Title
Beyond the Bilingual Advantage: Links between Code-switching and Task-switching in Bilingual Preschoolers

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**BEYOND THE BILINGUAL ADVANTAGE:
LINKS BETWEEN CODE-SWITCHING AND TASK-SWITCHING
IN BILINGUAL PRESCHOOLERS**

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Abstract

Beyond the Bilingual Advantage:

Links between Code-switching and Task-switching in Bilingual Preschoolers

Priscilla Sung

Inconsistencies in the literature on the effects of bilingualism on executive function (EF) highlight the need for work that identifies specific elements of bilingual experience that enhance specific components of EF. The current study investigated whether code-switching (shifting between languages) is one such bilingual experience that may strengthen task-switching (switching between two sets of rules) in a group of bilingual preschoolers. We measured children's code-switching behaviors in two contexts (home and school), distinguishing between language *switching* (shifting languages when changing conversational partners) and language *mixing* (shifting languages within a sentence while talking to one conversational partner). We tested the hypotheses that frequency of *switching* languages would predict task-switching performance, and that frequency of *mixing* languages would predict task-switching performance, but to a lesser extent than language *switching*. Results showed that language *switching* did not predict task-switching performance, but that language *mixing* significantly predicted some aspects of task-switching performance. Findings identify code-switching experience as a possible mechanism of the bilingual advantage in young children, adding support to other work proposing that the benefits of bilingualism vary across the lifespan.

Keywords: bilingualism, code-switching, task-switching, executive function, children

Dedication

For my parents, who finally won the bet

For my siblings, who knew all along that 講-ing 中文 and 英文 together is 好 for you

- and -

Per il mio Calimero, che mi ha sostenuta durante tutto con amore, umorismo, ed arancini;

senza di te, mi sarei arresa molto tempo fa.

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Beyond the Bilingual Advantage:

Links between Code-switching and Task-switching in Bilingual Preschoolers

A considerable body of empirical evidence in developmental psychology (see Bialystok, 2009, for a review) supports the existence of an early bilingual advantage across a variety of cognitive abilities within executive function (EF). EF is composed of several component parts that are necessary for planning, organizing, multitasking, and focus (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). For example, bilingual children typically demonstrate better inhibitory control (Martin-Rhee & Bialystok, 2008) and conflict resolution (Poarch & van Hell, 2012) than monolingual children, particularly on versions of these tasks that are more cognitively demanding (Bialystok, 2010). Bilingual children also consistently outperform monolingual children in task-switching (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011), a domain of EF that concerns their ability to shift between two different sets of rules.

However, over the last few years, Kenneth Paap and his research team have challenged the existence of a bilingual advantage in EF (Paap, 2014; Paap, Johnson, & Sawi, 2015, 2016; Paap et al., 2017). A number of recent studies with young adults have found no evidence for such an advantage (see Hilchey, Saint-Aubin, & Klein, 2014; Paap et al., 2015, for reviews). These studies find no difference between bilinguals and monolinguals in inhibitory control (Duñabeitia et al., 2014), conflict resolution (Kousaie & Phillips, 2012), selective attention (Goldman, Negen, & Sarnecka, 2014), or task-switching (von Bastian, Souza, & Gade, 2016). Paap et al. (2015) argue that studies reporting bilingual advantages in EF often do not replicate, and there is little convergent validity across different measures of EF subcomponents, making it difficult to uncover the relationship, if any, between bilingualism and EF. They conclude that bilingual advantages may occur “only in very specific circumstances that pair the right set of bilingual experiences with the resonating set of EF measures” (Paap et al., 2015, p. 275–276). In light of the inconsistencies in the literature, there is a need for more clarity regarding precisely which elements of bilingual experience enhance which component(s) of EF, and for which bilingual individuals (Paap & Greenberg, 2013).

Some researchers have proposed that these inconsistencies stem from the fact that links between bilingualism and EF shift over the course of the lifespan, emerging more prominently in childhood and older adulthood than in young adulthood (Yang, Hartanto, & Yang, 2016a). Indeed, bilingual advantages in EF are far more reliable among children and the elderly than among undergraduates (Bialystok, Craik, & Luk, 2012; Cepeda, Kramer, & Gonzalez de Sather, 2001). The current study therefore examined one potential resonating pair between EF and bilingual experience, specifically in young children. Code-switching (CS), defined broadly as shifting between different languages, has emerged as one bilingual experience that may strengthen task-switching (TS) abilities, a component of EF that refers to the impact on performance when switching from one set of rules to another. Given that CS requires that speakers shift between the distinct lexicons and morphosyntax of two language systems, it may be that engaging in CS exercises a general ability to switch between different sets of rules. If young bilingual children engage in CS in their everyday lives, and regular practice with CS indeed exercises cognitive abilities implicated in TS, this likely contributes to TS advantages in young bilingual children.

Organization

We begin by summarizing experimental research that has found TS advantages in bilingual children, and present other language-related factors that may be related to TS performance. We then present the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model of Code-switching (Green & Wei, 2014), which provide the theoretical framework for the current study. Finally, we describe the current study and hypotheses.

Task-switching Advantages in Bilingual Children

Bilingual advantages in TS have been well documented in developmental work comparing the EF abilities of bilingual and monolingual children. Studies have shown that young bilingual children often outperform monolingual children in a variety of TS tasks, and that this advantage persists through the preschool and kindergarten years. For example, bilingual 2.5-year-olds are more accurate than their monolingual counterparts in the Reverse Categorization task (Crivello et al., 2016), replicating similar findings with bilingual 3- and 4.5-year-olds (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010). In this task, children are first asked to sort animals into one of two buckets: large animals go into the “mommy” bucket, and small animals go into the “baby” bucket (pre-switch). Then, they are asked to re-sort the same items using the opposite rule: large animals now go into the “baby” bucket, and small animals go into the “mommy” bucket (post-switch). Children’s accuracy in the post-switch trials is the index of their TS ability.

Other TS tasks developed for this age range use a similar structure. In the Dimensional Change Card Sort (DCCS; Zelazo, 2006), children first classify objects according to one dimension (e.g., by color) in the pre-switch phase, then in the post-switch phase, they classify the same objects according to another dimension (e.g., by shape). Research has consistently shown that bilingual 4- to 6-year-olds make fewer errors than their monolingual peers during the post-switch phase (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Okanda, Moriguchi, & Itakura, 2010). In the advanced form of this task, which involves frequent rule switches between trials, Barac and Bialystok (2012) found that bilingual 5- to 7-year-olds experience smaller losses in speed when required to hold two rules in mind (advanced version) versus one (standard version).

This bilingual advantage in TS has also been replicated in linguistic TS tasks. In the Opposite Worlds task, which Bialystok and Senman (2004) adapted from the Test of Everyday Attention for Children (TEACh; Manly, Robertson, Anderson, & Ninmo-Smith, 1999), children first identify pigs and cows in a depicted scene (pre-switch). During the post-switch phase, they are asked to reclassify the animals according to their "upside-down" name—pigs are called cows, and cows are called pigs. Bilingual children typically outperform monolingual children in the post-switch phase: bilingual 3- and 4.5-year-olds make fewer errors than monolingual children of the same age (Bialystok et al., 2010), and bilingual 5.5-year-olds are both faster and more accurate than their monolingual counterparts (Bialystok & Shapero, 2005).

