Bilingual Proficiency Influences the Relationship between Code-Switching and Task-Switching in 8-Year-Old English-Chinese Singaporean Children

Carissa Kang and Barbara Lust

1. Introduction

A bilingual cognitive advantage has been well-documented, with many studies showing that bilingualism offers a host of positive cognitive consequences across the lifespan (see Adesope et al. (2010) for review). Some of these cognitive consequences include advantages in switching flexibly between two different rule sets in a task and being able to focus and ignore distracting information. These are broadly known as advantages in Executive Function (EF), or the set of inter-related attentional processes needed for planning, making decisions, and overcoming habitual actions. Although the bilingual EF advantage is well-attested, the specific mechanisms underlying this EF advantage are still unclear. It is necessary to investigate which aspects of the bilingual language experience might boost EF skills (Valian, 2015).

Intuitively, a bilingual’s language switching skills might result in the EF advantage, given that this is a cognitively demanding skill that monolinguals do not develop (Prior & Gollan, 2011). Language switching, or code-switching (CS) is loosely defined as alternating between two or more languages within a conversational discourse. A growing body of research has shown that the language control or switching abilities of bilinguals are associated with complex neural network systems like the dorsolateral prefrontal cortex (PFC) (Abutalebi & Green, 2007; Rodriguez-Fornells et al., 2005) and Anterior Cingulate Cortex (ACC) (Wang et al., 2007; Abutalebi & Green, 2007). Importantly, these same neural structures are also involved in general cognitive control (e.g., Abutalebi & Green, 2007).

CS has been most commonly linked to one specific aspect of EF – task-switching. During task-switching, an individual must keep two sets of rules active and shift attention between these two rule sets to perform the task accurately. A typical task-switching paradigm has two sets of rules – e.g., sorting stimuli by either shape and color. For example, when a participant sees a color wheel, he/she has to sort the target stimulus by color, and when a star-shaped object appears, he/she has to sort it according to shape. Task switching

* Carissa Kang, Cornell University, ck577@cornell.edu. We thank our research assistants (Cynthia Li, Yingxuan Chen and Jing Zheng) for their help with this project, and the cooperation of the school and parents in Singapore.

paradigms usually comprise 3 conditions. In the first blocked condition, participants sort the stimulus by a single rule (e.g., shape). The second blocked condition then requires participants to sort the stimulus by the other rule – color. Finally, in the mixed condition, participants have to sort the stimulus alternatively either by shape or color. As the cues appear randomly during this condition, performance for this condition is typically slower and/or less accurate. A switch cost is then calculated using the difference between accuracy and RT on blocked conditions and accuracy on mixed condition.

Several studies have revealed that adults who were proficient at CS were also good at task-switching (e.g., Prior & Gollan, 2011; Soveri, Rodriguez-Fornells & Laine, 2011; Yim & Bialystok, 2012). Yim & Bialystok (2012) examined if greater CS frequency correlated with better task-switching performance in Cantonese-English bilingual adults. Results revealed that those who switched more during the CS task also incurred smaller costs on verbal task-switching (as measured by their modified Semantic Fluency task).

1.1. Current Study

Our study was part of a larger set of studies examining the relationship between CS and different components of EF (Kang, in prep). In these studies, to measure CS, we developed a novel and ‘natural’ CS task in a discourse format that allows participants to code-switch (or not) on their own accord, attempting to mirror the CS that naturally occurs in bilinguals’ everyday discourse. Our CS task comprises two conditions – inter-sentential and intra-sentential condition. We define inter-sentential CS as when a speaker’s utterance in one language is followed immediately by an utterance in another language (Genesee, Nicoladis, & Paradis, 1995). The example below shows an inter-sentential CS from an English utterance to a Chinese utterance.

A: My mom has short hair and a very bad temper.
A: 我 最 喜欢 和 妈妈 看 故事书
   I most like with mother see storybook
   My favorite thing to do with my mother is to read storybooks.

On the other hand, Intra-sentential CS involves insertions of words or phrases from one language into the other language within a single sentence. In the example below, we see an insertion of the English noun “holiday” into a Chinese sentence:

A: 我 最 喜欢 的 holiday 是 新年
   I most like NOM is New Year (NOM: nominative)
   (My favorite holiday is New Year.)

