) of the ECITT task. The means and standard deviations for Accuracy are presented in Table 2. The results indicated a significant main effect of Age, $F(1,53) = 4.23$, $p = 0.5$, partial η2= 0.42. There was also a significant main effect of Condition $F(1,53) = 67.69$, $p < .001$, partial η2= 0.56, indicating that older children tended to perform better than younger children, and participants performed better on the prepotent trials than on the inhibition trials. There was no significant interaction between Age and Condition, $F(1,53) = 1.35$, $p = .25$, partial η2= 0.03.

The second two-way mixed ANOVA was performed to evaluate the effects of Age (two groups split by the median: 20.31 months) on Reaction Time condition (Prepotent Reaction Time vs. Inhibitory Reaction Time). The results indicated no significant main effect of Age, $F(1,50) = 1.29$, $p = 0.26$, partial η2= 0.03. However, there was a significant main effect of Condition, $F(1,50) = 8.54$, $p = 0.01$, partial η2= 0.15, indicating that children in both groups tended to respond faster on the prepotent trials than on the inhibition trials. The Age and Condition variables had no significant interaction, $F(1,50) = 0.43$, $p = .51$, partial η2= 0.01.

The third two-way mixed ANOVA was performed to evaluate the effects of language status (either monolingual or bilingual based on a 25% exposure cutoff) on the Accuracy condition (Group 1: Prepotent Accuracy; Group 2: Inhibitory Accuracy). The results indicated no effect of Language Group, $F(1,53) = 0.723$, $p = 0.393$, partial η2= 0.01. However, a significant main effect of Condition was found, $F(1,50) = 71.01$, $p < 0.001$, partial η2= 0.57, indicating that children in both groups tended to perform better on the prepotent trials than on the inhibition trials. There was no significant interaction between Language Group and Condition, $F(1,50) = 2.67$, $p = 0.11$, partial η2= 0.05.

Finally, the fourth two-way mixed ANOVA was performed to evaluate the effects of language exposure (either monolingual if less than 25% exposure to non-dominant languages, or bilingual if 25% or more exposure to non-dominant languages) on Reaction Time condition (Group 1: Prepotent Reaction Time; Group 2: Inhibitory Reaction Time). The results indicated no main effect of Language Group, $F(1,50) = 0.33$, $p = 0.57$, partial $\eta 2 = 0.01$. However, there was a significant main effect of Condition, $F(1,50) = 8.43$, $p = 0.01$, partial $\eta 2 = 0.15$, indicating that children performed better on the prepotent trials than on the inhibition trials. There was no significant interaction effect between Language Group and Condition, $F(1,50) = 0.26$, $p = 0.62$, partial $\eta 2 = 0.01$.

### *Bayesian Statistics*

Given the null results of the analyses of variance, we also performed Bayesian statistics. Overall, the results show that both monolingual and bilingual participants performed equally well in terms of accuracy and reaction time for both inhibition and prepotent trials. To further investigate this null effect, four Bayesian Independent Samples Normal tests were run. The tests showed evidence for the null hypothesis on accuracy in prepotent trials ($BF_{01}$ = 3.591, *error%* =.03), accuracy in inhibition trials ( $BF_{01}$ = 2.311, *error%* = .08), reaction time in prepotent trials ($BF_{01}$ = 4.555, *error%* = 138.95), and reaction time in inhibition trials ($BF_{01}$ = 3.954, *error%* = 229.40). In other words, these data are 3.591, 2.311, 4.975, 4.555, and 3.954 times more likely to occur under a model where there are no significant group differences in accuracy on prepotent and inhibition trials, and reaction time on prepotent and inhibition trials, respectively.

## Discussion

The current study investigated whether the Bilingual Cognitive Advantage, previously documented in adults and older children, can also be observed in very young children. The primary aim of the present study was to investigate whether exposure to a second language benefits inhibitory control skills in toddlers aged 20 months. This question was addressed through an experimental design that utilized a newly developed behavioural measure of inhibitory control (the ECITT), a parent-report questionnaire (the EEFQ) to assess multiple aspects of executive functioning, and a parent-report to assess vocabulary (The MCDI: WS)

Grounded in previous research demonstrating superior inhibitory control among bilingual adults, school-aged children and toddlers (Arizmendi et al., 2018; Carlson & Meltzoff, 2008; Lowe et al., 2021; Poulin-Dubois et al, 2011), it was first hypothesized that toddlers with greater exposure to a second language would show better inhibitory control than those with less or no such exposure. Secondly, consistent with prior findings indicating no significant bilingual advantage in regulation and cognitive flexibility in young children (Beaudin & Poulin-Dubois, 2022; Arizmendi et al., 2018; Gunnerud et al., 2020; Lowe et al., 2021), it was hypothesized that bilingual exposure would not benefit concerning flexibility or regulation skills. A third hypothesis posited that toddlers classified as bilingual, defined as having a minimum of 25% exposure to a second language, would demonstrate better inhibitory control than their monolingual peers. To test these predictions, bilingualism was operationalized both continuously (to test Hypotheses 1 and 2) and categorically (to test Hypothesis 3), enabling a more nuanced assessment of whether cognitive advantages scale with language exposure or emerge simply through the presence of dual-language experience. The ECITT and EEFQ were used to assess inhibitory control, while flexibility and regulation were evaluated through the EEFQ alone.