While there is ample work supporting the existence of a bilingual advantage in both linguistic and nonlinguistic TS in young children, much less is known about the origins of this advantage, or which conditions are necessary in order for this advantage to develop. Some work has suggested that TS abilities may be mediated by bilinguals' proficiencies in their two languages—not only in terms of the overall language proficiencies, but also in terms of the degree of balance between the two (Iluz-Cohen & Armon-Lotem, 2013; Rosselli, Ardila, Lalwani, & Vélez-Uribe, 2016; Tao, Taft, & Gollan, 2015; Yow & Li, 2015). Other empirical work has highlighted the potential role of specific bilingual language practices such as code-switching (Adamou & Shen, 2019; Barbu, Orban, Gillet, & Poncelet, 2018; Soveri, Rodriguez-Fornells, & Laine, 2011). We next describe prior research linking TS performance and these language factors.

Links to language proficiency. In one study, Iluz-Cohen and Armon-Lotem (2013) found that bilingual 4- to 7-year-olds with higher language proficiencies in one or both languages outperformed bilingual preschoolers who were less proficient in a classification task that required them to shift between three different sorting rules (shape, pattern, and numerosity). However, researchers found no difference between highly proficient balanced bilinguals and highly proficient unbalanced bilinguals. In several other studies exploring TS abilities in bilingual adults, researchers found that bilinguals with more balanced language proficiencies outperformed those with less balanced language proficiencies (Tse & Altarriba, 2015; Yow & Li, 2015).

Recently, Rosselli and colleagues (2016) compared the TS abilities of four groups of adults with varying language abilities: unbalanced bilinguals, balanced bilinguals with high proficiency in both languages, balanced bilinguals with low proficiency in both languages, and monolinguals. They found that high proficiency balanced bilinguals outperformed low proficiency balanced bilinguals, and that unbalanced bilinguals scored in between the two groups of balanced bilinguals. Their results did not support the existence of a broad bilingual advantage; instead, high proficiency monolinguals outperformed low proficiency balanced bilinguals, and performed similarly to high proficiency balanced bilinguals. Taken together, these studies underscore the importance of considering both overall language proficiency and degree of balance when investigating TS abilities in bilinguals.

Links to code-switching. Most multilingual speakers mix elements from their different languages in various ways in their everyday lives (Gardner-Chloros, 2009). This code-switching (CS) is defined as the use of more than one language within a phrase, sentence, conversation, or social situation. Researchers have proposed that CS and TS draw upon similar cognitive control mechanisms (Kroll, Bobb, & Hoshino, 2014; Prior & Gollan, 2011; Yang et al., 2016a), particularly as some research has found that training TS in one domain can transfer to another (Karbach & Kray, 2009; Strobach, Frensch, & Schubert, 2012). Indeed, studies have shown that, in comparison to bilingual adults who report infrequently engaging in CS, bilingual adults who report more frequent CS in their daily lives demonstrate an advantage in both linguistic (Adamou & Shen, 2019) and nonlinguistic (Barbu et al., 2018; Soveri et al., 2011) TS tasks. Recently, this link between CS and TS was tested experimentally by Yow and colleagues (2017), who found that bilingual adults who had completed a reading and comprehension task requiring constant CS prior to the TS task outperformed those who had completed the same task in one language.

These studies all suggest that regular experience with CS may boost TS abilities in bilingual adults. However, CS takes many forms. For example, a bilingual speaker may **mix** languages by producing a sentence mostly in her first language (L1) and inserting a single word from her second (L2), or starting a sentence using L1 and switching into L2 partway through. CS also occurs between conversational turns; a bilingual speaker may **switch** languages when responding to her Italian-speaking father versus her Cantonese-speaking mother. In practice, CS is dynamic and can involve frequent shifts within a single conversational context. Bilinguals engage in various types of CS in their everyday lives (Musk, 2010), and for different reasons (Auer, 1998; Kim, 2006; Myers-Scotton, 1988). Sociolinguistic and ethnographic work on CS has shown that from a young age, bilingual children are able to employ CS strategically and intentionally, and that their CS behaviors shift based on the situational context (Kwan-Terry, 1992; Paugh, 2005). In short, if CS experience indeed contributes to TS abilities, there is a need for a theoretical framework that takes into account the complexity of CS behaviors.

Adaptive Control Hypothesis and Control Process Model of Code-switching

Recently, Green and Abutalebi (2013) proposed that the bilingual advantage in TS may stem from engaging in a specific form of CS. Specifically, they posit that participating in *dual-language contexts*, where two languages are used in the same conversational context but with different speakers (i.e., language **switching**), exercises cognitive abilities that are most likely to translate into TS benefits. In their Adaptive Control Hypothesis, they describe three main "interactional contexts" in which bilinguals use their two languages: *single-language, dual-language,* and *dense CS*. Each of these interactional contexts calls upon different frequencies and types of CS and may therefore train different cognitive abilities. Of the three interactional contexts they outline in their theory, they highlight *dual-language* contexts as the most taxing to cognitive control and therefore the most likely to lead to advantages in TS.

In *dual-language* contexts, the bilingual uses two languages in the same context but with different speakers, such as speaking Spanish with one parent and English with the other. In this interactional context, there is likely to be more frequent language **switching** (CS when switching conversational partners) than language **mixing** (CS within sentences, while talking to a single conversational partner). In *single-language* contexts, the bilingual uses one language in one context, and the other in a second, separate context (e.g., a child growing up in a Spanish-only household and attending an English-only school), which would result in very infrequent language switching or language mixing. Finally, in *dense CS* contexts, where there is frequent interaction with other bilinguals, the bilingual engages often in language **mixing**, and may even adapt words from one language into the other. For example, a child may say to her mother, "I'll help you find a *parquedero* [parking spot] so I can go play *escondite* [hide and seek]," where *parquedero* is the English word "park" conjoined with the Spanish suffix "dero," which, when added to a Spanish verb root, creates a noun.

According to the Adaptive Control Hypothesis, each of these three interactional contexts draws differentially upon various cognitive control processes that underlie TS. The authors identify eight different processes, seven of which are implicated specifically in *dual-language* contexts: (1) goal maintenance, (2) conflict monitoring, (3) interference suppression, (4) salient cue detection, (5) selective response inhibition, (6) task disengagement, and (7) task engagement. For example, in a *dual-language* context, a bilingual must establish and maintain the goal of speaking in the appropriate language with each interlocutor (goal maintenance). At the same time, being in a *dual-language* context means that there are likely to be conflicting language cues in the immediate environment, requiring the bilingual to both monitor and suppress this linguistic interference (conflict monitoring, interference suppression). A bilingual must also attend to cues that indicate each interlocutor's language status (salient cue detection), so that he/she can select the appropriate language and inhibit the other (selective response inhibition). Finally, CS between interlocutors in a *dual-language* context calls on the bilingual to both disengage from the prior language and associated rules (task disengagement) and engage with the new one (task engagement).