To explore how CS relates to task-switching, we examine how different components of CS (as measured by our task) relate to switch costs in a verbal
task-switching test. In one component of our study, we used the same Semantic Fluency task as in Yim & Bialystok (2012) to measure verbal switch cost. Developmental data can provide critical insights into foundations of cognitive relations between CS and task-switching. Thus, here, we examine the relationship between CS and task-switching (measured by Semantic Fluency) in children.

Few studies have examined the developmental relationship between CS and task-switching in children. We recruited a sample of a highly bilingual developing population (i.e., Singaporean English-Chinese bilingual children), where CS is prolific. Singapore is a country with a mandatory bilingual education policy. In Singapore, English is taught as the first language and is the official medium of instruction in school. One’s second language (or ‘Mother Tongue’ is usually assigned based on one’s father’s ethnicity (i.e., Mandarin for Chinese, Bahasa Melayu for Malays etc.) and is taught as a secondary language at school. At homes, children are regularly exposed to both languages. Furthermore, due to the multilingual nature of the Singaporean society, pervasive and prolific CS occurs even in English-Chinese preschoolers (Kang, Yow & Lust, 2015; Yow, Patrycia & Flynn, 2016).

Importantly, as advantages in EF have been primarily observed in populations which are balanced bilinguals (i.e., exposed to both languages and speak both well) or have more balanced use of both languages (e.g., Bialystok, Craik & Luk, 2012; Carlson & Meltzoff, 2008; Videsott, Rosa, Wiater, Franceschini & Abutalebi, 2012), we constrain and assess bilingual proficiency. We assess bilingual proficiency through i) a language background questionnaire with caregivers’ estimates of children’s daily use and exposure of both languages (a subset of the Virtual Linguistics Lab Child Multilingualism Questionnaire (VLL CMQ, 2016) that was supplemented with an additional section on CS, ii) exam scores in both languages provided by the school, and iii) a brief production task (Elicited Imitation of complex sentences) in both languages (results from this portion are not reported in this paper).

In sum, we test the relationship between CS and task-switching in a highly proficient sample growing up in an environment where CS occurs pervasively. If CS is related to bilingual EF advantage, this should be evident in development (e.g., those who code-switch more should perform better on task-switching). However, this CS-EF relationship might not be significant in highly proficient bilinguals who frequently and “naturally” code-switch. Critically, we include more extensive assessments of bilingual language proficiency to examine if proficiency is significantly correlated with task-switching performance.

2. Method
2.1. Participants

Forty-three 8-year-old English-Chinese bilingual Chinese children (16 males; \( M = 100.00 \) months, \( SD = 3.32 \)) were recruited from the same Primary School in Singapore. Participants were all Primary Two students from seven different classes. All children were educated in both English and Mandarin at
school daily. Forty-two parents completed a portion of the Virtual Linguistics Lab (VLL) Child Multilingualism Questionnaire (2016) and their responses confirmed that our sample were simultaneous bilinguals who were exposed to both English and Chinese since birth, and spoke both languages at school, at home, and other places.

2.2. Tasks

**Bilingual language proficiency & language background history**

We obtained participants’ final examination scores for both English and Chinese languages from the school. Each language had an oral and written score. Based on the scoring criteria (see Kang & Lust, in prep), we grouped bilinguals into (1) High-proficient balanced bilinguals, (2) Low-proficient balanced bilinguals, (3) English-dominant unbalanced bilinguals, and (4) Chinese-dominant unbalanced bilinguals.

For language background, parents completed part of the VLL Child Multilingualism Questionnaire (2016). They were asked to rate their child’s overall language proficiency levels in both English and Chinese. This was on a scale of 1 to 7 (1: very poor, 2: poor, 3: fair, 4: functional, 5: good, 6: very good, 7: native-like for his/her age). Parents also provided estimates for their child’s daily language exposure and use for two languages. For each variable, the percentages add to 100% – that is, if a child is exposed to English 60% of the time in a typical day, then Chinese exposure would be 40%. We computed two ratios of daily exposure and daily use of English and Chinese (i.e., Daily Exposure/Use Ratio = \( \frac{\text{Percentage exposure or use [English]}}{\text{Percentage exposure or use [Chinese]}} \)). A score of 1 represents equal exposure/use to both languages, a score greater than 1 represents greater exposure/use to English and a score less than 1 represents greater exposure/use to Chinese. In addition, parents were asked to provide a rough estimate of their child’s CS frequency with family and friends on a scale of 1 to 7 (1: hardly ever, 7: all the time).

