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The Effects of Bilingual Experience on the Development of Executive Function in Early Childhood

By

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Introduction

This study examined the effects of bilingualism on children's executive function. It sought to understand how being bilingual and how variation in bilingual experience affects the growth trajectories of executive function skills during early childhood. Bilinguals refer to people who can speak two languages fluently (Bialystok, 2001) and are becoming increasingly prevalent worldwide. It has been estimated that more than half of the world's population are bilinguals and about two-thirds of the world's child population grow up in bilingual environments (Grosjean, 2010).

The coactivation of bilinguals' two languages during discourse is believed to enhance their executive function. According to Kroll et al. (2012), both languages of bilinguals are active when they use one language alone. The coactivation of the two languages creates competition across the two languages and requires bilinguals to actively control their two languages by effectively inhibiting one language while using the other or switching between languages. The expertise bilinguals develop in actively managing their two languages may enhance executive function.

Executive function typically includes three interrelated but distinct domain-general cognitive processes that regulate thoughts and behavior: inhibitory control, cognitive flexibility, and working memory (Miyake et al., 2000). Children with higher executive function are predicted to have more positive developmental outcomes. Executive function has shown to be essential for many aspects of child development, including school readiness (Blair & Diamond, 2008), academic achievement (McClelland et al., 2007), socioemotional competencies (Broidy et al., 2003), and physical health (Riggs et al., 2010). Notably, executive function develops rapidly and shows significant variations during early childhood (Carlson, 2005), a developmental period during which children's language skills also advance rapidly (Harris, 2013). The concurrent development of language and executive function skills during early childhood implies that the growth of executive function is likely influenced by bilingual experience.

Given the prevalence of bilingual children in the world and the importance of executive function in children's developmental outcomes, it is important to investigate the effects of bilingual experience on the growth of executive function during early childhood as these effects would be profound and have important implications for child development and education. The following sections of the introduction outline the current debate on the bilingual advantage in executive function, explain its potential causes, and describe how this study clarified this controversy.

The Debate on the Bilingual Advantage in Executive Function

A controversy has recently arisen over whether bilinguals have an advantage in executive function relative to monolinguals. While some studies identified a bilingual advantage in executive function relative to monolinguals (e.g., Bialystok & Viswanathan, 2009), other studies found little or no advantage in executive function among bilinguals (e.g., Nichols et al., 2020). Specifically, bilingual advantages have been reported across the three cognitive processes of executive function, including inhibitory control (Bialystok, 2001; Bialystok et al., 2006; Bialystok & Martin-Rhee, 2008; Goodrich et al., 2021), cognitive flexibility (Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009; Prior & MacWhinney, 2010), and working memory (Blom et al., 2014; Kroll et al., 2002). In contrast, other studies did not find bilingual advantages in one or more of these components of executive function, namely, inhibitory control (Dick et al., 2019; Hilchey & Klein, 2011; Okada et al., 2019; Paap & Greenberg, 2013), cognitive flexibility (Dick et al., 2019; Paap & Greenberg, 2013; Ross & Melinger, 2017), and working memory (Bialystok et al., 2008; Hartanto et al., 2019). Additionally, several meta-analytical studies have examined this topic among children (e.g., Gunnerud et al., 2020; Lowe et al., 2021) and adults (e.g., Lehtonen et al., 2018). These meta-analyses generally found little or no evidence for the bilingual advantage in executive function, failing to provide systematic support for the bilingual advantage hypothesis.

Potential Causes of the Discrepancy in Findings

Several potential explanations exist for the discrepancy in results across studies on the bilingual advantage in executive function. These explanations stem from three main factors which could moderate the effects of bilingualism on executive function: the age of the study participants, tasks used to measure executive function skills, and variations in bilinguals' language experience.

First, the age of study participants is an important factor in moderating the cognitive effects of bilingualism. Empirical evidence of the bilingual advantage in executive function has frequently been found in children (Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009) and older adults (Bialystok et al., 2008; Bialystok et al., 2004) but not with young adults (Paap and Greenberg 2013). For instance, Bialystok et al. (2005) reviewed a series of studies that used the Simon task to examine the bilingual advantage in inhibitory control at different life stages. They reported that bilinguals generally performed better than monolinguals on this task in early childhood and late adulthood. In contrast, no difference in performance on this task was found among young adults who were college students. Because young adults tend to be at the peak of their cognitive performance, bilingual experience may not offer additional boosts and its effects on executive function could be reduced.

Second, tasks that measure executive function skills could also moderate bilingual effects. If the tasks used are not challenging enough for monolingual and bilingual participants, the bilingual advantage in executive function cannot be revealed as both groups would perform well and equally. For example, in a study by Bialystok & Martin-Rhee (2008), bilingual children's advantage in inhibitory control was revealed in more challenging task conditions; in less demanding conditions, however, the bilingual advantage was not found as both bilingual and monolingual children were able to complete the task successfully. Additionally, some tasks of executive function skills are nonverbal while other tasks require verbal responses from study participants. Tasks that entail verbal responses can be problematic because bilinguals tend to have a disadvantage in verbal fluency relative to monolinguals, which could counteract their advantage in executive function (Bialystok et al., 2008). Relatedly, certain tasks that supposedly measure the same executive function skill actually tap different skills that do not necessarily correlate with one another, leading to low task validity and reliability (Laine, 2018). This could create measurement errors and distort research findings in empirical studies and meta-analyses that amalgamate various tasks of executive function skills.

Third, bilinguals' diverse language experience could also influence their performance in executive function tasks. There are considerable variations in bilingual experience, including but not limited to languages, language proficiency, sociolinguistic context, and the age of second language acquisition. Studies have repeatedly shown that the bilingual advantage in executive function is more pronounced among balanced bilinguals who are proficient in both languages than in unbalanced bilinguals who lack proficiency in one of their languages (Tse & Altarriba, 2012). Another related moderator is the switching frequency between bilinguals' two languages. Studies have shown that a higher frequency of language switching is associated with more enhanced executive function (Barbu, 2018; Prior & Gollan, 2011). In addition to language proficiency and language switching frequency, the age of second language acquisition has also been shown to be an important factor in moderating the cognitive effects of bilingualism. Studies have shown that bilinguals who acquired their second language early in life outperformed both monolinguals and bilinguals who acquired their second language later in life on tasks of executive function (Carlson & Meltzoff, 2008; Luk et al., 2011), suggesting that earlier age of second language acquisition is associated with more enhanced executive function.

The Present Study

The present study sought to clarify the controversy over the bilingual advantage in executive function by investigating how being bilingual and, importantly, how variations in bilingual experience affect the growth trajectories of executive function skills during early childhood, a time when executive function skills are developing rapidly and show a great deal of variation (Carlson, 2005). This study sheds light on this topic in two important ways. First, this study compared bilinguals with monolinguals longitudinally to examine how being bilingual affects the growth trajectories of executive function skills during early childhood. One major methodological limitation of the existing literature on the cognitive effects of bilingualism is that most studies have relied on cross-sectional observational or quasi-experimental data, which is problematic for studying growth trends over time. Longitudinal data, on the other hand, would make it possible to control random variations and enable researchers to examine the effects of bilingual experience on the development of executive function. Second, this study investigated how variations in bilingual experience affect the development of executive function during early childhood by comparing different groups of bilinguals. To date, most research on the cognitive consequences of bilingualism has conceptualized bilinguals as a homogenous group by comparing them directly to monolinguals, failing to consider variations within bilinguals. As noted above, bilinguals are a heterogeneous group with considerable variations in their bilingual experience, such as languages, language proficiency, sociolinguistic context, and the age of second language acquisition. It is important to consider variations in bilingual experience as these variations could significantly moderate the cognitive effects of bilingualism.

