The Cognitive Benefits of Growing Up Bilingual: A Longitudinal Study

Cristina Crivello

A Thesis

In

The Department

Of

Psychology

Presented in partial fulfillment of the Requirements
for the Degree of Master of Arts (Psychology) at
Concordia University
Montreal, Quebec, Canada

April 2015

CONCORDIA UNIVERSITY

School of Graduate Studies

This is to certify that the thesis prepared

By: Cristina Crivello

Entitled: The Cognitive Benefits of Growing Up Bilingual: A Longitudinal Study

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

Master of Arts (Psychology)

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

Signed by the final examining committee:

______________________________ Chair
Dr. Wayne Brake

______________________________ Examiner
Dr. Krista Byers-Heinlein

______________________________ Examiner
Dr. Norman Segalowitz

______________________________ Supervisor
Dr. Diane Poulin-Dubois

Approved by ____
Chair of Department or Graduate Program Director

__________2015 ____
Dean of Faculty

Abstract

The cognitive benefits of growing up bilingual: A longitudinal study

Cristina Crivello

The mastery of two languages provides bilingual speakers cognitive benefits over monolinguals, particularly on cognitive flexibility and selective attention. However, extant research is limited to comparisons between monolinguals and bilinguals at a single point in time. This study investigated whether growth in bilingual proficiency, as shown by increased proportions of translation equivalents (TEs) known over a 7-month period, improves executive function. We hypothesized that bilingual toddlers with a larger increase of TEs would have more practice switching across lexical systems, boosting executive function abilities. Expressive vocabulary and TEs were assessed at 24 and 31 months. A battery of tasks, including conflict, delay, and working memory tasks, was administered at 31 months. As expected, we observed a task-specific advantage in inhibitory control in bilinguals. More importantly, within the bilingual group, increases in proportion of TEs predicted performance on conflict tasks, but not on delay or working memory tasks. This unique longitudinal design offers a new approach to examine the relation between executive function and early bilingualism.

Acknowledgements

First and foremost, I would like to thank my supervisor, Dr. Diane Poulin-Dubois, for her significant guidance, encouragement, and support throughout this study. Thank you for believing in me and awarding me the opportunity to pursue graduate studies in this program. I would also like to thank the members of the Cognitive and Language Development Laboratory who have always been there for me and who have helped in so many ways. Additionally, I would like to thank the co-authors of this paper, Olivia Kuzyk, Monyka Rodrigues, Dr. Margaret Friend, Dr. Pascal Zesiger, and Dr. Diane Poulin-Dubois, for their much appreciated contributions to the manuscript. A special thank you to Jacqueline Legacy and Lyakout Mohamed Said who were also an integral part of data collection for this project. I also extend my heart-felt appreciation to Dr. Krista Byers-Heinlein and Dr. Norman Segalowitz, for accepting to be on my master's thesis committee and for their highly valued recommendations. Furthermore, I would like to thank Concordia University for providing financial support through internal awards and the National Institute of Health for funding this project through a grant (#R01 HD068458) awarded to Dr. Diane Poulin-Dubois, Dr. Margaret Friend, and Dr. Pascal Zesiger. Thank you as well to the families who participated in this longitudinal study. Lastly, I would like to thank my fiancé David, my parents, my sister, and the rest of my family and friends for their encouragement, support, and patience throughout my master's degree. You have always believed in me, and I am forever grateful. Without the help and support of these individuals, this thesis would not have been possible.

Contribution of Authors

Dr. Diane Poulin-Dubois, Dr. Margaret Friend, and Dr. Pascal Zesiger designed the study, while Cristina Crivello, Monyka Rodrigues, and Olivia Kuzyk collected and coded the data. Statistical analyses were conducted by Cristina Crivello, under the supervision of Dr. Diane Poulin-Dubois, Dr. Margaret Friend and Dr. Pascal Zesiger. Cristina Crivello and Dr. Diane Poulin-Dubois wrote a draft of the manuscript, and others provided important revisions. Every author agreed on the final manuscript. The manuscript has been submitted for publication to Journal of Experimental Child Psychology in 2014 and is to be revised and resubmitted. (Authorship: Crivello, C., Kuzyk, O., Rodrigues, M., Friend, M., Zesiger, P., & Poulin-Dubois, D.)

Table of Contents

List of Tables

The cognitive benefits of growing up bilingual: A longitudinal study

Bilingualism is a widespread phenomenon, as it is estimated that about half of the world's population speaks two or more languages (Grosjean, 2010). Due to this worldwide prevalence, the costs and benefits of bilingualism have increasingly become an important area of study in cognitive science. Researchers have demonstrated that there are cognitive advantages of bilingualism, particularly on tasks measuring cognitive flexibility and selective attention (Barac & Bialystok, 2012; Bialystok, 2001). These tasks require regulation of inhibitory mechanisms that allows one to focus their attention to relevant information, while suppressing attention towards misleading information (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Such benefits are evident on tasks involving conflicting attentional demands (conflict tasks), but not on tasks measuring response suppression (delay tasks), as the benefits of executive function are conveyed through conflict inhibition (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Poulin-Dubois et al., 2011). Despite the fact that many researchers have observed the cognitive benefits of bilingualism in adults (see review by Kroll & Bialystok, 2013) and children (see review by Adesope, Lavin, Thompson, & Undergleider, 2010 and Bialystok, 2005), findings are inconsistent. To illustrate, recent studies comparing executive function abilities in monolingual and bilingual samples have found no such bilingual advantage (Anton et al., 2014; Dunabeitia et al., 2014; Gathercole et al., 2014; Paap & Greenberg, 2013).