Green and Abutalebi (2013) propose that *dual-language* contexts are the most cognitively taxing, as they call upon more cognitive control processes in comparison to *single-language* and *dense CS* contexts, which only call upon three (goal maintenance, conflict monitoring, interference suppression) and one (opportunistic planning), respectively. Based on this reasoning, they predict that bilinguals who engage in frequent language **switching** (i.e., *dual-language* contexts) are likely to be faster and more accurate in TS tasks in comparison to those who engage in frequent language **mixing** (i.e., *dense CS* contexts) and those who rarely engage in language switching or mixing (i.e., *single-language* contexts).

Expanding upon this hypothesis, Green and Wei (2014) put forth the Control Process Model of Code-switching, which posits that in *single-language* and *dual-language* contexts, there is a competitive relationship between language schemas, where one language is activated while the other is suppressed. This ensures that the appropriate language is activated when addressing the interlocutor. In *single-language* contexts, the non-target language is effectively suppressed throughout the entire context, while in *dual-language* contexts, control moves back and forth between the two languages as language switching occurs. In contrast, in *dense CS* contexts, in which there is frequent language mixing, they propose that there is a cooperative relationship between language schemas, where the two languages are simultaneously activated, allowing for a "threading of outputs" (Green & Wei, 2014, p. 503). As a result, they predict that bilinguals who engage mostly in *dual-language* (frequent language **switching**) and *single-language* (infrequent language switching and mixing) contexts will outperform those who engage mostly in *dense CS* contexts (frequent language **mixing**) in tasks that draw upon competitive, rather than cooperative, cognitive processes—tasks such as TS.

Recently, Hartanto and Yang (2016) tested these models by comparing the TS performance of bilingual Singaporean undergraduates[1] who reported mostly using two languages within the same context (*dual-language*) to those who reported using them mostly in different contexts (*single-language*). In addition to asking participants about where they used their two languages, they also asked participants to rate the frequency with which they engaged in language switching and language mixing. In line with Green and Abutalebi's (2013) hypotheses, researchers found that *dual-language* context bilinguals outperformed *single-language* context bilinguals in a computerized color-shape switching task similar to the Dimensional Change Card Sort. Their results also backed Green and Wei's (2014) Control Process Model: bilinguals who engaged frequently in language **switching** (in *dual-language* contexts) demonstrated smaller losses in speed in trials in which there was a rule switch versus no rule switch (switch costs), while bilinguals who engaged frequently in language **mixing** (in *dense CS* contexts) demonstrated larger switch costs. In other words, more frequent language **switching** specifically predicted more efficient switching between rule sets. These findings support the idea that language mixing and language switching indeed draw upon different cognitive control processes, and that language **switching** in particular may enhance TS abilities.

[1] In this population, language mixing (*dense CS* context) is quite frequent. For this reason, *dual-language* and *single-language* contexts could not be clearly separated from the *dense CS* context, and researchers considered the *dual-language* and *single-language* contexts to be on opposite ends of a bipolar continuum.

This distinction between language mixing and language switching may explain some of the inconsistencies in the current literature. Recently, Paap and colleagues (2017) found that bilinguals who reported more frequent CS did not outperform bilinguals who reported infrequent CS in a TS task. However, participants were grouped as either frequent or infrequent code-switchers based on their response to the following survey question: “Some bilinguals switch from one language to the other many times every day because they converse with many others who speak the same languages. Others switch rarely because they only speak English here at SFSU and only speak their native language when they are at home. I usually switch from one language to the other…” (Paap et al., 2017, pp. 103–104). It is important to note that the example of frequent CS provided by the researchers aligns with the *dense CS* interactional context (implying frequent language **mixing**), and the example of infrequent CS aligns with the *single-language* context (implying infrequent language mixing and switching). The absence of a question measuring the extent to which participants engage specifically in the language **switching** practices characteristic of *dual-language* contexts indicates that these findings cannot be generalized to all types of CS and thus should be interpreted with caution.

Further complicating the picture is the fact that CS is difficult to measure. Many studies have relied on self-reported frequency of CS (Paap et al., 2017; Prior & Gollan, 2011; Soveri et al., 2011; Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2016), while other studies have induced CS in laboratory settings (Festman, Rodriguez-Fornells, & Münte, 2010; Yim & Bialystok, 2012). However, sociolinguistic research has shown that self-reported information on CS does not always align with observational data

(Gumperz, 1977), and that it is difficult to equate experimentally-induced CS with CS in naturalistic settings (Cox, LaBoda, & Mendes, 2019), where parameters governing the occurrence of CS are constantly shifting. Whether or not a speaker decides to engage in CS depends on a number of factors, including who their interlocutor is (Grosjean, 1982), the physical setting (Kim, 2006), immediate social goals (Cromdal, 2004), and broader societal attitudes toward CS (Bhatia & Ritchie, 2004). It is possible that a more multidimensional approach to measuring CS, one that considers everyday CS practices and multiple linguistic contexts, could help to clarify the relationship between bilinguals' CS experience and TS abilities.

A developmental perspective could also shed light on possible links between CS experience and TS performance. Some researchers have proposed that the cognitive benefits of bilingualism vary along a U-shaped function—that bilingualism yields clearer advantages in childhood and old age, but that effects are muted in young adulthood, when cognitive performance is essentially at peak efficiency (Bialystok et al., 2012; Cepeda et al., 2001). Indeed, the literature on bilingual advantages in TS in bilingual adults is far less consistent in comparison to the literature on young bilingual children and the bilingual elderly (Yang et al., 2016a). If CS experience contributes to TS ability, it is likely that effects would be most apparent early or late in the lifespan. To our knowledge, the only studies to date that have investigated possible links between CS experience and TS performance have included only bilingual young adults (e.g., Hartanto & Yang, 2016; Paap et al., 2017; Prior & Gollan, 2011; Soveri et al., 2011). Exploring this question with young bilingual children could provide important insight into the development of the relationship between everyday CS practices and TS abilities.

In recent years, researchers have identified CS as one aspect of the bilingual experience that may exercise the same cognitive control processes that are implicated in TS, but studies have varied widely in their operationalization of CS. To date, there is no research to our knowledge that investigates these questions with preschool-aged children while taking into account the multiple types and contexts of CS. The current study builds upon previous work by measuring different types of CS using a multidimensional approach that assessed young emerging bilinguals' CS behaviors in two different naturalistic contexts (home and school), in order to better understand the links between young bilingual children's everyday CS practices and TS performance.

Current Study

The current study examined relations between code-switching and task-switching in bilingual preschoolers. Specifically, we investigated whether engaging in specific types of CS behaviors at home and school would predict TS performance in laboratory tasks in 3- and 4-year-olds. Following other studies that have explored within-group differences in bilingual participants (Dong & Xie, 2014; Gollan, Kleinman, & Wierenga, 2014), we focused on a group of young emerging bilinguals: 3- and 4-year-olds attending a Chinese-English bilingual preschool who engage in various CS practices at home and school. Through teacher surveys and parent surveys and diary studies, we measured the frequency with which each child engaged in language switching and language mixing within each context. We measured their TS ability with one linguistic and four nonlinguistic TS tasks that have been used with 3- and 4-year-olds: the Opposite Worlds task (Bialystok et al., 2010), the Reverse Categorization task (Carlson, Mandell, & Williams, 2004), and three versions of the DCCS (Diamond, Carlson, & Beck, 2005; Frye, Zelazo, & Palfai, 1995; Zelazo, 2006) that varied in difficulty.