This study used the longitudinal data collected by the Early Childhood Longitudinal Study, Kindergarten Class of 2010-11 (ECLS-K:2011). Using this data file, this study constructed and compared the growth trajectories of three executive function skills (i.e., working memory, cognitive flexibility, inhibitory control) among four language groups: English monolinguals, Spanish English bilinguals, emergent Spanish English bilinguals (i.e., Spanish monolinguals who became Spanish English bilinguals during the ECLS-K:2011), and Asian language English bilinguals (i.e., children who spoke both English and an Asian language). In particular, by comparing the three groups of bilinguals with English monolinguals, this study sought to understand how being bilingual in general affects the development of executive function during early childhood. By comparing Spanish English bilinguals with emergent Spanish English bilinguals, this study sought to examine whether and how the age of second language acquisition affects the growth of executive function during early childhood. By comparing Spanish English bilinguals with Asian language English bilinguals, this study sought to investigate whether and how the degree of overlap between the linguistic systems of bilinguals' two languages affects the growth of executive function during early childhood. Hitherto, no study has purposely investigated whether the effects of bilingualism on executive function are moderated by the degree of overlap between the linguistic systems of bilinguals' two languages. While Spanish and English rely on the same writing system (i.e., alphabetic) and share more structural similarities, most Asian languages and English rely on different writing systems and share fewer structural similarities. A larger difference in linguistic structures may demand more cognitive resources to effectively control the two languages, leading to more enhanced executive function. Alternatively, a greater overlap between the linguistic systems of bilinguals' two languages may require more executive function to suppress a competing language. Given the argument that bilinguals' advantage in executive function emerges from their unique experience in managing two jointly activated competing languages (Kroll et al., 2012), it is worthwhile to investigate whether and how the degree of overlap between the linguistic systems of bilinguals' two languages moderates the bilingual effects on executive function.

Two recent studies have also used the ECLS-K:2011 data file to investigate the relationship between bilingual experience and executive function skills. In one study by Hartanto et al. (2019), data from kindergarten and first grade were used to examine the bilingual advantage in executive function skills via multiple regression. They reported that being bilingual in general was positively associated with cognitive flexibility, inhibitory control, and attentional focusing but not working memory. Cognitive flexibility and working memory were assessed through behavioral tasks while inhibitory control and attentional focusing were rated through teacher questionnaires. In another study by Goodrich et al. (2021), data from kindergarten were used to examine the bilingual advantage in executive function skills via propensity score matching. They found that Spanish English bilinguals had greater teacher-rated inhibitory control and attentional focus than English monolinguals, though only the effect for inhibitory control was robust to unobserved confounds. No effects of bilingualism were detected for performance-based measures of working memory or cognitive flexibility. Unlike these two cross-sectional studies which only used data from kindergarten to first grade, the present study adopted a longitudinal approach to examine the relationship between bilingual experience and executive function skills from kindergarten to fifth grade.

Relatedly, one study by Santillán and Khurana (2017) used another longitudinal dataset to examine the effects of bilingualism on the growth trajectories of inhibitory control during the transition from preschool to kindergarten via latent growth curve modeling. Participants were divided into three language groups in this study: English monolinguals, Spanish English bilinguals, and emergent Spanish English bilinguals who transitioned from Spanish monolinguals to Spanish English bilinguals during the original study. This study revealed that Spanish English bilinguals had higher inhibitory control performance at the beginning of preschool and showed steeper inhibitory control growth over time compared to English monolinguals. Emergent Spanish English bilinguals had the lowest inhibitory control performance at baseline, but their rate of inhibitory control growth exceeded that of English monolinguals and did not differ from that of Spanish English bilinguals. These findings suggest that acquiring bilingualism and continued bilingual experience are associated with more rapid inhibitory control growth during the transition from preschool to kindergarten. The present study extended this study by incorporating one additional language group, by including two additional components of executive function, and by extending the developmental window of executive function growth.

To summarize, the present study aimed to address the following questions using the ECLS-K:2011 data file. First, how does being bilingual in general affect the development of executive function skills during early childhood? Second, whether and how does the age of second language acquisition moderate the effects of bilingualism on the growth of executive function skills? Finally, whether and how does the degree of overlap between the linguistic systems of bilinguals' two languages moderate the bilingual effects on executive function skills?

Method

Data Source

This study used the public-use data file of the Early Childhood Longitudinal Study, Kindergarten Class of 2010-11 (ECLS-K:2011). The ECLS-K:2011 is a longitudinal study conducted by the National Center for Education Statistics (NCES) within the Institute of Education Sciences (IES) of the U.S. Department of Education. This study adopted a clustered, multistage probability design and collected a nationally representative sample of data on elementary school students' characteristics as they progressed from kindergarten in the 2010-11 school year through the spring of 2016 when most of the students were in fifth grade. Up until the second-grade year, there were two data collections: one at the beginning (fall) and one near the end (spring) of the school year. Beginning in third grade, data collection occurred only once, during the spring of each academic year. Multiple methods were used to collect data at these nine time points, including direct assessments, interviews, and questionnaires.

In the kindergarten and first-grade rounds of data collection, an English language screener test was administered to all children as the first component of the assessment. The screener consisted of two tasks from the Preschool Language Assessment Scale. The "Simon Says" task required children to follow simple, direct instructions given by the assessor in English. The "Art Show" task was a picture vocabulary assessment that tested children's expressive vocabulary. For children whose home language was English, the screener primarily served as a practice for the rest of the assessment since the items were of low difficulty. For children whose home language was one other than English, the screener determined whether the child understood English well enough to receive the rest of the assessment in English. All children received the first set of items on the reading assessment in English, regardless of their home language or performance on the language screener. Once this first set of items was administered, the cognitive assessments in English ended for children whose home language was not English and who did not achieve at least a minimum score on the language screener. Spanish-speaking children who did not achieve at least the minimum score on the screener were then administered a short reading assessment in Spanish that measured Spanish early reading skills, as well as the mathematics and executive function assessments that had been translated into Spanish. Children whose home language was one other than

English or Spanish and who did not achieve at least the minimum score on the screener were not administered any of the remaining cognitive assessments beyond the first set of reading items. Beginning in second grade, nearly all children demonstrated sufficient English proficiency to be assessed in English, so the Spanish-language assessments were not used in the subsequent rounds of data collection (see Tourangeau et al., 2019 for more details on the ECLS-K:2011).

Participants

A clustered, multistage probability design was used to collect a sample of data reflective of the U.S. child population. A total of 18,174 children from 968 schools across the United States participated in the ECLS-K:2011 during the fall of kindergarten, aged 3.73 to 7.83 years (M_{age} = 5.62 years, SD = 0.37, 51% males). Of the children who participated in the ECLS-K:2011, 47% were White children, 25% were Hispanic children, 13% were African American children, 9% were Asian children, and 6% were children from other or mixed ethnicities. Regarding family income, 17% lived in households with a family income of less than $15,000 per year, and 34% lived in households with a family income of more than $75,000 per year. With respect to parental education, 36% of their parents had a high school diploma or lower, and 32% had a bachelor's degree or higher.