The dominant explanation for bilinguals' enhanced executive control is that both languages are simultaneously activated in the bilingual brain, and thus these executive function mechanisms are continuously utilized to focus on the target language and disregard the non-target language (Colomé, 2001; Green, 1998; Kroll, Dussias, Bogulski, & Kroff, 2012; Rodriguez-Fornells et al., 2005). Moreover, bilinguals need to repeatedly direct their attention between language systems as a function of the linguistic context (Bialystok, 2008). The ongoing coordination of competing lexical systems prevents disruptions in speech and maintains fluency in either language, and in turn, strengthens executive function abilities (Bialystok, 2001).

There is evidence of enhanced selective attention and cognitive flexibility as a function of repeated practice. Bilinguals who began using both languages later on in life show greater interference on a conflict task than bilinguals who began using both languages early on in life (Luk, De Sa, & Bialystok, 2011; Poarch & Van Hell, 2012). Additionally, research comparing adult and child samples (Adesope et al., 2010) has revealed that this effect becomes more robust during adulthood, demonstrating that extensive practice leads to enhanced bilingual benefits. Even in studies examining this effect in childhood, the bilingual advantage becomes more apparent as children grow older and obtain more practice in language control. To illustrate, Poulin-Dubois and colleagues (2011) found a bilingual advantage on one conflict task with 2-year-olds while Bialystok, Barac, Blaye, and Poulin-Dubois (2010) found an effect on three tasks measuring executive control with 3- and 4-year-olds.

As bilinguals actively use both languages, they create two lexical representations for one concept in either language, also referred to as translation equivalents (TEs; e.g., *dog* and *chien*). Children acquire TEs early on in language development and the proportion of TEs is directly related to the amount of second language exposure (Genesee & Nicoladis, 2007; Pearson, Fernandez, Lewedeg, & Oller, 1997). The acquisition of TEs allows the bilingual child to acquire more experience in inhibiting one language while using the other because of the need to keep the TEs from being used in the appropriate language. In accordance with the precocious acquisition of TEs, research using semantic priming to examine language switching in young bilinguals has shown that bilingual toddlers are able to retrieve words in their second language once primed by a related word in their first language (Singh, 2014). The researcher speculated that words are accessed and processed from independent language systems (Singh, 2014). Independent language systems require bilinguals to switch across language systems, thereby strengthening their selective attention and inhibition abilities (Patterson & Pearson, 2004). It is hypothesized that these abilities would be enhanced as a function of TE acquisition.

Across numerous studies examining executive function abilities, researchers have indicated that bilingual experience has a substantial effect on children's cognitive performance. To illustrate, executive function benefits of bilingualism have been reported by Carlson and Meltzoff (2008), whereby 6-year-old bilinguals outperformed their monolingual counterparts on conflict tasks, but not on delay tasks. Poulin-Dubois and colleagues (2011) reported similar findings with 24-month-old bilinguals and monolinguals. The bilinguals outperformed the monolinguals on the Shape Stroop task, a conflict task in which children need to selectively attend to a target stimulus while ignoring a non-target stimulus, but comparable between-group performance was observed on the delay tasks. There is even some evidence of executive function benefits in seven-month-old bilingual infants on a switch task measuring inhibitory control; however, it is noteworthy that this finding is based on a single task, and second language exposure was not documented (Kovacs & Mehler, 2009).

Despite these findings, studies examining such bilingual advantage early on in development are scarce and most of the evidence of bilingual cognitive benefits comes from research on older children and adults. Furthermore, the majority of research in this field involves comparisons between monolinguals and bilinguals and studies examining within-bilingual comparisons are scarce. As such, some researchers remain critical of these group comparisons given that extraneous variables may have confounded results (e.g., socioeconomic status, culture) (Morton & Harper, 2007). In addition to examining differences in executive function performance across monolingual and bilingual toddlers, the present study is the first to investigate the effects of bilingualism on executive function using a longitudinal design. Such design offers a unique opportunity to assess the cognitive underpinnings of a putative bilingual advantage early in development while controlling for group inequalities. The goal of the current study was to replicate previous studies demonstrating a bilingual advantage when comparing monolingual and bilingual young children on conflict tasks. More importantly, the main goal was to examine mechanisms that may underlie the cognitive advantage in bilinguals. Thus, we investigated whether an increased proportion of TEs during the second and third year of life predicts performance on executive function tasks. We reasoned that such increase provides additional opportunity for practicing switching between languages, therefore boosting the cognitive processes that are assumed to benefit from bilingualism. Children's ability to respond to conflicting attentional demands, as well as their working memory and response suppression abilities, were assessed through these tasks. Examining growth in proportion of TEs during this critical period of language development provides us with the opportunity to directly measure how increased cross-language switching influences executive function abilities. We hypothesized that toddlers who show a greater increase in the proportion of TEs during a 7-month-period will show superior performance on executive function conflict tasks, but not on delay or working memory tasks.

Method

Participants

A total of 92 participants were tested, which consisted of 49 bilinguals and 43 monolinguals. Bilingual participants were tested in Montréal, Québec and were recruited from birth lists provided by a governmental health agency, while monolingual participants were tested in San Diego, California and were recruited through birth records and flyers. Of these 49 bilingual participants, 10 were excluded due to missing the second wave of data collection (n = 4) and missing a vocabulary measure (n = 6). After these exclusions, 39 bilingual participants remained. For bilinguals, language requirements consisted of being exposed to English and French from birth, and having at least 20% exposure to their second language (L2). If the child was exposed to a third language, it was at or below 10%. For monolinguals, language requirements consisted of having at least 90% exposure to English. At Wave 1, bilingual participants had an L2 exposure between .21 and .50 (M = .36, SD = .10) and were between 22.10 and 25.40 months of age (M = 24.00, SD = .88). At Wave 2, bilingual participants had an L2 exposure between .22 and .50 (M = .36, SD = .08) and were between 28.80 and 33.50 months of age (M = 30.91, SD = 1.02). Monolingual participants were only tested at Wave 2 and were between 29.80 and 32.90 months of age (M = 30.95, SD = .78).