Contrary to our predictions, the results revealed no significant relation between the degree of bilingual exposure and inhibitory control as measured by the ECITT, thus failing to support the first hypothesis. Similarly, no significant differences in inhibitory control were observed between categorically defined bilingual and monolingual toddlers, failing to reject the third null hypothesis. However, as predicted in the second hypothesis, the data confirmed no significant effects of bilingual exposure on toddlers' regulation or flexibility skills, thus failing to reject the second null hypothesis. There was also no link between inhibitory control, as measured by a parental questionnaire, EEFQ, and the amount of second language exposure.

Although the main hypotheses of the present study were not supported, the findings nonetheless offer important contributions to the literature on executive functions in infancy, particularly regarding the validity and replicability of the ECITT as a measure of inhibitory control in early development. Notably, the results closely mirror those reported by the team that originally developed the ECITT to capture the emergence of inhibitory skills in toddlers (Hendry et al, 2021; Holmboe et al, 2021). Specifically, our data replicated two key findings from these studies. Firstly, older toddlers consistently outperformed their younger peers in both prepotent and inhibition trials, reflecting age-related improvements even within a relatively narrow developmental window (Kang et al., 2022). Secondly, performance on prepotent trials consistently exceeded that on inhibition trials for both accuracy and reaction time, reflecting the cognitive challenge of suppressing a dominant motor response at this age. The similarities of results across studies confirm the ECITT's sensitivity to developmental change and its construct validity as an age-appropriate behavioural measure of inhibitory control. It should be noted that a condition × age interaction effect was not replicated, most likely due the fact that previous experiments tested children aged 18 to 30 months.

In addition to its methodological contributions, the current study adds to the growing body of work on the developmental timing of the bilingual cognitive advantage. Numerous studies have reported superior performance among bilingual children on EF tasks later in development, particularly after the preschool years (e.g., Bialystok et al., 2012; Crivello et al., 2016). More recent research suggests that these advantages do not reliably emerge until after the second year of life, once both the executive system and the demands of bilingual language management have matured. For instance, Poulin-Dubois et al. (2022) reported no evidence of a bilingual advantage in inhibition or other EF domains in 17- to 18-month-old toddlers despite using a battery of well-validated, age-appropriate tasks. These results are echoed in the present study, which also failed to find a significant relationship between bilingual exposure and inhibitory control among toddlers aged 20 months.

Using a task designed explicitly for toddlers, such as the ECITT, enhances the interpretation of these null findings. Rather than a consequence of methodological limitations, the current lack of observed bilingual advantages, as in other recent studies based on other tasks, likely reflects an absence of executive functioning benefits associated with bilingualism during the second year of life. The current study also adds to the growing body of research suggesting that vocabulary size is positively associated with enhanced executive functioning (EF) skills (Bohlmann et al., 2015; Fuhs & Day, 2011). Specifically, the findings demonstrate that a larger vocabulary is linked to greater accuracy in inhibition trials, as measured by the ECITT, and improved cognitive flexibility.

Although the present study contributes to the growing literature on bilingualism and executive functioning, several limitations must be acknowledged. First, the sample lacks representativeness, particularly in terms of socioeconomic status (SES). Most participants were from upper-income households (i.e., annual income > $150,000), highly educated, and identified as of European descent. Importantly, SES was not a significant predictor in regression analyses, diverging from prior findings identifying SES as a potential mediator of the bilingual cognitive advantage (Naeem et al., 2018). The only exception was the unexpected negative correlation between SES and flexibility on the EEFQ, as well as accuracy on prepotent trials. Future studies should prioritize recruiting participants across a broader range of socioeconomic backgrounds to ensure more generalizable and inclusive findings. Secondly, the study was limited by incomplete data from the MacArthur-Bates Communicative Development Inventory: Words and Sentences (MCDI: WS). Due to missing responses from several parents, more detailed analyses of vocabulary development were not performed. Specifically, analyses of translation equivalents and total conceptual vocabulary in bilingual children could not be performed on a limited sample of French-English bilinguals. These metrics could have offered additional insight into how language development interacts with executive functioning, as having more doublets makes code-switching more frequent. Future studies should conduct a more detailed analysis of vocabulary data, as this would enable the exploration of the relationship between bilingual language exposure and cognitive development at a finer-grained level.

The findings of this study open several promising directions for future research. One potential avenue involves examining whether a domain-specific BCA emerges later in development by administering the ECITT task, which has been validated for older toddlers, to children aged 24 to 30 months. Finally, future studies could diversify the bilingual population by using the MCDI-WS across a broader range of languages beyond English and French. Expanding the sample size would also enable the analysis of doublets, providing deeper insight into bilingual development.

In conclusion, these findings indicate no evidence for a bilingual advantage in inhibitory control, regulation, or flexibility at this early developmental stage. These findings support the view that a potential bilingual advantage may emerge only after children have acquired more extensive, structured experience managing two languages. This study makes a unique contribution to the literature on the BCA in infancy by employing a novel and age-appropriate touchscreen task to compare inhibition control between bilingual and monolingual 16–to 24-month-olds. It also serves as a useful replication of previous findings for the ECITT, further validating the task.

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