Measures

Language Group

The participants of the ECLS-K:2011 were classified into four language groups in this study: the English monolingual group, the Spanish English bilingual group, the emergent Spanish English bilingual group, and the Asian language English bilingual group. The English monolingual group included children whose home language was exclusively English and who passed the English language screener test in the fall of kindergarten. Children's home language was reported by their parents during parent interviews. The Spanish English bilingual group included children whose home language was Spanish and who passed the English language screener test in the fall of kindergarten. The emergent Spanish English bilingual group (i.e., Spanish monolinguals who became Spanish-English bilinguals during the ECLS-K:2011) included children whose home language was Spanish and who did not pass the English language screener test in the fall of kindergarten. The Asian language English bilingual group included children whose home language was an Asian language (e.g., Chinese, Korean, Japanese, Filipino) and who passed the English language screener test in the fall of kindergarten. Of the 18,174 children included in the ECLS-K:2011, 4,147 (22.8%) did not meet any of the classification criteria above and were excluded from this study.

Executive Function Skills

Measures of executive function skills included direct assessments of working memory, cognitive flexibility, and inhibitory control. Final scores for these three executive function skills were rescaled from their original scales to 1 – 10. The Numbers Reversed task of the Woodcock-Johnson III Tests of Cognitive Abilities (Mather & Woodcock 2001) was used to assess working memory, the ability to maintain and manipulate information over short periods. In this task, children were asked to repeat increasingly long sequences of orally presented numbers in reverse order, ranging from two to eight digits. The task continued until the child got three consecutive number sequences of the same length incorrect or completed all number sequences correctly. This task remained the same across all rounds of data collection from kindergarten through fifth grade. The task consisted of 30 items and the raw score was computed as the sum of correct items. The final score was then determined using norming data provided by the publisher. A child was assigned the final score from the publisher's norming data that was associated with the child's raw score, the child's age, and the language of administration (see Tourangeau et al., 2019 for more details on the computation of working memory scores).

The Dimensional Change Card Sort task (Zelazo, 2006) was used to assess cognitive flexibility, the ability to switch between multiple tasks, operations, or mental sets. In this task, children were asked to sort a series of 22 picture cards into one of two trays according to different rules. Each card had a picture of either a red rabbit or a blue boat; one tray had a picture of a red boat and the other had a picture of a blue rabbit. Children were asked to sort the cards first by color and then by shape. If the child correctly sorted four of the six cards by shape, then he or she moved on to a third sorting rule: if the card had a black border, the child was to sort by color; if the card did not have a black border, the child was to sort by shape. Final scores were computed as the sum of the scores of the color, shape, and border games. This task was administered as physical card sorting in kindergarten and first grade and was changed to electronic card sorting beginning in second grade to capture response time. Final scores were computed as the sum of the accuracy and reaction time scores (see Tourangeau et al., 2019 for more details on the computation of accuracy and reaction time scores).

The NIH Toolbox Flanker Inhibitory Control and Attention Task (Zelazo et al., 2013) was used to assess inhibitory control, the ability to inhibit a dominant response in favor of a subdominant response. This computerized task was administered in fourth grade and fifth grade. In this task, children were asked to focus on a central stimulus while ignoring or inhibiting attention to stimuli presented on either side of the central stimulus. The stimulus used for children eight years and older was a series of five arrows, pointing either left or right. The arrows that “flank” the central arrow, which were referred to as “flankers,” either pointed in the same direction as the central arrow (congruent) or in the opposite direction as the central arrow (incongruent). The flanker arrows acted as distractors, taking attention away from the central arrow that was supposed to be the focus of the child’s attention. Children were presented with 20 arrow trials and were asked to press a button on the computer to indicate the direction the central stimulus (arrow) was pointing. Final scores were computed as the sum of the accuracy and reaction time scores (see Tourangeau et al., 2019 for more details on the computation of accuracy and reaction time scores).

Language Proficiency

Children’s reading scores were used as the index of language proficiency. Their reading scores were rescaled from their original scales to 1 – 10 and centered around the grand mean. In the kindergarten and first-grade rounds of data collection, English reading scores were used as the index of language proficiency for children who passed the English language screener test and received the remaining cognitive assessments in English. Spanish reading skills were used as the index of language proficiency for children who did not pass the English language screener test and received the remaining cognitive assessments in Spanish. Beginning in second grade, English reading scores were used as the index of language proficiency for all children as all cognitive assessments were administered in English.

Socioeconomic Status

The SES index was centered around the grand mean before entering into multilevel and multiple regression models. SES was computed based on five indicators collected through parental interviews: household income, maternal and paternal education, and maternal and paternal occupational prestige scores. All five SES components were z-transformed, and then the SES index was computed as the average of the five z-transformed SES components. When there were missing values for any of the SES components, the SES index was computed by averaging the z-scores of available components (see Tourangeau et al., 2019 for more details on the computation of the SES index).

Time

There were nine rounds of data collection in total in the ECLS-K:2011. Time was recoded from 1 – 9 to 0 – 8 so that 0 represents the first round of data collection.

Gender

Parent reports of child sex were used to create a dummy variable for gender. Males were coded as 1 and females were coded as 0.

Analytic Approach

Given that measures at different time points are nested within each child, four multilevel regression models were built to model the growth trajectories of working memory, cognitive flexibility, and inhibitory control during early childhood. Two multilevel regression models predicting cognitive flexibility were built due to changes in the format and scoring criteria of the task measuring cognitive flexibility that occurred in the fall of second grade (T4). Level 1 predictors included time and language proficiency. Level two predictors included language group, socioeconomic status, and gender. In addition to the main effects of these predictors, a cross-level interaction term "Time × LanguageGroup" was added to examine how language group moderates the relationships between time and each executive function skill. Intercepts and slopes for level 1 predictor "Time" were allowed to vary according to each child's identification number in models predicting working memory and cognitive flexibility. Because inhibitory control was only measured at two time points, only intercepts were set to be random in the model predicting inhibitory control so that the number of random effects did not exceed the number of observations per child. Multilevel regression equations are written below. Υ_{00} represents the fixed intercept; Υ_{01} represents the fixed effect of time; Υ_{02} represents the fixed effect of language proficiency; Υ_{10} represents the fixed effect of language group; Υ_{20} represents the fixed effect of socioeconomic status; Υ_{30} represents the fixed effect of gender; Υ_{11} represents the fixed effect of the interaction between time and language group; μ_{0j} represents random intercepts; μ_{1j} represents random slopes for time; e_{ij} represents level 1 residuals.

$$\text{WorkingMemory}_{ij} = \Upsilon_{00} + \Upsilon_{01}\text{Time}_{ij} + \Upsilon_{02}\text{Proficiency}_{ij} + \Upsilon_{10}\text{LanguageGroup}_j + \Upsilon_{20}\text{SES}_j + \Upsilon_{30}\text{Gender}_j + \Upsilon_{11}\text{LanguageGroup}_j\text{Time}_{ij} + e_{ij} + \mu_{0j} + \mu_{1j}\text{Time}_{ij}$$

$$\text{CognitiveFlexibility}_{ij} = \Upsilon_{00} + \Upsilon_{01}\text{Time}_{ij} + \Upsilon_{02}\text{Proficiency}_{ij} + \Upsilon_{10}\text{LanguageGroup}_j + \Upsilon_{20}\text{SES}_j + \Upsilon_{30}\text{Gender}_j + \Upsilon_{11}\text{LanguageGroup}_j\text{Time}_{ij} + e_{ij} + \mu_{0j} + \mu_{1j}\text{Time}_{ij}$$

$$\text{InhibitoryControl}_{ij} = \Upsilon_{00} + \Upsilon_{01}\text{Time}_{ij} + \Upsilon_{02}\text{Proficiency}_{ij} + \Upsilon_{10}\text{LanguageGroup}_j + \Upsilon_{20}\text{SES}_j + \Upsilon_{30}\text{Gender}_j + \Upsilon_{11}\text{LanguageGroup}_j\text{Time}_{ij} + e_{ij} + \mu_{0j}$$