Measures

Language Exposure Questionnaire (LEQ). The Language Exposure Questionnaire (LEQ) has been used in previous studies to differentiate bilinguals from monolinguals (Bosch & Sebastian-Galles, 1997; Fennell, Byers-Heinlein, & Werker, 2007). The experimenter administered an electronic adaptation of the LEQ (DeAnda, Arias-Triejo, Poulin-Dubois, Zesiger, & Friend, in press) through a semi-structured interview with the child's parents, in which they were asked about who converses with their child on a weekly basis (e.g., parents, grandparents, educators), what language they speak to their child, and for how many hours. A global estimate of the proportion of time the child is exposed to each language was calculated.

MacArthur-Bates Communicative Development Inventory: Words and Sentences (MCDI: WS). The MCDI: WS is a parent report vocabulary checklist that measures toddlers' expressive vocabulary and proportion of translation equivalents. The English version (Fenson et al., 1993) and the French Canadian version (Trudeau, Frank, & Poulin-Dubois, 1999) contain 680 and 624 words, respectively, and include nouns, verbs, and adjectives that are appropriate for toddlers 16 to 30 months of age.

Executive Function Tasks. Four executive function tasks were administered, which consisted of two conflict tasks, a delay task, and a working memory/response control task. These tasks were chosen based on a battery of tasks from Carlson (2005) that have been used to measure executive function in toddlers.

Conflict Tasks.

Reverse Categorization Task. The Reverse Categorization task (adapted from Carlson, Mandell, & Williams, 2004) is a measure of cognitive flexibility, which consists of a pre-switch phase and a post-switch phase. The experimenter presented the child with a big bucket and a little bucket, and then set them aside. Six big blocks and six little blocks were then presented to the child, and the child was given 20 s to play with them. In the pre-switch phase, the experimenter placed the buckets back on the table, and demonstrated that the little blocks go in the little bucket and the big blocks go in the big buckets. The child was asked to help for six trials. The experimenter verbally repeated the rule, gave the child the block, and placed the two buckets in front of him or her for each trial. In the post-switch phase, the experimenter said that they are going to play a silly game, where they will put the little blocks in the big bucket and the big blocks in the little bucket. The same procedure followed for a total of 12 trials. The number of correct trials from the post-switch phase was recorded.

Shape Stroop Task. The Shape Stroop task (adapted from Kochanska, Murray, & Harlan, 2000) is a measure of inhibitory control, which consists of an identification phase and a Stroop phase. In the identification phase, the experimenter presented the child with three colored images of fruits (apple, banana and orange), and then presented the child with the same fruits but smaller in size aligned below the larger fruit. The experimenter then labeled each of the six fruits by name and size. Following this, the images of the smaller fruits were removed, and the experimenter asked the child to point to each fruit. Verbal reinforcement was given, as well as the correct answer if necessary. In the Stroop phase, the experimenter presented the child with three colored images of small fruits embedded in different larger fruits (e.g., a small apple in a big banana). The experimenter then asked the child to point to each little fruit (e.g., "Show me the little apple"), and no feedback was provided. The number of trials from the Stroop phase where the child correctly identified the little fruits was recorded.

Delay Task.

Gift Delay Task. The Gift Delay task (adapted from Kochanska et al., 2000) is a measure of response suppression. First, the experimenter placed a gold gift bag on the table and told the child that they were getting a gift for doing such a great job. Following this, the experimenter looked at the gift bag and told the child "Uh oh! I forgot the bow! Let me go get it. But let's play another game. Sit here and don't open the present until I come back with the bow. Don't touch the gift until I come back with the bow, okay?" The experimenter then left the room for three minutes or until the child opened the gift. The child was given a score from 1 to 5 (1 = pulls gift from bag, 2 = searches bag, 3 = touches bag many times, 4 = touches bag once, 5 = does not touch bag).

Response Control and Working Memory task.

Multilocation Task. The Multilocation task (adapted Zelazo, Reznick, & Spinazzola, 1998) is a measure of working-memory and response control, which consists of a pre-switch and post-switch phase. A wooden box with five drawers was placed in front of the child, with the center drawer having a knob with an animal on it. The two drawers adjacent to the center drawer had no knobs and were glued shut, while the furthest right and furthest left drawers were bare but not glued shut. During the warm-up trial, the experimenter put a treat in the center drawer and showed the child how to retrieve the treat. The pre-switch phase followed the warm-up trial, whereby the experimenter switched the furthest right and furthest left drawers to new drawers with knobs of two different animals. The experimenter hid a treat in the center drawer and said, “Here is the treat” and pointed to the correct location. The experimenter then pointed to the furthest right and left drawers and said, “There is no treat here”. A towel was then placed on the wooden box and the child was asked to find the treat. The pre-switch phase ended once the child retrieved the treat from the center drawer three times in a row. Following this, the post-switch phase was administered where the experimenter hid the treat in either the furthest right or left drawers through counterbalancing, and followed the same script showing the child where the treat is located. However, a 10 second delay was imposed before asking the child to find the treat. The number of trials (maximum 6) required to find the treat in the new location was recorded.