The current study tested Green and Abutalebi's (2013) Adaptive Control Hypothesis and Green and Wei's (2014) Control Process Model of Code-switching, which together propose that engaging in frequent language **switching**—and not language **mixing**—is likely to lead to TS advantages. While some work with bilingual adults has found that language **switching** positively predicts TS performance (Hartanto & Yang, 2016), others have found that language **mixing** also positively predicts TS performance (Soveri et al., 2011). The current study attempts to clarify possible links between TS performance and these two different types of CS behaviors in a group of young bilingual children. The two main research questions were:

1) What types of CS behaviors do 3- and 4-year-old bilingual children engage in at home and preschool?
2) How do each of these CS behaviors relate to their TS abilities?

Given past research that shows that children's CS behaviors shift based on situational context, we expected that preschoolers would engage in a variety of different types of CS behaviors (e.g., language switching and language mixing), and that their CS behaviors at home would differ from their CS behaviors at school. Based on the Adaptive Control Hypothesis (Green & Abutalebi, 2013), Control Process Model of Code-switching (Green & Wei, 2014), we hypothesized that more frequent language **switching** (at home and school) would predict greater accuracy and smaller shift,[2] mix,[3] and switch[4] costs in the TS tasks.

In light of inconsistencies in the literature regarding the relationship between language **mixing** and TS performance in bilingual adults (Hartanto & Yang, 2016; Paap et al., 2017; Soveri et al., 2011), we hypothesized that among bilingual children, more frequent language **mixing** (at home and school) might predict greater accuracy and smaller shift, mix, and switch costs in the TS tasks, but to a lesser extent than language switching.

Over the last decade, Paap and his research team (Paap, 2014; Paap & Greenberg, 2013; Paap et al., 2015, 2016) have consistently urged the field to move away from overly general conclusions about bilingual advantages in EF and have challenged researchers to identify specific "resonant pairs" of bilingual experience and components of EF. Research has shown that the cognitive benefits of bilingualism may change over the lifespan: while bilingual young adults have not demonstrated a consistent advantage in TS (Paap & Sawi, 2014; Prior & Gollan, 2011), studies with bilingual children (e.g., Bialystok & Martin, 2004; Crivello et al., 2016) and the elderly (e.g., Bialystok et al., 2006; Houtzager et al., 2017) have yielded more consistent results. Therefore, in this

[2] Shift cost refers to the difference in response latencies in post-switch trials versus pre-switch trials.
[3] Mix cost refers to the difference in response latencies in non-switch trials within the mixed block versus unmixed block trials.
[4] Switch cost refers to the difference in response latencies in switch trials versus non-switch trials within the mixed block.

study, we focused on young bilingual children in order to explore CS and TS, in hopes of identifying one resonant pair of bilingual experience and EF.

Method

Participants

Participants were 20 3-year-olds (*n* = 12 females) and 11 4-year-olds (*n* = 5 females) enrolled at a Mandarin-English bilingual preschool in San Francisco, their parents, and the two bilingual teachers at the preschool. The preschool classroom was Montessori-based and mixed-age (ages 2 to 5) and was co-taught by four teachers: two monolingual English-speaking teachers, and two bilingual Mandarin-English teachers. Daily classroom activities included lessons and songs taught in both Mandarin and English, and bilingual teachers engaged regularly in both language mixing and language switching throughout the day. The program did not follow a strict language policy, but all children were expected to be able to both understand and produce basic conversational phrases in Mandarin when prompted (e.g., good morning, thank you, wash your hands). The principal investigator had volunteered at the preschool as a classroom aide and administrative assistant for three years prior to the start of the study, and all of the children were comfortable with her.

Participants were recruited for the study at preschool community events and via email. In order to participate, parents were required to be fluent English speakers, and children needed to be three or four years old. Of the 34 eligible preschool families, 91% participated in the study. Nearly all (97%) children in the study came from two-parent families, and nearly all parents (97%) participated in the study. Table 1 presents a demographic profile of the participants in the study.

Children ranged in age from 37 to 57 months (*M* = 45.45, *SD* = 6.35), and on average, had been enrolled at the preschool for roughly one year (*M* = 391.83 days, *SD* = 267.57, Range = 58–1011). Most children (67%) were of Asian racial/ethnic background, and 27% were of mixed heritage. Relatively few participants (7%) were White, non-Hispanic. Half of the participants were only children; 40% had a younger sibling, and 10% had an older sibling.

Participants generally came from highly educated, high-income families. The vast majority (90%) of parents had obtained at least a Bachelor's degree, and more than half (53%) had a combined average household income of at least $200,000.

Home language use. Nearly all (97%) children lived in households where English was spoken at least some of the time. The vast majority (80%) lived in households where more than one language was regularly spoken; and nearly one-third (30%) came from households where at least three languages were regularly spoken. Other languages spoken at home included: Mandarin (43%), Cantonese (40%), Korean (10%), and French (10%), among other languages (see Table 2 for more detailed information about home language use).

There was considerable variation in how often each language was used at home, and the degree to which language use was balanced.[5] One-third of families used English

[5] Balance in household language use was calculated using Simpson's Index of Qualitative Variation (IQV), which is a traditional measure of qualitative variability for nominal variables such as race or gender

at least 80% of the time, while 1 in 5 families used English less than 25% of the time. Some families used each language relatively equally, while others used one language far more often than the other. For example, 33% of families had a language balance IQV score of .75 or higher ("balanced"), and 17% had a score of .25 or lower ("unbalanced").

Preschoolers' parents also came from diverse language backgrounds. Forty-two percent of parents grew up in households where English was not spoken at all. More than half of parents grew up in households where either Cantonese (28%), Mandarin (22%), or other Chinese dialects such as Taiwanese, Toisanese, and Shanghainese (7%) were spoken, but other parents grew up speaking various other languages, such as Korean, French, Japanese, Marathi, Konkni, Tagalog, Cambodian, Telugu, Hokkien, and Malay. Forty percent of parents grew up in households where more than one language was regularly spoken.

School language use. There was considerable variation in how much English and Mandarin each child used at school (see Table 3). Most children (63.33%) spoke relatively more English than Mandarin, but a few (13.33%) used Mandarin at least 75% of the time. Some children used English and Mandarin relatively equally (16.67%

(Simpson, 1949); in our case, variables were the languages spoken within each household. The IQV ranges from 0 to 1, where 1 indicates perfect balance (equal proportions) and 0 indicates complete imbalance. In our study, the IQV for each household was calculated based on parental report of the percentage of time each language was spoken at home. Households were then categorized as *balanced* (IQV = .76 to 1), *somewhat balanced* (IQV = .51 to .75), *somewhat unbalanced* (IQV = .26 to .50), or *unbalanced* (IQV = 0 to .25) based on these scores.