**Code-Switching (CS) Task**

Our novel CS task (which we describe in greater detail in Kang, in prep) comprised two conditions – inter-sentential (inter-CS) and intra-sentential CS (intra-CS) – with eight questions in each condition. In both conditions, participants were told to answer the questions as fast as possible and to say as much as they can. This ensured that they can choose which language they want to respond in (i.e., internally-generated response) for it to be more reflective of CS in natural discourse. In the Inter-CS condition, the experimenter asked questions in alternating languages (e.g., Question 1 in English, Question 2 in Chinese, Question 3 in English etc.). In the Inter-CS condition, there were 2 question orders – English- or Chinese-first. Order of language was counterbalanced. After each question, the child was given 20 seconds to respond.
After 20 seconds, the experimenter interrupted the child (even if the child was still speaking) and asked another question in the other language, for example, “What were your favorite animals at the zoo? Why?” In the Intra-sentential (Intra-CS) condition, the questions included cross-language insertions. For example,

‘Can you tell me all about yourself? For example, 你的名字, 年龄, and hobbies?’

you NOM name age

(For example, your name, age, and hobbies)

There was only one order of questions in this condition, and all participants completed this task in the same order. For this task, we measured CS Fluency (RT), defined as the time taken for child to respond to each question, and CS Insertion Frequency – broadly defined by the number of times a child inserts words, phrases or other constituents from another language in a sentence.

Semantic Fluency Task

Semantic Fluency is one of two tasks (the other being phonemic fluency) in the Verbal Fluency test that measures executive function and linguistic skills (e.g., Monsell, 2003). In this task, participants were given 30 seconds to list items that belong in a semantic category (e.g., types of animals). Responses were recorded using a handheld digital tape recorder.

There were four conditions in this task – two blocked and two mixed-language conditions. Four categories comprising animals, types of clothing, food and drinks, and body parts were tested. Participants were always first asked to list items once in each language (blocked language conditions). After this, they completed two mixed-language conditions, where items in each category had to be listed in alternate languages without repeating any item in both languages (e.g., for the category “Animals”, an example of how an individual should respond is, “dog, 蛇 (snake), horse, 熊猫 (panda), giraffe, 鱼(fish), etc.”). For the mixed-language conditions, participants were told which language to begin with. None of the categories were repeated, and these were counterbalanced for language and order.

Participants completed the blocked-language conditions first, followed by the two mixed-language conditions. For both blocked- and mixed-language conditions, we counterbalanced the starting language – either English or Chinese first. Incorrect or inaccurate responses were responses that were in the incorrect category, or had language and/or repetition errors (e.g., if the item was listed in the wrong language, or had already been repeated either in the same or the other language). A switch cost was calculated based on the difference between the

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2 Instead of the usual 60 seconds for the Semantic Fluency task, we reduced this to 30 seconds, since pilot testing revealed that it was challenging for children to produce items for the entire 60 seconds.
average number of accurate responses on the blocked-language and the mixed-language conditions. This is similar to calculating a global switch cost in a task-switching paradigm, but there were no non-switch trials in the mixed-language conditions.

2.3. Procedure

When parents completed the consent form and a portion of the VLL Child Language Questionnaire (2016), they returned these forms in sealed envelopes to the school. All participants were interviewed individually in a quiet room at the school. This was part of a larger study that took approximately 25-30 minutes to complete. Participants first completed the CS task, followed by 3 Executive Function tasks (Semantic Fluency, Stroop, and Hearts and Flowers task\(^3\)) and a brief Elicited Imitation (EI) task assessing language production in English and Chinese, with the language order counterbalanced (For description and results of all the other tasks, see Kang, in prep; Kang & Lust, in prep). Participants were given a coloring set (worth $10) each for their participation.