In addition to the four multilevel regression models outlined above, three multiple regression models were built to compare executive function scores by language group in the spring of fifth grade (T8) while controlling for gender, language proficiency, and socioeconomic status. The dependent variables were working memory, cognitive flexibility, and inhibitory control. The predictors included language group, language proficiency, socioeconomic status, and gender. Multiple regression equations are written below. β_0 represents the intercept; β_1 represents the main effect of language group; β_2 represents the main effect of language proficiency; β_3 represents the main effect of socioeconomic status; β_4 represents the main effect of gender; e_i represents residuals.

$$WorkingMemory_i = \beta_0 + \beta_1 LanguageGroup_i + \beta_2 Proficiency_i + \beta_3 SES_i + \beta_4 Gender_i + e_i$$

$$CognitiveFlexibility_i = \beta_0 + \beta_1 LanguageGroup_i + \beta_2 Proficiency_i + \beta_3 SES_i + \beta_4 Gender_i + e_i$$

$$InhibitoryControl_i = \beta_0 + \beta_1 LanguageGroup_i + \beta_2 Proficiency_i + \beta_3 SES_i + \beta_4 Gender_i + e_i$$

These multilevel and multiple regression models were selected to examine the effects of bilingual experience on the development of executive function during early childhood because they included essential terms, had a great model fit, and did not overcomplicate the interpretation of the results. The assumptions underlying multilevel regression modeling (i.e., linearity, normality of errors, homoscedasticity, no autocorrelation, no multicollinearity) and the assumptions underlying multiple regression modeling (i.e., linearity, normality of errors, homoscedasticity, independence, no multicollinearity) were met.

Results

Descriptive Statistics

Table 1 *Descriptive statistics of demographic characteristics by language group*

Variable	Language group			
	English monolingual	Spanish English bilingual	Emergent Spanish English bilingual	Asian language English bilingual
Number	n = 11616	n = 1531	n = 344	n = 536
%Males	51.5%	51.1%	50.3%	49.4%
Age (years)				
Mean (SD)	7.83(1.84)	7.81(1.82)	7.85(1.83)	7.68(1.84)
Range	3.73 – 13.13	4.75 – 12.43	4.80 – 12.33	4.65 – 12.14
SES				
Mean (SD)	0.11(0.77)	-0.65(0.60)	-0.98(0.41)	0.44(0.96)

Range	-2.26 – 2.52	-2.26 – 2.38	-2.26 – 0.47	-1.71 – 2.67
Proficiency				
Mean (SD)	0.01(1.58)	-0.28(1.51)	-0.23(1.49)	0.28(1.57)
Range	-3.19 – 4.40	-3.16 – 4.59	-4.00 – 4.76	-3.18 – 2.98

Note: Descriptive statistics of number, %males, and SES were computed at baseline (i.e., fall of kindergarten). Descriptive statistics of age and proficiency were computed across the nine data collection time points.

Table 1 displays the descriptive statistics of age, gender, socioeconomic status, language proficiency, and the number of participants by language group. As shown in Table 1, of the 14027 children included in the final sample, 11616 were in the English monolingual group, representing 82.8% of the total sample, 1531 (10.9%) were in the Spanish English bilingual group, 344 (2.5%) were in the emergent Spanish English bilingual group, and 536 (3.8%) were in the Asian language English bilingual group. Child gender was evenly distributed within each language group. There was no significant difference in age among the four language groups. On average, the Asian language English bilingual group had the highest socioeconomic status and language proficiency among the four language groups.

Table 2 *Descriptive statistics of executive function skills scores by language group: Mean (SD)*

	Language group			
Variable (Possible range: 1 – 10)	English monolingual	Spanish English bilingual	Emergent Spanish English bilingual	Asian language English bilingual
Working memory T0	1.65(1.50)	0.84(1.27)	0.38(0.91)	1.90(1.58)
Working memory T1	2.48(1.47)	1.73(1.53)	1.17(1.47)	2.80(1.51)
Working memory T2	2.83(1.37)	2.35(1.45)	1.78(1.52)	3.17(1.46)
Working memory T3	3.41(1.23)	2.89(1.38)	2.20(1.57)	3.63(1.19)
Working memory T4	3.61(1.15)	3.26(1.25)	2.76(1.32)	3.77(1.35)
Working memory T5	3.93(1.12)	3.69(1.17)	3.25(1.32)	4.21(1.16)
Working memory T6	4.37(1.09)	4.16(1.06)	3.84(1.10)	4.72(1.09)
Working memory T7	4.74(1.08)	4.53(1.00)	4.27(1.02)	5.05(1.09)
Working memory T8	5.04(1.12)	4.84(0.97)	4.51(1.06)	5.42(1.06)
Cognitive flexibility T0	8.04(1.73)	7.43(2.04)	6.08(2.55)	7.97(1.83)
Cognitive flexibility T1	8.52(1.49)	8.20(1.57)	7.33(2.10)	8.53(1.54)
Cognitive flexibility T2	8.84(1.26)	8.49(1.38)	8.15(1.53)	8.98(1.18)
Cognitive flexibility T3	9.00(1.25)	8.70(1.29)	8.21(1.59)	9.03(1.29)
Cognitive flexibility T4	6.44(1.37)	6.11(1.56)	5.05(1.83)	6.39(1.46)
Cognitive flexibility T5	6.75(1.31)	6.55(1.42)	5.87(1.59)	6.92(1.29)
Cognitive flexibility T6	7.14(1.46)	7.01(1.39)	6.43(1.69)	7.49(1.01)
Cognitive flexibility T7	7.65(0.97)	7.54(0.92)	7.14(1.06)	7.85(0.93)
Cognitive flexibility T8	8.00(0.95)	7.86(0.91)	7.54(1.03)	8.20(0.89)
Inhibitory control T7	7.87(1.76)	7.75(1.42)	7.28(2.19)	8.03(2.43)
Inhibitory control T8	8.37(1.40)	8.23(1.25)	7.84(1.98)	8.61(1.56)

Note: T0= fall of kindergarten, T1 = spring of kindergarten, T2 = fall of first grade, T3 = spring of first grade, T4 = fall of second grade, T5 = spring of second grade, T6 = spring of third grade, T7 = spring of fourth grade, T8 = spring of fifth grade.

Table 2 presents the descriptive statistics of executive function skills scores at each time point by language group. For working memory, the Asian language English bilingual group had the highest score on average among the four language groups at each time point. For cognitive flexibility, the English monolingual and Asian language English bilingual groups had higher scores on average than the other two language groups at each time point. For inhibitory control, the Asian language English bilingual group had the highest score on average among the four language groups at both time points. The emergent Spanish English bilingual group had the lowest scores on average for each executive function skill at every time point among the four language groups.