Procedure

Bilingual participants visited the laboratory at Wave 1 when they were 24 months. The LEQ was administered to the parents to ensure that participants met the criteria for bilingualism. Following this, parents were instructed on how to fill out the MCDI: WS. If the parents were an expert in English and/or French, then they were asked to complete the vocabulary checklist. If not, then someone who communicates with the child in that language and who has a good knowledge of the child's vocabulary completed the questionnaire (e.g., educator, grandparents). The proportion of translation equivalents (TEs) were calculated using the MCDI: WS by subtracting the number of cognate pairs (e.g., *block* and *bloc*) and semi-cognates pairs (e.g., *mittens* and *mitaines*) from the number of TE pairs, multiplying this number by two, and then dividing this number by their total vocabulary, minus the number of cognates, semi-cognates, and non-equivalents. Cognates and semi-cognates were subtracted from the TE pairs as they can inflate the proportion of TEs due to their similar phonology (Bosch & Ramon-Casas, 2014). Non-equivalents are words that do not have a translation on the MCDI: WS. Conceptual vocabulary was also assessed through the MCDI: WS by subtracting the TEs from the total number of words produced.

Bilingual participants returned to the laboratory 7 months later (M = 6.90, SD = .55) when they were 31 months old, and the same procedure was administered. However, at this wave, executive function tasks were added to the procedure and were administered in the child's dominant language in a fixed order (Multilocation task, Reverse Categorization task, Shape Stroop task, Gift Delay task). All of these tasks at Wave 2 were administered on a table where the child sat across from the experimenter in a high chair, with their caregiver(s) sitting behind them. At both waves, parents received $25 financial compensation, and children received a gift and a certificate of merit. At this second wave, monolinguals were tested on the executive function tasks to compare performance across groups, and parents were given the MCDI to fill out in English.

Results

Between Group Comparisons

The vocabulary of the two groups was first analyzed to compare participants' language abilities. In line with previous research, a significant difference was found between monolinguals and bilinguals in their L1 on the MCDI, $t(80) = 3.06$, $p = .003$, $d = .68$. Monolinguals produced an average of 523.07 words ($SD = 163.10$) whereas bilinguals produced an average of 419.13 words ($SD = 141.93$) in their L1. Similarly, monolinguals' vocabulary ($M = 523.07$, $SD = 163.10$) was slightly higher than bilinguals' conceptual (total vocabulary minus translation equivalents) vocabulary ($M = 457.92$, $SD = 142.62$), $t(80) = 1.92$, $p = .06$, $d = .43$. Furthermore, there were no significant differences in age, $t(80) = 1.90$, $p = .85$, gender, $\chi^2 = 1.79$, $p = .18$, or maternal education, $t(80) = -1.37$, $p = .18$. A series of independent t-tests were computed to compare bilinguals and monolinguals on the conflict tasks, gift delay task, and multilocation task.

Conflict tasks.

To obtain a composite estimate of set-shifting, we combined the scores on the Shape Stroop and Reverse Categorization tasks by calculating the total score, as both tasks measure attention to conflicting information. Furthermore, both tasks were significantly correlated, $r(70) = .34$, $p = .003$. Twenty-nine bilingual participants were included in the conflict tasks as an additional ten bilingual participants were excluded due to fussiness ($n = 6$) or failure to pass the training trials ($n = 4$). All 43 monolingual participants were included in the conflict tasks. The mean number of correct responses in the pre-switch trials for bilingual participants was 8.48 ($SD = .12$), and 8.27 ($SD = 1.33$) for monolingual participants. No significant difference was found between the groups on the pre-switch trials, $t(70) = -.66$, $p = .51$, $d = -.17$. In terms of post-switch trials, the mean number of correct responses for bilingual participants was 10.38 ($SD = 4.70$), and 8.11 ($SD = 4.76$) for monolinguals. As expected, bilinguals had superior performance to monolinguals on the post-switch trials of the conflict tasks, $t(70) = -1.99$, $p = .05$, d = -.48 (see Table 1).

Table 1

Mean scores on the executive function tasks for each group

	Monolinguals			Bilinguals		
	M	*SD*	Range	*M*	*SD*	Range
Composite Conflict Tasks						
Number of correct pre-switch trials	8.27	1.33	4–9	8.48	1.21	3–9
Number of correct post-switch trials	8.11	4.76	0–15	10.38	4.70	0–15
Gift Delay Task						
Scale Score	3.79	1.26	1–5	3.23	1.40	1–5
Multilocation Task						
Number of correct trials	1.15	.48	1–3	1.37	.67	1–3

Gift Delay task.

Thirty-five bilingual participants were included in the Gift Delay task as an additional four bilingual participants were excluded due to fussiness ($n = 1$) or parental interference ($n = 3$). All 43 monolingual participants were included in this task. Bilingual participants obtained a mean score of 3.23 ($SD = 1.40$) and monolinguals obtained a mean score of 3.79 ($SD = 1.26$), indicating that on average, participants in both groups touched the gift bag many times when the experimenter was not present in the room. As expected, the bilinguals did not have a superior performance on the gift delay task. In fact, the monolinguals performed better than the bilinguals at the trend level, $t(76) = 1.85$, $p = .07$, $d = .42$ (see Table 1).

Multilocation task.

Thirty-eight bilingual participants and 40 monolingual participants were included in the Multilocation task as an additional four participants (1 bilingual and 3 monolingual) were excluded due to parental interference ($n = 1$), fussiness ($n = 1$), and not completing the pre-switch trials ($n = 2$). Two outliers in the bilingual group and one outlier in the monolingual group were found and were transformed to the next most extreme score within three standard deviations from the mean. The mean number of trials it took for bilingual participants to retrieve the treat three times in a row in the pre-switch phase was 3.34 ($SD = 1.19$), and 2.70 ($SD = .86$). The mean number of trials to retrieve the treat in the new location in the post-switch trials for bilingual participants was 1.37 ($SD = .67$) and 1.15 ($SD = .48$) for the monolinguals. As expected, no significant difference was found between the bilinguals ($M = 1.37$, $SD = .67$) and monolinguals ($M = 1.15$, $SD = .48$) on the post-switch trials of the Multilocation task, $t(76) = -1.65$, $p = .10$, $d = -.38$ (see Table 1).