3. Results

3.1. Bilingual language proficiency and VLL Child Multilingual Questionnaire

As reported in Kang & Lust (in prep), our sample comprised 34 Balanced bilinguals, out of which 19 were high-proficient and 15 were low-proficient balanced bilinguals. There were 8 Unbalanced bilinguals, out of which 6 were English-dominant and 2 were Chinese-dominant unbalanced bilinguals.

According to the VLL Child Multilingual Questionnaire (2016), in general, all parents (\(n = 41\)) reported that their child was exposed to and used at least two languages on a daily basis, thus confirming that this sample is productively bilingual. More precise analyses revealed that for Written exam scores in this sample, the average score for English was 90.00% (\(SD = 5.68\)) and 87.53% for Chinese (\(SD = 7.51\)). A paired-samples \(t\)-test revealed that the Written English scores were significantly higher than Written Chinese scores, \(t(41) = 2.10, p < .05\). For Oral exam scores, the average for English was 77.83% (\(SD = 9.68\)) and 82.54% for Chinese (\(SD = 10.51\)). A paired-samples \(t\)-test revealed that Oral Chinese was significantly higher than Oral English, \(t(41) = 2.41, p < .05\).

For parents’ estimates of proficiency level for each language, these were significantly higher for English (\(M = 5.38, SD = 0.80\)) than Chinese (\(M = 5.01, SD = 1.05\)), \(t(40) = 2.10 (p < .05\). The average Daily Language Use Ratio was 6.17 (\(SD = 15.38\)) while average Daily Language Exposure Ratio was 2.85 (\(SD = 3.21\)). On a daily basis, most children were using English 6 times more than Chinese and exposed to English about 3 times more than Chinese. Finally, for CS frequency, the average was 4.04 (out of 7; 4 representing ‘somewhat true’)

\(^3\) Results and details for both the Hearts and Flowers (Davidson, Amso, Anderson & Diamond, 2006) and the Stroop task are not included in this paper.
(SD = 1.63), thus confirming that the sample frequently engaged in CS with family and friends.

Thus, in this highly proficient bilingual population, precise analyses reflected subtle asymmetries that generally pointed to this sample being English-dominant – higher Written English scores, higher parents’ ratings for English proficiency (compared to Chinese) as well as higher daily language exposure and use for English compared to Chinese.

3.2. CS Task

a. CS Fluency

Overall, children were fast at responding to the experimenter’s questions, whether it was in the Inter-CS (Inter-sentential) or Intra-CS (Intra-sentential) condition. Average Inter-CS Fluency was 1.48s (SD = 0.76) while average Intra-CS Fluency was 1.47s (SD = 0.74). A repeated-samples t-test revealed no significant differences in CS Fluency across both conditions, p > .05.

b. CS Insertion Frequency

CS Insertion Frequency was significantly higher in the Intra-CS (M = 4.00, SD = 3.05) compared to Inter-CS condition (M = 0.63, SD = 0.98), t(42) = 7.11, p < .01. This might be expected because the Intra-CS condition comprised mixed-language questions, thereby triggering greater CS, compared to the Inter-CS condition, where questions were asked in either English or Chinese.

3.3. Semantic Fluency Task

On the Semantic Fluency task, participants produced more items in the blocked-language condition (M = 9.00, SD = 1.66) than the mixed-language condition (M = 5.87, SD = 1.25), t(42) = 10.78, p < .01. This is in line with adults’ performance in previous literature (e.g., Yim & Biaystok, 2012). Within the blocked-language condition, participants listed significantly more English (M = 10.35, SD = 3.45) than Chinese items (M = 7.65, SD = 3.06), t(42) = 3.15, p < .01, corresponding to the sample’s English-dominance. Finally, the average switch cost was 3.13 (SD = 1.90). That is, there were approximately 3 less items produced on the mixed-language condition compared to the blocked language condition. Fig. 1 summarizes participants’ performance across each condition on Semantic Fluency.
To examine how language proficiency influences Semantic Fluency performance, we first estimated a multiple regression model predicting Semantic Fluency switch cost from language proficiency scores (e.g., Written and Oral exam scores in both languages). Results revealed that language proficiency explained 17.1% of the variance ($R^2 = .17$, $F(4, 41) = 1.90$, $p > .10$). Oral Chinese significantly predicted switch cost, $B = 0.07$, $SE (B) = 0.03$, $p < .05$.