Multilevel Regression Models

Table 3 *Regression estimates from multilevel regression models*

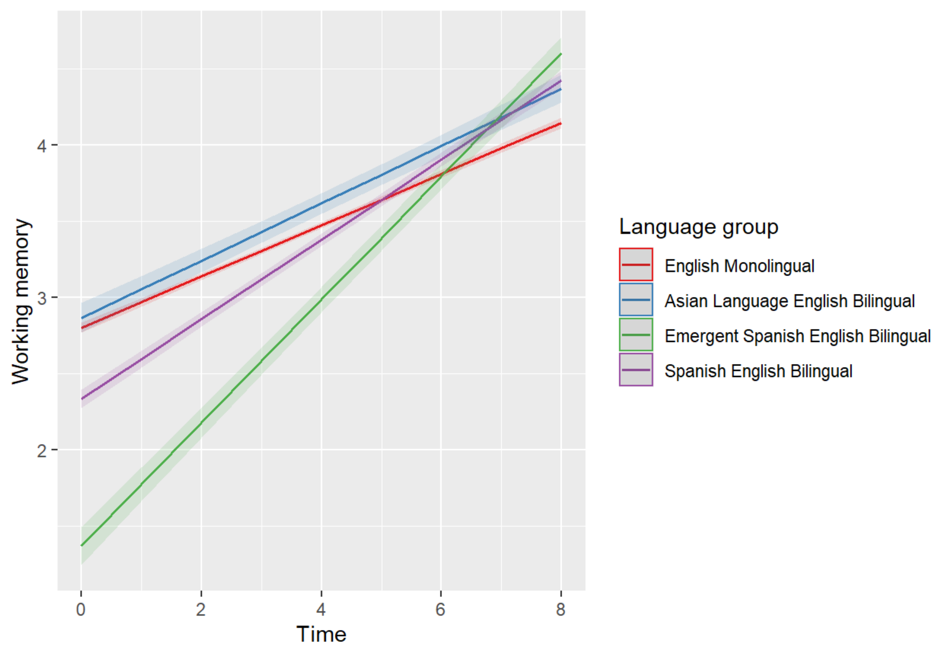
Model	M1: Working memory (T0 – 8)	M2: Cognitive flexibility (T0 – 3)	M3: Cognitive flexibility (T4 – 8)	M4: Inhibitory control (T7 – 8)
Model fit				
ICC	0.54	0.40	0.78	0.26
Pseudo-R² (fixed effects)	0.55	0.13	0.24	0.07
Pseudo-R² (total)	0.74	0.36	0.54	0.31
Fixed effects: Coefficient (SE)				
Intercept	2.80***(0.02)	8.90***(0.03)	5.11***(0.03)	4.78***(0.16)
Time	0.17***(0.00)	0.07***(0.01)	0.26***(0.01)	0.34***(0.02)
Asian language English bilingual	0.06(0.05)	-0.21***(0.07)	0.00(0.15)	-0.48(0.74)
Emergent Spanish English bilingual	-1.43***(0.06)	-2.03***(0.09)	-1.33***(0.17)	0.36(0.83)
Spanish English bilingual	-0.47***(0.03)	-0.31***(0.04)	-0.08(0.08)	0.15(0.43)
Time × Asian language English bilingual	0.02*(0.01)	0.04(0.03)	0.02(0.02)	0.07(0.10)
Time × Emergent Spanish English bilingual	0.24***(0.01)	0.63***(0.04)	0.17***(0.02)	-0.06(0.11)
Time × Spanish English bilingual	0.09***(0.00)	0.12***(0.02)	0.02(0.01)	-0.01(0.06)
Proficiency	0.47***(0.01)	0.36***(0.01)	0.40***(0.01)	0.43***(0.02)

SES	0.21***(0.01)	0.17***(0.01)	0.07***(0.01)	0.05*(0.02)
Male	-0.04***(0.01)	-0.09***(0.02)	-0.02(0.02)	0.12***(0.02)
Random effects:				
SD				
μ_0	0.93	1.04	1.71	0.75
μ_1	0.13	0.26	0.17	NA
e	0.87	1.26	0.91	1.27

Note: *p < .05, ** p < .01, *** p < .001

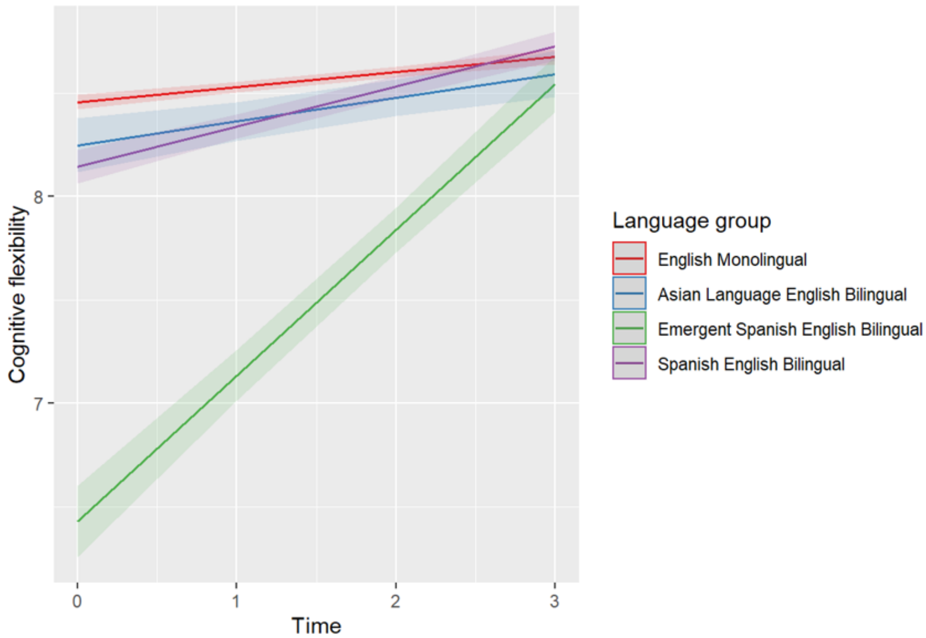
Table 3 presents regression estimates from the four multilevel regression models. Model 1 predicts working memory from the fall of kindergarten (T0) to the spring of fifth grade (T8). The coefficient for the Asian language English bilingual group is not significant, indicating that this group of bilinguals initially had similar working memory scores as the English monolingual group. The coefficients for the Spanish English bilingual and emergent Spanish English bilingual groups are negative and significant, indicating that these two groups of bilinguals initially had lower working memory scores than the English monolingual group. The coefficients for the three interaction terms are positive and significant, indicating that all three groups of bilinguals had a faster growth rate of working memory than the English monolingual group. Within the three bilingual groups, the emergent Spanish English group had the fastest growth rate of working memory, followed by the Spanish English bilingual group, then by the Asian language English bilingual group. A graphical representation of the growth trajectories of working memory from T0 to T8 by language group is shown in Figure 1.