Bilingual Within-Sample Comparisons

We first examined bilinguals' conceptual vocabulary and proportion of TEs at both waves. Participants had a mean conceptual vocabulary of 262.87 words ($SD = 162.22$) at Wave 1 and 457.92 ($SD = 142.62$) at Wave 2, confirming an increase in conceptual vocabulary ($SD = 99.93$), $t(38) = 12.19$, $p < .001$, $d = 1.28$. A positive correlation between conceptual vocabulary at Wave 1 and Wave 2 was found, $r(37) = .79$, $p < .001$. Additionally, participants' mean proportion of TEs was 46.89% ($SD = 19.00$) at Wave 1 and 57.75% ($SD = 25.05$) at Wave 2, $t(38) = 2.95$, $p = .005$, $d = .49$. A positive correlation between the proportion of TEs at Wave 1 and Wave 2 was also observed, $r(37) = .48$, $p = .002$.

Zero-order correlations were first computed between the difference in proportion of TEs across waves and executive function scores. The change in proportion of TEs from Wave 1 to

Wave 2 was significantly correlated with performance on the conflict tasks, $r(27) = .379$, $p = .043$. No such effect was found between the change in proportion of TEs and performance on the Gift Delay task, $r(33) = -.072$, $p = .679$, or Multilocation task, $r(36) = .152$, $p = .362$.

A series of three hierarchical multiple regression analyses were conducted to evaluate how well an increase in proportion of TEs during the second and third year of life predict performance on executive function tasks. However, in order to ensure that the relation between these conflict executive function tasks and an increase in proportion of TEs was not solely due to a larger increase in vocabulary size, the difference score in conceptual vocabulary was included as a predictor. For each regression, a difference score representing the change in children's conceptual vocabulary from Wave 1 to Wave 2 was entered in Step 1, and the change in proportion of TEs from Wave 1 to Wave 2 was entered in Step 2. The criterion variable was performance on the conflict tasks, Gift Delay task, and Multilocation task at Wave 2.

Conflict Tasks.

In Step 1 of the regression model, the difference score of conceptual vocabulary only explained 2.3% of the variance in performance on the conflict tasks. When the difference score of proportion of TEs was added to the model in Step 2, the predictor explained an additional 12.1% of the variance in performance on the conflict tasks above and beyond the variance explained by the difference score of conceptual vocabulary, $\Delta R^2 = 12.1$, $\Delta F(1, 26) = 3.68$, $p = .066$ (see Table 2). The difference score of proportion of TEs predicted performance on the conflict tasks at the trend level, $\beta = .37$, $t(28) = 1.92$, $p = .066$. In other words, a larger increase in proportion of TEs from Wave 1 to Wave 2 is associated with a higher number of correct post-trials on the conflict tasks. These results indicate that the predictive power of the difference score of proportion of TEs is approximately 6 times greater than the difference score of conceptual vocabulary. Importantly, there was no significant relation between change in proportion of TEs and performance on the pre-trials in the conflict tasks, β = .09, $t(28) = .45$, $p = .66$, indicating that the trend can be attributed exclusively to those trials that required a shift in set.

Table 2

Conflict task scores regressed on growth of proportion of TEs controlling for growth of conceptual vocabulary

Predictors	B	SE	β	t	p	ΔR^2
Step 1						.023
Difference score in conceptual vocabulary	.007	.009	.152	.797	.432	
Step 2						.121
Difference score in conceptual vocabulary	.001	.009	.027	.142	.888	
Difference score in proportion of TEs	.082	.043	.370	1.918	.066	

Gift Delay Task.

In Step 1 of the regression model, the difference score of conceptual vocabulary explained 3.2% of the variance in performance on the delay task. When the difference score of proportion of TEs was added to the model in Step 2, the predictor only explained an additional 2.6% of the variance in performance on the delay task above and beyond the variance explained by the difference score of conceptual vocabulary, $\Delta R^2 = .03$, $\Delta F(1, 34) = .89$, $p = .38$ (see Table 3). As expected, change in proportion of TEs did not significantly predict performance on the delay task, β = -.18, $t(34) = -.94$, $p = .35$.

Table 3

Gift Delay task score regressed on growth of proportion of TEs controlling for growth of conceptual vocabulary

Predictors	B	SE	β	t	p	ΔR^2
Step 1						.032
Difference score in conceptual vocabulary	.002	.002	.180	1.051	.301	
Step 2						.026
Difference score in conceptual vocabulary	.003	.003	.254	1.346	.188	
Difference score in proportion of TEs	-.011	.011	-.178	-.944	.352	

Multilocation Task.

In Step 1 of the regression model, the difference score of conceptual vocabulary only explained 1% of the variance in performance on the Multilocation task. When change in proportion of TEs was added to the model in Step 2, the predictor only explained an additional 2.3% of the variance in performance on this task above and beyond the variance explained by the difference score of conceptual vocabulary, $\Delta R^2 = .02$, $\Delta F(1, 35) = .82$, $p = .37$. The change in proportion of TEs did not significantly predict performance on the Multilocation task, $\beta = .16$, $t(37) = .91$, $p = .37$.