"balanced" and 43.33% "somewhat balanced"), while others used one language more often than the other (13.33% "unbalanced" and 26.67% "somewhat unbalanced").[6]

Children's language proficiencies. Children's language proficiencies were measured in two areas: receptive (comprehension) and productive (speaking). The vast majority (87%) of parents rated their children's English *receptive* proficiency[7] as "good" or "excellent," and most (73%) rated their children's English *productive* proficiency[8] as "good" or "excellent." Of the 27 children who spoke or understood a non-English language, nearly two-thirds (63%) were reported to have "good" or "excellent" *receptive* proficiency in that language, and 41% had "good" or "excellent" *productive* proficiency. Of the 15 children who spoke or understood a third language, 40% had "good" or "excellent" *receptive* proficiency in the third language, and 20% had "good" or "excellent" *productive* proficiency. Children's receptive and productive proficiency scores were combined to produce a mean proficiency score of each child's abilities in that language (Anderson, Hawrylewicz, & Bialystok, 2018). Table 4 presents children's language proficiencies as reported by parents.

[6] Following the method for calculating household language balance, school language balance was calculated using Simpson's Index of Qualitative Variation (Simpson, 1949), which yielded a balance score ranging from 0 (complete imbalance) to 1 (complete balance). As we did for household language use, we then categorized children as *balanced* (IQV = .76 to 1), *somewhat balanced* (IQV = .51 to .75), *somewhat unbalanced* (IQV = .26 to .50), or *unbalanced* (IQV = 0 to .25) in their English and Mandarin usage at school based on these scores.
[7] Survey question: "How would you rate your child's current ability to UNDERSTAND English? (1 = *poor*, 2 = *fair*, 3 = *average*, 4 = *good*, 5 = *excellent*)
[8] Survey question: "How would you rate your child's current ability to SPEAK English? (same scale as prior question)

Language proficiency balance. There was considerable variation in the extent to which children's language proficiencies were balanced.[9] For example, some children were similarly proficient in English and their second language (L2), while other children were notably more proficient in one language than another. The overall mean language balance proficiency was .54 out of 1 (*SD* = .31), and balance scores ranged from 0 (unbalanced) to 1 (completely balanced). Most children (85%) were reported to be more proficient in English than in the non-English language.

Overall language proficiency. Each child's highest language proficiency score was used as a general measure of his/her language abilities. Across the sample, the mean overall language proficiency was 4.37 out of 5 (*SD* = 0.81).

Design

Children completed five TS tasks that have been used with preschool-aged children (Carlson, 2005). The TS tasks progressed in difficulty,[10] and were administered in the same order to all participants: (1) Reverse Categorization, (2) Opposite Worlds, (3) DCCS – Easier version, (4) DCCS – Standard version, (5) DCCS – Advanced version.

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[9] A single score capturing balance in children's language proficiencies was calculated by first calculating the standard deviation of each child's language proficiencies as a measure of the variation. This number was then standardized and subtracted from 1 to create a final language proficiency balance score, where 1 indicated perfectly balanced proficiency, and 0 indicated perfectly unbalanced proficiency.

[10] We determined the level of difficulty of each of the tasks based on the ages of children who are typically able to pass the task (at least 70% of post-switch trials correct). Most 3-year-olds pass the Reverse Categorization task (Carlson, Mandell, & Williams, 2004; Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok, 2012). Most 4-year-olds pass the Opposite Worlds task, but 3-year-olds typically have more trouble with this task (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Bialystok & Senman, 2004). Most 3-year-olds fail the standard DCCS while most 4- and 5-year-olds pass (Zelazo, 2006), but in the easier version of the task, children typically succeed about six months earlier (Diamond, Carlson, & Beck, 2005). In contrast, most 4-year-olds fail the advanced DCCS (Zelazo, 2006).

Children also completed one working memory task[11] (Spin the Pots task, Hughes & Ensor, 2005) that was administered on a different day to prevent fatigue. The order of tasks (TS versus working memory) was counterbalanced. In total, the TS tasks took on average 15.83 minutes to complete (*SD* = 2.67, Range = 11.98–22.00), and the working memory task, 8.13 minutes (*SD* = 2.16, Range = 4.77–13.77). Tasks were administered during free play/exploration time, in a quiet corner of the classroom, in English for all but two (6.67%) participants who were not yet proficient in English. For these two children, the tasks were administered in Mandarin. The procedure was videotaped for coding and reliability.

Within one month of the day that children participated in the TS tasks, parents completed the demographic survey online or on paper (93% online), and then participated in a semi-structured interview, either on the phone or in person (87% via phone). Following the interview, they participated in a 7-day diary study during which they observed and reported their child's CS behaviors daily via a Google Form. Nearly half (45%) of parents completed diary entries for at least six out of the seven days, and 39% completed diary entries for four or five days. Five parents[12] (16%) did not make any diary study entries over the seven days. One week after the end of the diary study, parents

[11] TS performance is likely moderated by working memory capacity (Engle, 2002; Roberts Jr & Pennington, 1996), and studies have shown that bilingual children demonstrate advantages in working memory over monolingual children (Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Morales, Calvo, & Bialystok, 2013; Purić, Vuksanović, & Chondrogianni, 2017), suggesting that it is important to include working memory as a covariate that likely contributes to the bilingual advantage in TS.
[12] These were treated as missing data.

completed a brief online follow-up survey about their children's CS behaviors overall (response rate: 87%).

Within one month of the day that children participated in the TS tasks, the two bilingual preschool teachers completed a brief online survey about the Chinese language use and CS behaviors of each participant. Both teachers completed surveys for all 31 participants (response rate: 100%), resulting in two reports of each child's language use and CS behaviors.

Materials and Procedure

Linguistic task-switching. This task tested children's ability to switch from naming objects to naming them according to a new rule.

Opposite Worlds task (Bialystok et al., 2010)**.**

Familiarization. Children were introduced to a large (2' x 1.5') board with drawings of a windmill and barn at the top, and a curvy path leading up to the barn (see Figure 1). Along the path were six pigs and six cows, in random order. The experimenter told the child a story about a protagonist taking a walk to the barn and seeing animals along the way. The experimenter demonstrated with the first two animals on the path.

Pre-switch. The experimenter moved the protagonist (a drawing of a child) up the path, starting at the bottom of the scene. Children were asked to name each animal as the protagonist passed it ("And then he/she saw a…?"). There was a total of ten trials (five with each animal).

Post-switch. The experimenter told the child about a strong wind that blew the barn and windmill upside-down and turned the animals' names upside-down as well

("Now, all the pigs are called cows, and all the cows are called pigs"). The experimenter moved the protagonist (now held upside-down) back to the beginning of the path at the bottom of the scene and demonstrated with the first two animals on the path. Children were reminded of the "upside-down" rule before the 1st, 3rd, 6th, and 9th trials ("Remember, now everything is turned upside-down, so all the pigs are called cows, and all the cows are called pigs").

Scoring. Accuracy scores for this task were calculated as a percentage of correct post-switch responses out of the number of trials in which the child was paying attention to the task.[13] Following other studies that have used this task with preschoolers (Bialystok & Senman, 2004; Bialystok & Shapero, 2005), we measured the *total* time that children took to name all of the animals in the pre-switch phase and the post-switch phase.