In addition, we conducted correlational analyses to examine how language proficiency correlated with performance on individual components of Semantic Fluency. Oral Chinese was significantly correlated with a) number of items produced on the Chinese block ($r = 0.35$) and b) with switch cost ($r = 0.33$), both $p$’s < .05. The average items produced on the mixed-language condition were also significantly correlated with Written and Oral English scores, $r = 0.34$ and 0.36 respectively, both $p$’s < .05.

3.4. CS Frequency & Semantic Fluency

Here, we correlated CS Insertion Frequency with Semantic Fluency switch cost. We only used Intra-CS Insertion Frequency because participants rarely code-switched in the Inter-CS condition. Semantic Fluency switch cost was negatively correlated with Intra-CS Insertion Frequency, $r = -0.09$. Although those who code-switched more during our conversational CS task incurred lower switch costs on the Semantic Fluency task, this relationship was not significant, $p > .10$.

3.5. Summary of Results

Our CS task results revealed that our sample was highly proficient at CS. This was reflected in their fast CS Fluency across both conditions, where children responded in approximately 1.5s. Importantly, when we correlated Intra-CS Insertion Frequency and Semantic fluency switch cost, we did not find
a significant relationship between the two, although this was a negative relationship.

However, critically, when we examined the relationship between language proficiency (measured by Written and Oral exam scores in both languages) and Semantic Fluency performance, we found correlations between bilingual asymmetries and components of Semantic Fluency. Oral Chinese performance significantly predicted Semantic Fluency switch cost – the better the Oral Chinese performance, the worse the performance on task-switching.

Correlational analyses also further confirmed that Oral Chinese was positively correlated with number of items produced on the Chinese block in Semantic Fluency. That is, the better the performance on Oral Chinese exam scores, the more Chinese items produced on the Chinese block. In addition, the average items produced on the mixed-language condition were also significantly positively correlated with Written and Oral English scores. The better the performance on English proficiency exams (Written and Oral), the more items produced on the mixed-language condition of the Semantic Fluency task. In sum, these results demonstrate that language asymmetry influences Semantic Fluency performance despite evidence for apparently balanced bilingualism in our sample.

4. Discussion

Overall, we found no significant relationship between CS and task-switching, as measured by the Semantic Fluency task. In previous literature, results had provided evidence that CS Frequency was significantly negatively correlated with Semantic Fluency switch cost (Yim & Bialystok, 2012). That is, the greater the CS frequency, the lower the switch cost. Although we did find a similar negative correlation between the two variables, this relationship was not significant.

An explanation for our insignificant results may lie in the fact that in our population CS occurs pervasively even becoming habitual. This may not tax EF to the same extent as in other populations where bilinguals engage less frequently in CS. That is, the direct link between CS and EF may not hold across all types of bilingual populations, and may be influenced by factors like bilingual language proficiency or the broader sociolinguistic environment (e.g., whether CS occurs pervasively in society).

We also found that bilingual language proficiency asymmetries were correlated with components of the Semantic Fluency task. That is, bilingual language proficiency influenced verbal task-switching performance. Those who had higher Oral Chinese exam scores produced more items in the pure-Chinese block of Semantic Fluency. In addition, those with higher English exam scores (Written and Oral) also produced more items in the mixed-language conditions. This is in line with previous studies showing that bilingual language proficiency and language background (use/exposure) influence EF performance (e.g., Bialystok, Craik & Luk, 2012; Carlson & Meltzoff, 2008; Videsott et al., 2012). The language asymmetry on the performance across different components of
Semantic Fluency task may have contributed to this non-significant relationship. Thus, our results suggest that language proficiency may influence the effects of CS on EF, suggesting that the relation between CS and EF is more indirect than previously assumed (as we argue in Kang & Lust, in prep).

Our results necessitate advancement in the assessment of the precise nature of bilingual proficiency in examining the EF bilingual cognitive advantage (e.g., Lust et al., 2016). Future research would be necessary to tease this issue apart by looking at how the CS-EF relationship may differ across bilinguals.

References