Discussion

The present research provides a unique contribution to the literature on the cognitive benefits of bilingualism, as this is the first study to assess the cognitive advantages of early bilingualism using a longitudinal design. In addition to examining differences in executive function abilities between monolingual and bilingual toddlers, the design of the present study allowed for within-group comparison in order to investigate mechanisms to explain the superior performance of the bilingual group. Consequently, we were able to assess whether becoming more fluent in two languages, as shown by increases in proportion of TEs over 7 months, predict later executive function abilities. We replicated previous research showing a bilingual advantage exclusively on the executive function conflict tasks, such that bilinguals outperformed their monolingual counterparts. Moreover, as anticipated, a larger increase in toddlers' proportion of TEs predicted stronger executive function mechanisms, even though the effect was modest. What is noteworthy is that the observed effect was specific to those executive function abilities on which bilingual individuals typically show an advantage (e.g., inhibition of attention to conflicting responses options) but not others (e.g., working memory, inhibition of habitual response). Moreover, only the measure of increase in bilingualism (translation equivalents) and not vocabulary growth per se predicted the cognitive benefits. This supports the notion that language switching underlies the bilingual advantage on conflict tasks. Although the effect size is small, this is the first study to look at variability in fluency among young bilinguals and executive function using a longitudinal design and offers a new way to examine this relation. Further, our within-sample design addresses some of the concerns raised about the numerous studies based on between-group comparisons (monolinguals versus bilinguals), as these results have been challenged as due to potential confounding variables such as SES (Morton & Harper, 2007; but see Barac & Bialystok, 2012).

As in a previous study comparing executive function in monolingual and bilingual toddlers (Poulin-Dubois et al., 2011), a battery of tasks was administered to evaluate different aspects of executive function, including selective attention, cognitive flexibility, and response inhibition. It is important to assess both conflict inhibition and response suppression because prior studies have shown that bilinguals do not outperform monolinguals on all measures of inhibition (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Poulin-Dubois et al., 2011). Bilingual children typically show superior performance on conflict tasks in which they are required to inhibit their attention to a non-target stimulus and focus on the relevant one, but this group difference is not found on delay tasks in which they are required to suppress a desired action (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Poulin-Dubois et al., 2011). Furthermore, many studies have found no bilingual advantage on tasks assessing working memory (e.g., Bialystok, Craik, & Luk, 2008; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012), with bilingual advantages appearing only from working memory tasks that impose subsequent cognitive demands (Morales, Calvo, & Bialystok, 2013). Our results are consistent with these findings in two ways: bilingual toddlers outperformed monolinguals only on conflict tasks, and change in proportion of TEs from Wave 1 to Wave 2 predicted executive function, but only on conflict tasks. In support of our hypothesis, it appears that as bilingual toddlers progress through lexical development and acquire more TEs in their expressive vocabularies, their cognitive flexibility and selective attention is enhanced. We would therefore expect this effect to be more robust later in childhood, as children become more proficient in both languages.

The present findings are consistent with recent cross-sectional studies showing a gradient in the cognitive advantages of bilingualism as a function of practice. Studies have shown that individuals who learn a second language earlier in life and actively use both languages more frequently have a superior performance on conflict tasks than individuals who learn a second language later on and do not use both languages as frequently (Luk et al., 2011; Poarch & Van Hell, 2012). Furthermore, studies have demonstrated that the differences in executive function abilities between monolinguals and bilinguals become larger as children grow older (Adesope et al., 2010; Bialystok et al., 2010; Poulin-Dubois et al., 2011). Based on this previous research, we used a direct measure of practice by examining increases in proportion of TEs in expressive vocabulary from 24 to 31 months of age. It was theorized that toddlers would acquire more practice in control over which language to choose given the speaking context while avoiding interference from the language not in use. Given that increases in conceptual vocabulary score had a weaker association with performance on conflict tasks compared to increases in proportion of TEs, it appears that the ability to produce words in two languages is central to strengthening executive function in bilingual children.

It is worth noting that approximately 46% of children's expressive vocabulary was made up of TEs at Wave 1, and approximately 57% at Wave 2, with considerable variability across children. This finding provides evidence that by the end of the third year, the average bilingual child uses two words for most concepts in his or her vocabulary. Thus, young bilingual children develop experience switching across lexical systems, and this switching becomes more frequent as children grow older and as their vocabulary size increases. Therefore, the superior performance on these conflict tasks appears to be due to bilinguals' strengthened cognitive flexibility and selective attention abilities as they have increased experience in switching across languages in expressive vocabulary.

It is important to note that the statistical effects found in the present paper are modest, and do not account for the majority of variance in performance on executive function conflict tasks. One explanation is that proportion of TEs is only a proxy of language switching, in that it is not directly measuring how frequently a bilingual child switches across language systems. For example, two children might have the same proportion of TEs in their vocabulary but may have different opportunities to switch across languages. Future research should examine whether increased usage of TEs represents a stronger predictor of performance on conflict tasks.

In sum, the present study offers a unique insight into the cognitive benefits of bilingualism. Our results demonstrate that learning cross-language synonyms positively affects executive function early in development ostensibly through children's increased opportunities for switching across lexical systems. Furthermore, the present findings support the prevailing hypothesis in the literature, that relative to monolinguals, bilinguals have superior selective attention and inhibitory control through focusing their attention to the target language and ignoring the non-target language. The present study provides evidence in a unique way that the bilingual advantage stems from extensive practice of these executive function abilities early in development.

References

Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research*, *80*(2), 207–245. doi:10.3102/0034654310368803

Antón, E., Duñabeitia, J. A., Estévez, A., Hernández, J. A., Castillo, A., Fuentes, L. J., … Carreiras, M. (2014). Is there a bilingual advantage in the ANT task? Evidence from children. *Frontiers in Psychology*, *5*. doi:10.3389/fpsyg.2014.00398

Barac, R., & Bialystok, E. (2012). Bilingual effects on cognitive and linguistic development: Role of language, cultural background, and education. *Child Development*, *83*(2), 413–422. doi:10.1111/j.1467-8624.2011.01707.x

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

Bialystok, E. (2005). Consequences of bilingualism for cognitive development. In J. F. Kroll & A. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 417-432). Oxford: Oxford University Press.