Nonlinguistic task-switching. These four tasks tested children's ability to switch from sorting objects based on one rule to sorting them based on a different rule (see Figure 2).

Reverse Categorization task (Carlson et al., 2004)**.**

Familiarization. Children were introduced to two boxes: a "mommy" box and a "baby" box. The experimenter demonstrated sorting one large animal into the "mommy" and one small animal into the "baby" box, stating the rule for each animal (e.g., "This one is *big*, so I'm going to put it in the *mommy* box").

[13] In instances when a child changed his/her mind about the name of an animal before the next trial, the latter decision was scored. If the child changed his/her mind after the next trial began, the initial decision was scored.

Pre-switch. The experimenter asked the child to help sort the remaining five large animals and five small animals (in random order) into the correct boxes. The experimenter labeled each animal by size as she handed it to the child for sorting ("Here's a *small* one, where does it go?"). No feedback was provided regarding whether the child sorted correctly.

Post-switch. After the child finished sorting the ten animals, the experimenter emptied out the two boxes and said, "Now let's play a silly game! Let's put the *big* animals into the *baby* box, and the *small* animals into the *mommy* box. I'll go first." The experimenter demonstrated the new rule using one large animal and one small animal, labeling the size of the animal before each trial ("This is a *big* animal, so now it goes in the *baby* box"). The experimenter then asked the child to help sort the remaining ten animals (five of each size), labeling the animal by size before each trial, and providing no feedback regarding accuracy. If a child asked for feedback, the experimenter repeated the sorting rule.

Scoring. Accuracy scores for this task were calculated as they were in the Opposite Worlds task. Response latencies were calculated for each trial by one of four undergraduate research assistants using the Behavioral Observation Research Interactive Software (Friard & Gamba, 2016). Each response latency began either from the end of each spoken cue ("Where does it *go*?") or when the child took the animal from the experimenter's hand, whichever came first.[14] Each response latency ended when the child moved the animal to a box.[15]

Dimensional Change Card Sort – Easier version (Diamond et al., 2005)**.** In this version of the DCCS, children sort by the color of the card's background, rather than the object pictured on the card. While they must still successfully switch rule sets (sorting by color vs. shape), in this version, the color is a property of the background rather than of the object itself. Diamond et al. (2005) found that separating the dimensions aids young children's ability to switch rule sets: more children were successful at this task than at the standard DCCS, and they succeeded about six months earlier.

Familiarization. Children were shown two boxes with cards affixed to the front: one with a black fish against a yellow background, and one with a black star against a green background. The experimenter labeled the boxes using both dimensions ("Here's a fish on a yellow card, and here's a star on a green card"). The experimenter described the "shape game"[16] to the child, where all fishes go into the "fish box" and all stars go into the "star box." The experimenter demonstrated the shape game to the child using one card with a fish on a green background, and one card with a star on a yellow background

[14] This was due to the fact that in some instances, children took the animal from the experimenter's hand before the word "go."
[15] In some cases, children began to play by suspending the animal high above the box, waiting, and then dropping it. Given that response latency was intended to measure the time it took children to make the decision about how to sort the animal, we decided to end the response latency at the point at which it appeared that the child had made a decision.
[16] Half of the children were randomly assigned to play the "shape game" before the "color game," and the other half played the "color game" before the "shape game."

(e.g., “This one is a fish. So I’m going to put it here, in the fish box”). The familiarization phase included two trials in which the experimenter provided feedback to the child.

Pre-switch. The child was asked to sort five additional fish/green background cards and five additional star/yellow background cards. The experimenter labeled each card by shape as she handed it to the child for sorting (“This one’s a star; where does it go?”). Feedback about accuracy was not provided to the child.

Post-switch. After the child finished sorting the ten cards, the experimenter said, “Now we’re going to play a new game, the color game. Now in the color game, all the yellow ones go here, and all the green ones go here.” The experimenter demonstrated with two cards, this time labeling them by color (“This one is yellow. So I’m going to put it here, in the yellow box”). Again, there were two familiarization trials, followed by ten test trials (five fish/green background cards and five star/yellow background cards). Before each trial, the experimenter labeled the relevant dimension and asked the child to place it in the correct box (“This one is green; where does it go?”).

Scoring. Accuracy scores for this task were calculated as they were in the Reverse Categorization and Opposite Worlds tasks. Response latencies were calculated as they were in the Reverse Categorization task.

Dimensional Change Card Sort – Standard version (Frye et al., 1995)**.**

Familiarization. The experimenter affixed two new cards to the front of the sorting boxes: one with a red flower (on a white background), and one with a blue Crayon (on a white background). The experimenter labeled the boxes using both dimensions (“Here’s a red flower and here’s a blue Crayon”). The experimenter re-introduced the shape game[17] to the child ("Remember the shape game that we played before? We're going to play it again. Now, all the flowers go into the flower box and all Crayons go into the Crayon box"). The experimenter provided two demonstration trials, labeling each card by shape (e.g., "This one is a flower. So I'm going to put it here, in the flower box"). Following the structure of the Easy DCCS, the familiarization phase included two trials in which the experimenter provided feedback to the child.

Pre-switch. The child was asked to sort five additional blue flower cards and five additional red Crayon cards. The experimenter labeled each card by shape as she handed it to the child for sorting. Feedback was neutral as to whether the child had sorted the card correctly (e.g., "Okay, let's do another one").

Post-switch. After the child finished sorting the ten cards, the experimenter said, "Do you remember the color game? Let's play the color game again. In the color game, all the red ones go here, and all the blue ones go here." The experimenter demonstrated with one red Crayon card and one blue flower card, this time labeling each by color ("This one is red. So I'm going to put it here, in the red box"). As in the pre-switch phase, there were two familiarization trials and ten test trials.

Scoring. Accuracy scores for this task were calculated as they were in the other TS tasks. Response latencies were calculated as they were in the Reverse Categorization and Easy DCCS tasks.

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[17] Children played the games in the same order as they did in the Easy DCCS: if they began the easy DCCS with the "shape game," they began again with the "shape game" in the Standard DCCS. As a result, all participants needed to shift dimension at the start of this version of the DCCS.

Dimensional Change Card Sort – Advanced version (Zelazo, 2006)**.** In this extension of the DCCS, the rule by which children sort depends on whether a card has a rainbow-colored border around it (e.g., no border = shape game, border = color game). This adds a second higher-order rule for children to keep in mind while determining how to sort the card. Zelazo (2006) found that while the majority of 4- and 5-year-olds pass the standard DCCS, most 4-year-olds and approximately half of 5-year-olds fail the advanced DCCS. In this task, there was no pre-switch phase.

Familiarization. The experimenter said: "Okay, you played that last game really well. Now I have a really tricky game. In this tricky game, some of the cards have a rainbow around them [show a red Crayon card with a rainbow border]. If there's a rainbow, we're going to play the *color* game. Remember that in the color game, the red ones go here, and the blue ones go there. This one is red, so I'm going to put it right here [place in correct box]. But some of the cards have *no* rainbow around them, like this one [show a red Crayon card without a border]. For these cards, we're going to play the *shape* game. Remember that in the shape game, the flowers go here, and the Crayons go there. This one's a Crayon, so I'm going to put it right here [place in correct box]."