Figure 1 *Model-based estimates of working memory growth by language group (T0 – T8)*



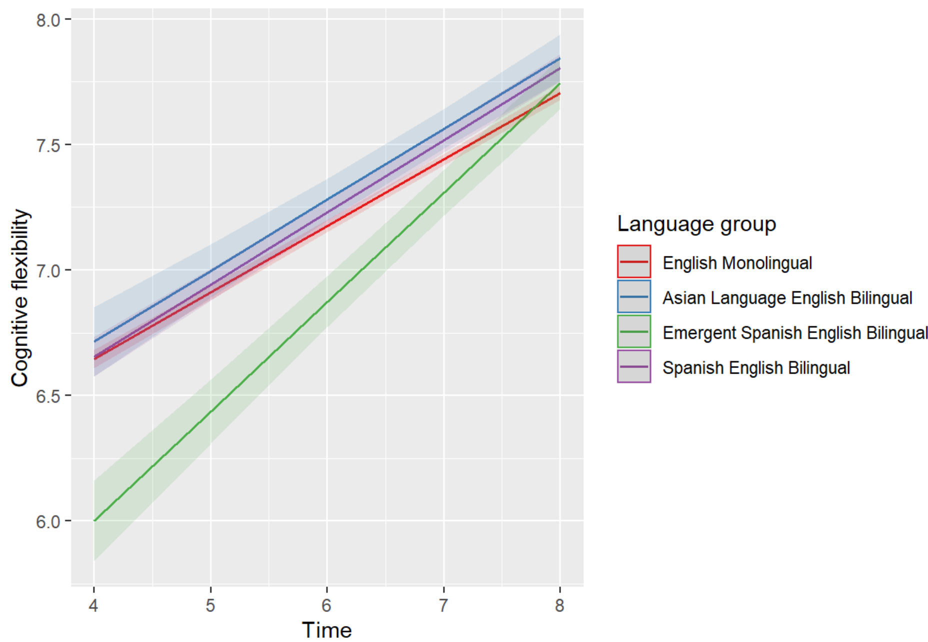
Model 2 predicts cognitive flexibility from the fall of kindergarten (T0) to the spring of first grade (T3). The coefficients for the three bilingual groups are negative and significant, indicating that these three groups of bilinguals initially had lower cognitive flexibility scores than the English monolingual group. The coefficient for the interaction term for the Asian language English bilingual group is insignificant, indicating that this group of bilinguals had a similar growth rate of cognitive flexibility as the English monolingual group. The coefficients for the interaction terms for the Spanish English bilingual and emergent Spanish English bilingual groups are positive and significant, indicating that these two groups of bilinguals had a faster growth rate of cognitive flexibility than the English monolingual group. Within these two groups of bilinguals, the emergent Spanish English bilingual group had a faster growth rate of cognitive flexibility than the Spanish English bilingual group. A graphical representation of the growth trajectories of cognitive flexibility from T0 to T3 by language group is shown in Figure 2.

Figure 2 *Model-based estimates of cognitive flexibility growth by language group (T0 – T3)*



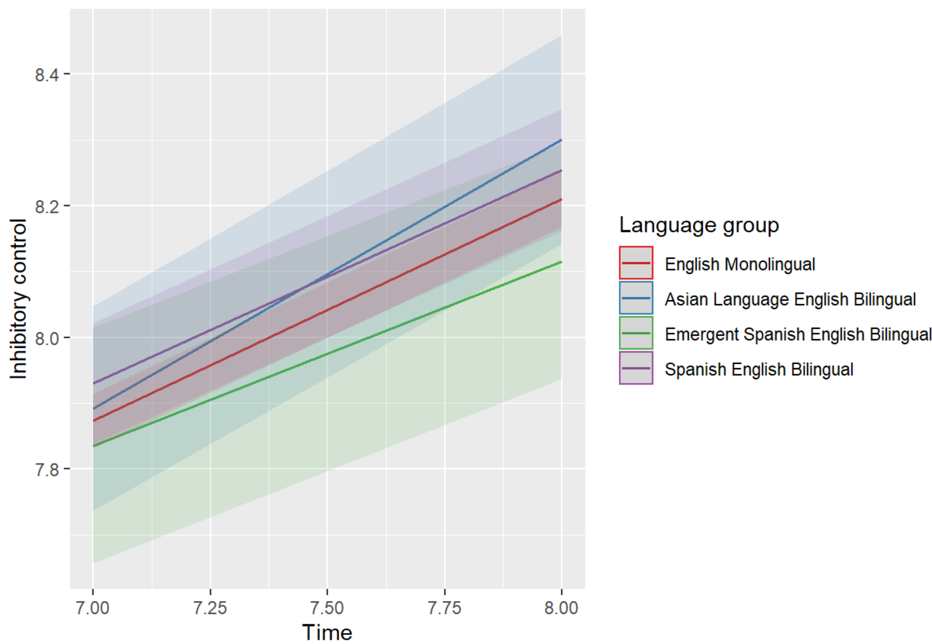
Model 3 predicts cognitive flexibility from the fall of second grade (T4) to the spring of fifth grade (T8). The coefficients for the Asian language English bilingual and Spanish English bilingual groups are insignificant, indicating that these two groups of bilinguals initially had similar cognitive flexibility scores as the English monolingual group. The coefficient for the emergent Spanish English group is negative and significant, indicating that this group of bilinguals initially had lower cognitive flexibility scores than the English monolingual group. The coefficients for the interaction terms for the Asian language English bilingual and Spanish English bilingual groups are insignificant, indicating that these two groups of bilinguals had a similar growth rate of cognitive flexibility as the English monolingual group. The coefficient for the interaction term for the emergent Spanish English bilingual group remains positive and significant, indicating that this group of bilinguals continued to have a faster growth rate of cognitive flexibility than the English monolingual group. A graphical representation of the growth trajectories of cognitive flexibility from T4 to T8 by language group is shown in Figure 3.

Figure 3 *Model-based estimates of cognitive flexibility growth by language group (T4 – T8)*



Model 4 predicts inhibitory control from the spring of fourth grade (T7) to the spring of fifth grade (T8). The coefficients for the three bilingual groups are insignificant, indicating that these three groups of bilinguals initially had similar inhibitory control scores as the English monolingual group. The coefficients for interaction terms for the three bilingual groups are also insignificant, indicating that these three groups of bilinguals had a similar growth rate of inhibitory control as the English monolingual group. A graphical representation of the growth trajectories of inhibitory control from T7 to T8 by language group is shown in Figure 4.

Figure 4 *Model-based estimates of inhibitory control growth by language group (T7 – T8)*



Additionally, the coefficients for time, language proficiency, and socioeconomic status are positive and significant across the four models, indicating that these three variables were positively associated with working memory, cognitive flexibility, and inhibitory control scores. The coefficient for gender is statistically significant in models 1, 2, and 4 but not in model 3. Boys scored lower on working memory but higher on inhibitory control than girls on average. Boys also scored lower on cognitive flexibility than girls on average from T0 to T3, but this gender difference disappeared from T4 to T8.