Bialystok, E. (2008). Cognitive effects of bilingualism: How linguistic experience leads to cognitive change. *International Journal of Bilingual Education and Bilingualism*, *10*(3), 210–223. doi:10.2167/beb441.0

Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development*, *11*(4), 485–508. doi:10.1080/15248372.2010.516420

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. doi:10.1037/0278-7393.34.4.859

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science*, *7*(3), 325–339. doi:10.1111/j.1467-7687.2004.00351.x

Bosch, L., & Ramon-Casas, M. (2014). First translation equivalents in bilingual toddlers' expressive vocabulary: Does form similarity matter?. *International Journal Of Behavioral Development*, *38*(4), 317-322. doi:10.1177/0165025414532559

Bosch, L., & Sebastián-Gallés, N. (1997). Native-language recognition abilities in 4-month-old infants from monolingual and bilingual environments. *Cognition*, *65*(1), 33–69. doi:10.1016/S0010-0277(97)00040-1

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology*, *40*(6), 1105–1122. doi:10.1037/0012-1649.40.6.1105

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. doi:10.1111/j.1467-7687.2008.00675.x

Colomé, À. (2001). Lexical activation in bilinguals' speech production: Language-specific or language-independent? *Journal of Memory and Language*, *45*(4), 721–736. doi:10.1006/jmla.2001.2793

DeAnda, S., Arias-Triejo, N., Poulin-Dubois, D., Zesiger, P., & Friend, M. (in press). Effects of Minimal L2 Exposure and SES on Early Word Comprehension in English and Spanish: New Evidence from a Direct Assessment. *Journal of Bilingualism: Language and Cognition*.

Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited: Myth or reality? *Experimental Psychology*, *61*(3), 234–251. doi:10.1027/1618-3169/a000243

Engel de Abreu, P. M. J., Cruz-Santos, A., Tourinho, C. J., Martin, R., & Bialystok, E. (2012). Bilingualism enriches the poor: Enhanced cognitive control in low-income minority children. *Psychological Science*, *23*(11), 1364–1371. doi:10.1177/0956797612443836

Fennell, C. T., Byers-Heinlein, K., & Werker, J. F. (2007). Using speech sounds to guide word learning: The case of bilingual infants. *Child Development*, *78*(5), 1510–1525. doi:10.1111/j.1467-8624.2007.01080.x

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., et al (1993). The MacArthur Communicative Development Inventories: User's guide and technical manual. San Diego: Singular Publishing Group. doi:10.1017/S0142716400001053

Gathercole, V. C. M., Thomas, E. M., Kennedy, I., Prys, C., Young, N., Viñas Guasch, N., … Jones, L. (2014). Does language dominance affect cognitive performance in bilinguals? Lifespan evidence from preschoolers through older adults on card sorting, Simon, and metalinguistic tasks. *Frontiers in Psychology*, *5*. doi:10.3389/fpsyg.2014.00011

Genesee, F., & Nicoladis, E. (2007). Bilingual acquisition. In E. Hoff & M. Shatz (Eds.), *Handbook of language development* (pp. 324–342). Oxford, UK: Blackwell.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and cognition*, *1*(02), 67–81. doi:10.1017/S1366728998000133

Grosjean, F. (2010). *Bilingual: life and reality*. Cambridge, MA, US: Harvard University Press.

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, *36*(2), 220–232. doi:10.1037/0012-1649.36.2.220

Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology, 25*(5), 497–514. doi:10.1080/20445911.2013.799170.

Kroll, J. F., Dussias, P. E., Bogulski, C. A., & Kroff, J. R. V. (2012). Juggling two languages in one mind: What bilinguals tell us about language processing and its consequences for cognition. In B.H. Ross (Ed.), The *psychology of learning and motivation* (Vol. 56) (pp. 229–262). San Diego, CA, US: Elsevier Academic Press. doi:10.1016/B978-0-12-394393-4.00007-8

Luk, G., De Sa, E., & Bialystok, E. (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition*, *14*(4), 588–595. doi:10.1017/S1366728911000010

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *11*(1). doi:10.1017/S1366728907003227

Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *114*(2), 187–202. doi:10.1016/j.jecp.2012.09.002

Morton, J. B., & Harper, S. N. (2007). What did Simon say? Revisiting the bilingual advantage. *Developmental Science*, *10*(6), 719–726. doi:10.1111/j.1467-7687.2007.00623.x

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology*, *66*(2), 232–258. doi:10.1016/j.cogpsych.2012.12.002

Patterson, J., & Pearson, B. Z. (2004). Bilingual lexical development: Influences, contexts, and processes. In B.A. Goldstein (Ed.), *Bilingual language development and disorders in Spanish—English speakers* (pp. 77–104). Baltimore, MD: Paul H Brookes Publishing.

Pearson, B. Z., Fernandez, S. C., Lewedeg, V., & Oller, D. K. (1997). The relation of input factors to lexical learning by bilingual infants. *Applied Psycholinguistics*, *18*(1), 41-58. doi:10.1017/S0142716400009863

Poarch, G. J., & van Hell, J. G. (2012). Executive functions and inhibitory control in multilingual children: Evidence from second-language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology*, *113*(4), 535–551. doi:10.1016/j.jecp.2012.06.013

Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology*, *108*(3), 567–579. doi:10.1016/j.jecp.2010.10.009

Rodriguez-Fornells, A., van der Lugt, A., Rotte, M., Britti, B., Heinze, H.-J., & Münte, T. F. (2005). Second language interferes with word production in fluent bilinguals: Brain potential and functional imaging evidence. *Journal of Cognitive Neuroscience*, *17*(3), 422–433. doi:10.1162/0898929053279559

Singh, L. (2014). One world, two languages: Cross-language semantic priming in bilingual toddlers. *Child Development*, *85*(2), 755–766. doi:10.1111/cdev.12133

Trudeau, N., Frank, I., & Poulin-Dubois, D. (1999). Une adaptation en français québécois du MacArthur Communicative Development Inventory [A Quebec-French Adaptation of the

MacArthur Communicative Development Inventory]. *La revue d'orthophonie et d'audiologie*, *23*, 61–73.