The experimenter asked the child to sort four cards, one of each type (red Crayon with rainbow border; red Crayon with no border; blue flower with rainbow border; blue flower with no border), each time identifying the game, reminding the child of the rules, and labeling the appropriate dimension before giving the card to the child ("Look, it's the shape game! So the flowers go here, and the Crayons go there. This one is a Crayon, so where does it go?"). In this version of the DCCS, there were four familiarization trials.

Test trials. Children were asked to sort 12 cards (three of each type: blue flower with rainbow, blue flower without rainbow, red Crayon with rainbow, red Crayon without rainbow). Half of the trials required a rule set switch, and half of the trials did not. Before each trial, the experimenter identified the game, reminded the child of the rule, and labeled the appropriate dimension. Feedback was neutral and non-corrective.

Response latencies from the end of each spoken cue ("Where does it *go*?") to the moment when the child placed the card in a box were computed using the Behavioral Observation Research Interactive Software (Friard & Gamba, 2016).

Scoring. Accuracy scores for this task were calculated as they were in the other TS tasks. Response latencies were calculated as they were in the Reverse Categorization, Easy DCCS, and Standard DCCS tasks.

Spin the Pots task (Hughes & Ensor, 2005)**.**[18] Children's working memory was measured using the Spin the Pots task, a multilocation search task in which successful retrieval of the prizes (stickers) requires the storage and continuous updating of information. Children were first introduced to ten visually distinct opaque containers arranged around a circular spinning lazy-Susan tray. After selecting eight stickers, they placed each sticker in a different container (leaving two containers empty). Before each trial, the experimenter scrambled the containers on the tray, covered the tray with an

[18] The original version of the task, which was administered to 2-year-olds, included six stickers and eight containers. Other studies that have used this task with 3- and 4-year-olds (Beck, Schaefer, Pang, & Carlson, 2011; Hostinar, Stellern, Schaefer, Carlson, & Gunnar, 2012) have included eight stickers and ten containers. We chose to include this task over other working memory tasks such as the Forward and Backward Digit/Word Span (Davis & Pratt, 1996) because it does not draw on children's expressive verbal abilities; they simply have to reach for containers to complete the task.

opaque scarf, and spun it around. The experimenter then removed the scarf, and asked children to choose one container to open. Each time they chose a container with a sticker inside, the sticker was removed from the container and set aside for them to keep. After each trial, the experimenter congratulated or encouraged the child, scrambled the containers on the tray, covered the tray with the scarf, and spun it around. The task continued until all stickers were found, with a maximum of 16 possible trials.

Scoring. Children's working memory score was calculated as the proportion of number of stickers found to the total number of spins required (maximum: 16) to find all the stickers (range: 0 to 1).

Parent survey. Parents completed a 5- to 10-minute demographic survey either online (via SurveyGizmo) or on paper. In addition to basic questions about the child, the survey included questions about their child's home language environment and language proficiencies, as well as their own childhood home language environments (see Appendix A).

Parent interview. Parents participated in a 30-minute semi-structured interview that included questions about their child's language environment and CS practices with his/her various interlocutors (see Appendix B). The interviewer asked the parent to describe who their child interacts with over the course of a typical weekday and weekend day, what languages they typically speak, and the extent to which their child engages in language switching and language mixing with each conversational partner. Interview data were transcribed by one of four undergraduate research assistants using Express Scribe (NCH Software, 2019), and subsequently checked by a different research assistant.

Parent diary study. For seven consecutive days, parents observed their children's CS practices and reported specific instances of these CS practices via a daily Google Form (see Appendix C). For each instance of CS, they reported what their child had said, who else was involved in the interaction, and the general situational context surrounding the interaction (e.g., having dinner and talking about what happened during the day). In cases where children engaged frequently in CS, parents were permitted to stop making entries after five instances of each type of CS (language switching or mixing). Diary study data were coded by one of two undergraduate research assistants (see "Coding" section).

Parent follow-up survey. One week after the end of the diary study, parents completed a two-question online survey (via Google Forms) that asked them to rate how often their child engages in language switching and language mixing at home, overall (see Appendix D). Parents rated the frequency of children's language switching and mixing (separately) on a scale of 0 to 4, where 4 = *Always/Very often* (multiple times per day), 3 = *Often* (once or twice a day), 2 = *Sometimes* (once or twice a week), 1 = *Rarely* (once every so often), and 0 = *Never*.

Teacher survey. Teachers completed a brief online survey (via SurveyGizmo) for each participant, in which they rated how often the child engaged in language switching and language mixing at school, and estimated the percentage of time that the child spoke Chinese to them (see Appendix E). Teachers rated the frequency of children's language switching and mixing (separately) on a scale of 0 to 4, where 4 = *Always/Very often* (multiple times per day), 3 = *Often* (once or twice a day), 2 = *Sometimes* (once or twice a week), 1 = *Rarely* (once every so often), and 0 = *Never*.

Coding Diary Study Data

In this study, we aimed to identify the extent to which children engaged in language **switching** (shifting languages when changing conversational partner) and language **mixing** (shifting languages in the middle of an utterance while talking to one conversational partner). The purpose of coding parents' diary study entries was to categorize children's utterances in a way that would allow us to identify children's rates of language switching and language mixing. To do this, it was necessary to determine: 1) whether the child was talking to the same conversational partner or switched partners during the interaction, and 2) whether the child shifted languages within one utterance (intra-sentential), between utterances (inter-sentential), or both, simultaneously. Based on these two factors, we categorized each entry as language mixing, language switching, or both.

Each instance of CS reported by parents was first coded into one of the following five categories: (A) Same partner: Inter-sentential CS, (B) Same partner: Intra-sentential CS (C) Switch partner: Inter-sentential CS, (D) Switch partner: Intra- and inter-sentential CS, or (X) Not CS. Coding categories A and B were considered language mixing, category C was language switching, and category D was both language mixing and switching. Entries that were coded as category X were excluded from analyses.

Language mixing.

Same partner: Inter-sentential CS. This category included all utterances in which the child spoke an entire sentence or phrase in one language, then spoke in another language for the next sentence or phrase, while talking to one conversational partner. For example: "妈妈你要坐我的小火车吗 [Mandarin: Mommy, do you want to take my little train]? My train is leaving soon."

Same partner: Intra-sentential CS. This category included all utterances in which the child mixed languages within a single sentence or phrase while talking to one conversational partner. For example: "我想食 [Cantonese: I want to eat] cake."

Language switching.

Switch partner: Inter-sentential CS. This category included all utterances in which the child switched languages when changing conversational partners. For example: "妈妈这是什么汤 [Mandarin: Mommy, what is that]?" followed by "Papa, peux-tu m'aider? Qu'est-ce que c'est? [French: Daddy, can you help me? What is that?]"

Both language mixing and switching.

Switch partner: Inter- and Intra-sentential CS. This category included all utterances in which the child mixed languages in one sentence or phrase, then switched languages when changing conversational partners (or vice versa). For example: "You didn't say please" to sister, followed by "爸爸請给我 [Mandarin: Daddy, please give me] 蛋 [Cantonese: egg]."