Multiple Regression Models

Table 4 *Regression estimates from multiple regression models*

Model	M5: Working memory (T8)	M6: Cognitive flexibility (T8)	M7: Inhibitory control (T8)
Model fit			
R^2	0.25	0.13	0.06
F statistic	512.46***	216.71***	100.13***
Main effects: Coefficient (SE)			
Intercept	3.68***(0.03)	7.19***(0.03)	7.52***(0.04)
Asian Language English bilingual	0.17***(0.05)	0.07(0.05)	0.12(0.07)
Emergent Spanish English bilingual	0.14*(0.06)	-0.05(0.06)	-0.11(0.08)
Spanish English bilingual	0.11***(0.03)	0.04(0.03)	0.03(0.04)

Proficiency	0.69***(0.01)	0.42***(0.01)	0.41***(0.02)
SES	0.08***(0.01)	0.04***(0.01)	0.04*(0.02)
Male	0.01(0.02)	-0.01(0.02)	0.12***(0.03)

Note: *p < .05, ** p < .01, *** p < .001

Table 4 presents regression estimates from the three multiple regression models. The F statistics for the three models are significant (p < .001), indicating that these three models provided a better fit than the intercept-only model. Model 5 predicts working memory in the spring of fifth grade (T8). The coefficients for the three bilingual groups are positive and significant, indicating that all three groups of bilinguals had significantly higher working memory scores than the English monolingual group at the end of the study. The three bilingual groups had no significant difference in working memory scores. Model 6 predicts cognitive flexibility in the spring of fifth grade (T8). The coefficients for the three bilingual groups are insignificant, indicating that all three groups of bilinguals had similar cognitive flexibility scores as the English monolingual group at the end of the study. Model 7 predicts inhibitory control in the spring of fifth grade (T8). Like model 6, the coefficients for the three bilingual groups are insignificant, indicating that all three groups of bilinguals had similar inhibitory control scores as the English monolingual group at the end of the study. Additionally, the coefficients for language proficiency and socioeconomic status are positive and significant across the three models, indicating that these two variables were positively associated with working memory, cognitive flexibility, and inhibitory control scores. The coefficient for gender is not significant in models 5 and 6 but is significant in model 7. Boys scored higher on inhibitory control than girls on average, but there was no significant gender difference in working memory or cognitive flexibility scores.

Discussion

The goals of the present study were to examine how being bilingual in general affects the development of executive functions skills during early childhood, assess whether and how the age of second language acquisition moderates the effects of bilingualism on the growth of executive function skills, and determine whether and how the degree of overlap between the linguistic systems of bilinguals' two languages moderates the bilingual effects on executive function skills.

The results of multilevel and multiple regression analyses suggest that bilingual experience is associated with the enhancement of certain components of executive function during early childhood. In particular, being bilingual is associated with enhanced working memory but not cognitive flexibility or inhibitory control. All three groups of bilinguals displayed a faster growth rate of working memory and demonstrated higher working memory scores than the English monolingual group at the end of the study. Furthermore, the fact that there was no significant difference in working memory scores within the three bilingual groups at the end of the study implies that the age of second language acquisition and the degree of overlap between the linguistic systems of bilinguals' two languages do not moderate the effects of bilingual experience on the development of working memory during early childhood. In contrast to the bilingual effects on working memory, bilingual experience does not affect the development of either cognitive flexibility or inhibitory control during early childhood. Only the emergent Spanish English bilingual group consistently displayed a faster growth rate of cognitive flexibility than the English monolingual group. There was no significant difference in cognitive flexibility or inhibitory control scores between the English monolingual group and the three bilingual groups at the end of the study.

Notably, the emergent Spanish English bilingual group displayed the fastest growth rate of working memory among the three bilingual groups. This could suggest that acquiring bilingualism might be associated with more rapid working memory development during early childhood than continued bilingual experience. However, this interpretation remains inconclusive as an alternative explanation could be that children with lower working memory scores tend to exhibit more rapid working memory growth. As shown in the descriptive statistics of working memory scores by language group, the emergent Spanish English bilingual group had the lowest mean working memory score while the Asian language English bilingual group had the highest mean working memory score at each time point. These statistics align with the growth rates of working memory among the three bilingual groups: the emergent Spanish English bilingual group displayed the fastest rate of working memory growth while the Asian language English bilingual group displayed the slowest growth rate of working memory. Additionally, children's language proficiency should not explain the differences in the growth rate of working memory as it was controlled in the multilevel regression model. More research is needed to determine whether acquiring bilingualism is associated with more rapid working memory development during early childhood than continued bilingual experience.

The finding that bilingual experience is associated with enhanced working memory does not converge with studies that have used the same data file (Goodrich et al., 2021; Hartanto et al., 2019). The reason for this discrepancy could be that the bilingual advantage in working memory does not emerge early in life. The other two studies only used the data from kindergarten to first grade and found no bilingual advantage in working memory. In line with this result, no bilingual advantage in working memory was found if only the data up until first grade were considered in this study. It should be noted that the average working memory scores were relatively low and a large number of children scored zero in kindergarten and first grade. As children advanced to higher grades, their working memory scores also increased and the bilingual advantage in working memory started to emerge. Besides, the finding that bilingual experience is not associated with enhanced inhibitory control is also inconsistent with the other two studies. The reason for this inconsistency could be the measurement methods of inhibitory control. Specifically, inhibitory control was rated subjectively by teachers in kindergarten and first grade. In fourth and fifth grade, however, it was assessed objectively through a behavioral task. The other two studies used teacher-rated inhibitory control scores in their analyses while the present study used the performance-based measure of inhibitory control. Unlike the performance-based measure of inhibitory control, teacher-rated inhibitory control scores do not measure growth over time as these scores indicate children’s status relative to their peers. Thus, findings regarding the bilingual effects on inhibitory control might not be comparable between this study and the other two studies.

In addition, the conclusion that the age of second language acquisition does not moderate the bilingual effects on working memory during early childhood is not in line with the previous finding that earlier age of second language acquisition is associated with more enhanced executive function (Carlson

& Meltzoff, 2008; Luk et al., 2011). One reason for this discrepancy could be the age of the participants. Only kindergarten children were included in the study by Carlson & Meltzoff (2008). As such, late bilinguals might be too young to show their bilingual advantage in executive function as they had not yet acquired enough bilingual experience. In contrast, participants were young adults and late bilinguals were defined as people who became bilinguals after age ten in the study by Luk et al. (2011). In the present study, however, late bilinguals referred to emergent Spanish English bilinguals who became Spanish English bilinguals before second grade in elementary school. Thus, there may be a threshold below which the age of second language acquisition does not moderate the bilingual effects on executive function. More research is needed to determine this threshold. Alternatively, the age of second language acquisition might moderate the bilingual effects on some executive function skills but not others as the task used to measure working memory in the ECLS-K:2011 was not used in the other two studies. In particular, a total of nine tasks were used to assess executive function in the study by Carlson & Meltzoff (2008). Among the nine tasks administered to the participants, a visually cued recall task (Zelazo et al., 2002) was used to measure working memory. However, inhibitory control is also required to complete this task successfully. A flanker task (Zelazo et al., 2013) was used to assess executive function in the study by Luk et al. (2011). This task measures inhibitory control instead of working memory. Thus, it is also possible that the age of second language acquisition moderates the bilingual effects on specific aspects of executive function.

One of the limitations of the present study is that no causal inference can be drawn from this study. Nonetheless, the longitudinal analytic approach adopted by this study did control some random variations and helped elucidate the bilingual effects on the development of executive function skills during early childhood. Future studies should use alternative analytic strategies (e.g., propensity score stratification) or employ other research designs (e.g., quasi-experimental design) to draw causal inferences. Another limitation is that this study only tested linear models. Future studies should examine whether the growth trajectories of executive function skills could follow non-linear patterns for different language groups. The results of the multilevel modeling of cognitive flexibility suggest that executive function growth could be better modeled as a quadratic function. Two multilevel models were built to predict cognitive flexibility due to changes in the format and scoring criteria of the task assessing cognitive flexibility that occurred in the fall of second grade. It turned out that all three groups of bilinguals had a slower growth rate during the second half of the study compared to their respective growth rate during the first half of the study, suggesting a quadratic growth model.