Von Holzen, K., & Mani, N. (2012). Language nonselective lexical access in bilingual toddlers. *Journal of Experimental Child Psychology*, *113*(4), 569–586. doi:10.1016/j.jecp.2012.08.001

Zelazo, P. D., Reznick, J. S., & Spinazzola, J. (1998). Representational flexibility and response control in a multistep multilocation search task. *Developmental Psychology*, *34*(2), 203–214. doi:10.1037/0012-1649.34.2.203

Appendix A

Language Exposure Questionnaire

Path to Literacy
Bilingual Language Exposure Questionnaire

Date of Study: _______________ E1 and E2 initials: _____________________

Study ID: _________ Study Name: Path to Literacy

Child's Date of Birth: ________________ Parent/Caregiver: ______________________

<u>Language Environment</u>

Global Parent Estimate: French [ ] **English** [ ] **Other** [ ]

Who spends time with the baby and what languages do they speak (Exposure to monolingual or to bilingual adults)?

Person	**Language 1**	**%**	**Language 2**	**%**	**Notes**

Waking Hours (nap time hours)

Mother's Work Hours

Father's Work Hours

Daycare Hours

Other Hours

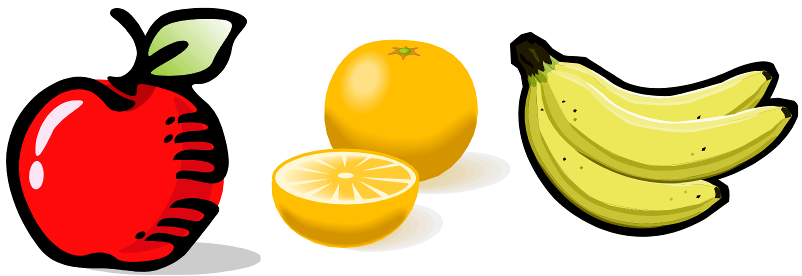
Appendix B

Executive Function Stimuli

Multilocation Task

Shape Stroop Task

Identification Trials



Stroop Trials

Reverse Categorization Task

Gift Delay Task

Appendix C

Executive Function Coding Sheets

ID: ______________ Experimenter: _______________ Date tested: _______________

Coder: ___________ Date coded: _____________ Language: __________ Lap Baby: Y N

Multilocation Task Completed: O yes O no

Warm-up:

Number of trials it took child to get the treat alone: ________

Pre-switch:

Number of trials it took child to get 3 in a row correct: ________

Post-switch:

Number of trials it took child to go directly to new location: ________ max: 6

COMMENTS:

____

____

____

____

Reverse Categorization Completed: O yes O no

Pre-switch Training

Can you show me where the **little** block goes?

# of prompts until correct response _____ never got (99)

Can you show me where the **big** block goes?

# of prompts until correct response _____ never got (99)

Pre-switch trials

Big blocks go here and little blocks go here.

1) Here is a **little** block. BIG _____ **Small** _____

2) Here is a **big** block. **BIG** _____ Small _____

3)	Here is a **little** block.	BIG _____	**Small** _____
4)	Here is a **big** block.	**BIG _____**	Small _____
5)	Here is a **big** block.	**BIG** _____	Small _____
6)	Here is a **little** block.	BIG _____	**Small** _____

Total # correct _____ out of _____ trials = _____ % correct PRE-SWITCH

<u>Post-switch Training</u>

Can you show me where the **little** block goes?

# of prompts until correct response _____ never got (99)

Can you show me where the **big** block goes?

# of prompts until correct response _____ never got (99)

<u>Post-switch trials</u>

Big blocks go here and little blocks go here.

1)	Here is a **little** block.	**BIG** _____	Small _____
2)	Here is a **big** block.	BIG _____	**Small** _____
3)	Here is a **big** block.	BIG _____	**Small** _____
4)	Here is a **big** block.	BIG _____	**Small** _____
5)	Here is a **little** block.	**BIG** _____	Small _____
6)	Here is a **little** block.	**BIG** _____	Small _____
7)	Here is a **little** block.	**BIG** _____	Small _____
8)	Here is a **little** block.	**BIG** _____	Small _____
9)	Here is a **big** block.	BIG _____	**Small** _____
10)	Here is a **big** block.	BIG _____	**Small** _____
11)	Here is a **little** block.	**BIG** _____	Small _____

12) Here is a **big** block. BIG _____ **Small** _____

Total # correct _____ out of _____ trials = _____ % correct POST-SWITCH

COMMENTS:

____
____
____
____

Shape Stroop
Completed: O yes O no

Identification:

1) Show me the APPLE Apple _____ Other ______ None _____

2) Show me the ORANGE Orange _____ Other ________ None ______

3) Show me the BANANA Banana _____ Other ________ None ______

Number of correct trials: _______

Shape Stroop- Little Fruit:

1) Now show me the LITTLE apple
Little apple _____ Big apple _____ Other _________ None _____

2) Now show me the LITTLE banana
Little banana _____ Big banana _____ Other _________ None _____

3) Now show me the LITTLE orange
Little Orange _____ Big Orange _____ Other _________ None _____

Number of correct trials: ____

COMMENTS:

____
____
____
____

Gift Delay
Completed: O yes O no

Score:

1: Pulls gift from bag
2: Search in bag
3: Touches many times
4: Touches once
5: No touch

Latency coding:

Latency to touches bag: ______________ in seconds

Latency to open bag: ______________ in seconds

COMMENTS:
____
____
____
____