In addition, since inhibitory control was only measured at two time points, only intercepts were set to be random in the multilevel model predicting inhibitory control so that the number of random effects did not exceed the number of observations per child. As such, the results of that model should be interpreted with caution. Besides, the Asian language English bilingual group encompassed children who spoke English and a variety of different Asian languages (e.g., Chinese, Korean, Japanese, Filipino). This study was not able to specify the Asian language spoken by each bilingual in this group as this information was not collected in the ECLS-K:2011. Consequently, it remains inconclusive whether and how the degree of overlap between the linguistic systems of bilinguals' two languages moderates the effects of bilingualism on the growth of executive function skills. Future research should specify languages spoken by bilinguals to investigate this question in depth. Finally, culture was not controlled in the present study. Although this study had three groups of bilinguals differing in their bilingual experience, there was only one monolingual control group: English monolinguals. Monolinguals of other languages as well as participants who are bicultural but not bilingual should be included in future studies to control confounding variables such as culture.

Despite these limitations, this is the first study of its kind to take a longitudinal approach to examine the effects of bilingualism on executive function by statistically modeling the growth of executive function skills among four groups that differ in their bilingual experience using a nationally representative sample of children in the United States. Taken together, the results of the present study suggest that bilingual experience is associated with the enhancement of certain components of executive function during early childhood. In particular, being bilingual is associated with enhanced working memory but not cognitive flexibility or inhibitory control. Moreover, the age of second language acquisition and the degree of overlap between the linguistic systems of bilinguals' two languages do not seem to moderate the effects of bilingual experience on the growth of working memory during early childhood. These findings advance our understanding of both the specificity and generalizability of the effects of bilingual experience on the development of executive function skills during early childhood.

References

Barbu, C., Orban, S., Gillet, S., & Poncelet, M. (2018). The impact of language switching frequency on attentional and executive functioning in proficient bilingual adults. *Psychologica Belgica, 58*(1), 115–127.

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition.* New York: Cambridge University Press.

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 3*, 325–339.

Bialystok, E., & Martin-Rhee, M. M. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*(1), 81-93.

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition, 112*, 494–500.

Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(6), 1341-1354.

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19*(2), 290–303.

Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. Journal of Experimental Psychology. *Learning, Memory, and Cognition, 34*(4), 859–873.

Bialystok, E., M. M. Martin, and M. Viswanathan. (2005). Bilingualism across the lifespan: the rise and fall of inhibitory control. *International Journal of Bilingualism, 9*, 103–119.

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology, 20*, 899–911.

Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish–Dutch children. *Journal of Experimental Child Psychology, 128*, 105–119.

Broidy, L. M., Nagin, D. S., Tremblay, R. E., Bates, J. E., Brame, B., Dodge, K. A., . . . Vitaro, F. (2003). Developmental trajectories of childhood disruptive behaviors and adolescent delinquency: A six-site, cross-national study. *Developmental Psychology, 39*, 222–245.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28*, 595–616.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science, 11*(2), 282–298.

Dick, A. S., Garcia, N. L., Pruden, S. M., Thompson, W. K., Hawes, S. W., Sutherland, M. T., Riedel, M. C., Laird, A. R., & Gonzalez, R. (2019). No evidence for a bilingual executive function advantage in the ABCD study. *Nature Human Behaviour, 3*(7), 692.

Goodrich, J. M., Koziol, N. A., Yoon, H., & Leiva, S. (2021). Do Spanish-English bilingual children outperform monolingual English-speaking children on executive function tasks in early childhood? A propensity score analysis. *Journal of Educational Psychology.*

Grosjean, F. (2010). *Bilingual: Life and Reality*. Harvard University Press

Harris, M. (2013). *Language experience and early language development: From input to uptake.* Hove, East Sussex: Psychology Press.

Hartanto, A., Toh, W. X., & Yang, H. (2019). Bilingualism Narrows Socioeconomic Disparities in Executive Functions and Self-Regulatory Behaviors during Early Childhood: Evidence from the Early Childhood Longitudinal Study. *Child Development, 90*(4), 1215–1235.

Hilchey, M. D., and R.M. Klein. 2011. Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin and Review, 18*, 625–58.

Kroll, J. F., Dussias, P. E., Bogulski, C. A., Valdes-Kroff, J. (2012). *Juggling two languages in one mind: What bilinguals tell us about language processing and its consequences for cognition*. San Diego: Academic Press.

Kroll, J. F., Michael, E., Tokowicz, N., & Dufour, R. (2002). The development of lexical fluency in a second language. *Second Language Research, 18*, 137–171.

Laine, M., & Lehtonen, M. (2018). Cognitive consequences of bilingualism: where to go from here? *Language, Cognition & Neuroscience, 33*(9), 1205–1212.

Luk, G., E. De Sa, and E. Bialystok. (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition, 14*, 588–95.

Mather, N., & Woodcock, R. W. (2001). *Examiner's manual: Woodcock-Johnson III tests of cognitive abilities*. Riverside Publishing.

McClelland, M.M., Cameron, C.E., Connor, C.M., Farris, C.L., Jewkes, A.M., & Morrison, F.J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*, 947–959.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Nichols, E. S., Wild, C. J., Stojanoski, B., Owen, A. M., & Battista, M. E. (2020). Bilingualism Affords No General Cognitive Advantages: A Population Study of Executive Function in 11,000 People. *Psychological Science, 31*(5), 548–567.

Okada, K., He, G., & Gonzales, A. (2019). Monolinguals and bilinguals differ in performance on the taboo stroop task. *Open Psychology Journal, 12*(1), 135–140.

Paap, K. R., & Z. I. Greenberg. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology, 66*, 232–58.

Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*, 253–262.

Prior, A., and T. H. Gollan. 2011. Good language-switchers are good task-switchers: Evidence from Spanish–English and Mandarin–English bilinguals. *Journal of International Neuropsychological Society, 17*, 682–91.

Putnam, S. P., & Rothbart, M. K. (2006). Development of short and very short forms of the Children's Behavior Questionnaire. *Journal of Personality Assessment, 84*, 102–112.

Riggs, N., Chou, C.-P., Spruijt-Metz, D., & Pentz, M. A. (2010). Executive cognitive function as a correlate and predictor of child food intake and physical activity. *Child Neuropsychology, 16*, 279–292.

Ross, J., & Melinger, A. (2017). Bilingual advantage, bidialectal advantage or neither? Comparing performance across three tests of executive function in middle childhood. *Developmental Science, 20*(4).

Tourangeau, K., Nord, C., Lê, T., Wallner-Allen, K., Vaden-Kiernan, N., Blaker, L., & Najarian, M. (2019). *Early Childhood Longitudinal Study, Kindergarten Class of 2010–11 (ECLS-K:2011) User's Manual for the ECLS-K:2011 Kindergarten–Fifth Grade Data File and Electronic*

Codebook, Public Version (NCES 2019-051). U.S. Department of Education. Institute of Education Sciences. Washington, DC: National Center for Education Statistics.

Tse, C. S., & J. Altarriba. (2012). The effects of first- and second-language proficiency on conflict resolution and goal maintenance in bilinguals: evidence from reaction time distributional analyses in a Stroop task. *Bilingualism: Language and Cognition, 15*, 663–76.

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1*, 297–301.

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. In P.D. Zelazo and P.J. Bauer (Eds.), *National Institutes of Health Toolbox Cognition Battery (NIH Toolbox CB): Validation for Children Between 3 and 15 Years. Monographs of the Society for Research in Child Development.*

Zelazo, P. D., Jacques, S., Burack, J., & Frye, D. (2002). The relation between theory of mind and rule use: evidence from persons with autism-spectrum disorders. *Infant and Child Development, 11,* 171–195.