Not CS. This category included utterances in which the child did not actually engage in CS or code-switched only for a name or proper noun, for example: "Where did 婆婆 [Cantonese: Grandma] go?" or "我想看 [Mandarin: I want to watch] Frozen!"

Reliability

Two undergraduate research assistants coded the diary study data. A randomly selected 50 utterances (20%) were coded by both research assistants (94% agreement, Cohen's Kappa = .91). At the end of coding, the same 20 utterances (8%) were coded by both research assistants and the principal investigator to check for alignment with the original coding scheme (85-90% agreement, Cohen's Kappas = .79-.87).

Four undergraduate research assistants scored children's performance on the TS tasks for accuracy and response latencies. A randomly selected 20 percent of participants were scored by all four research assistants, and a high degree of interrater reliability was found in both accuracy (99% agreement, Cohen's Kappas = .95-.98) and response latency (ICC = .93).

Measures Derived from Task-switching Tasks

Task-switching. Children's task-switching performance was measured in three ways: accuracy (proportion correct), speed (response latencies), and efficiency. Efficiency scores were calculated by dividing the mean response latency (of all responses, correct or incorrect) by the proportion correct, thus capturing the speed-accuracy trade-off (as in Paap et al., 2017). For speed and efficiency scores, we calculated three difference indices of children's TS performance: shift costs, mix costs, and switch costs (Park, Ellis Weismer, & Kaushanskaya, 2018).

Shift costs, which compare post-switch trials to pre-switch trials, provide a measure of the extent to which children are able to successfully overcome perseveration and switch to the new rule in the post-switch phase (Frye et al., 1995). Mix costs, which compare non-switch trials in mixed blocks (Advanced DCCS) to trials in unmixed blocks (Standard DCCS), provide a measure of monitoring ability, or the change in performance when children need to hold two rules in mind versus only one (e.g., Tse & Altarriba, 2015). Finally, switch costs, which compare switch to non-switch trials within mixed blocks (Advanced DCCS), provide a measure of the ability to move flexibly between different rules (e.g., Prior & MacWhinney, 2010).

Accuracy. Scores for each of the five TS tasks were calculated by dividing the number of correct post-switch responses by the number of trials, excluding trials in which the child was clearly not attending to the task.[19] These five scores were then averaged to create a final score for overall TS accuracy that ranged from 0 to 1.

Speed.

[19] Behavioral indicators of children's lack of attention included: not looking at the card or box, talking about other topics, and quickly sorting all cards into the same box. In general, children were very attentive throughout the five TS tasks, though attention tended to decrease slightly as children progressed through the tasks, from 100% of trials in the Reverse Categorization task to 91% of trials in the Advanced DCCS (see Table 6).

Linguistic task-switching. Shift costs for the Opposite Worlds task were calculated as the percent change in task duration[20] between the pre-switch and post-switch phase: ($\frac{Duration_{post} - Duration_{pre}}{Duration_{pre}}$).

Nonlinguistic task-switching. Shift costs for the Reverse Categorization, Easy DCCS, and Standard DCCS tasks were calculated as the percent change in mean response latency between correct pre-switch test trials and correct post-switch test trials ($\frac{\overline{RL}_{post} - \overline{RL}_{pre}}{\overline{RL}_{pre}}$), excluding incorrect trials and trials in which the child was clearly not attending to the task.

Mix costs were calculated as the percent change in mean response latency between correct pre-switch Standard DCCS trials and correct Advanced DCCS non-switch trials (Tse & Altarriba, 2015).

Switch costs were calculated as the percent change in mean response latency between correct non-switch trials and correct switch trials in the Advanced DCCS.

Efficiency. We calculated children's efficiency in the TS tasks by dividing mean response latencies by accuracy, which yielded an efficiency score in terms of seconds per correct response. Lower numbers indicated fewer seconds per correct response, and thus represented better performance.

Linguistic task-switching. Efficiency scores for the Opposite Worlds task were calculated by dividing the total task duration of each phase (pre- and post-switch) by the

[20] In this task only, children could see all of the visual stimuli (pigs and cows) during the entire task, and could therefore respond *before* the experimenter provided the verbal cue. As a result, past studies with this task have measured total task duration rather than response latency (Bialystok & Shapero, 2005).

number of correct responses in each phase. Shift costs for this task were calculated as the percent change in efficiency score between the pre-switch phase and the post-switch phase ($\frac{\overline{ES}_{post} - \overline{ES}_{pre}}{\overline{ES}_{pre}}$).

Nonlinguistic task-switching. Efficiency scores for the Reverse Categorization, Easy DCCS, Standard DCCS, and Advanced DCCS tasks were first calculated by dividing mean response latencies in each phase (pre- and post-switch separately) by the number of correct responses in that phase (Paap et al., 2017). As in the measures of accuracy and speed, we excluded trials in which the child was clearly not attending to the task.

Shift costs for the Reverse Categorization, Easy DCCS, and Standard DCCS tasks were calculated as the percent change in efficiency score between the pre-switch phase and the post-switch phase ($\frac{\overline{ES}_{post} - \overline{ES}_{pre}}{\overline{ES}_{pre}}$).

Mix costs were calculated as the percent change in efficiency score between pre-switch Standard DCCS trials and Advanced DCCS non-switch trials.

Switch costs were calculated as the percent change in efficiency score between non-switch trials and switch trials in the Advanced DCCS.

Analytical Plan

First, we conducted an exploratory factor analysis (EFA) to determine the structure underlying children's CS behaviors at home and school. Then, we conducted multiple hierarchical regression analyses to predict TS performance (accuracy, shift cost, mix cost, switch cost) from children's CS behaviors at home and school. We included age (in months), working memory score, language proficiency balance, and language proficiency[21] as control variables[22] in each of the models.

Results

The aim of the current study was to explore children's code-switching (CS) behaviors at home and school, and to investigate links between these CS behaviors and their task-switching (TS) performance. Specifically, we were interested in two types of CS behaviors: language **mixing** (e.g., "我想去 [Mandarin: I want to go] swing!"), and language **switching** (e.g., "Papa, je veux jouer avec ton telephone [French: Daddy, I want to play with your phone]. 妈妈,我可以玩你的手机吗 [Mandarin: Mommy, can I play with your cell phone]?"). We expected that children's frequencies of both language **switching** and language **mixing** would positively predict their TS performance, but that language **switching** would be a stronger predictor of TS performance than language **mixing**. First, we present results from each of the measures of children's CS behaviors, followed by an exploratory factor analysis (EFA) that revealed the underlying structure of these behaviors. Then, we present overall results from each of the measures of TS performance (accuracy, speed, and efficiency). Finally, we present the results of multiple regression analyses linking children's CS behaviors and their TS performance.

[21] We used the highest language proficiency (receptive and productive combined) reported by parents. For example, if a child was more proficient in Cantonese than English, we used their Cantonese language proficiency.
[22] We omitted gender from our analyses because we found no effect of gender on any of the measures of TS performance or CS behaviors at home or school.

Children's Code-switching Behaviors

In this section, we present findings related to children's CS behaviors. We measured children's language switching and mixing in two different contexts: at home and at school. Results showed that children engaged in language switching and language mixing at different rates in each context, suggesting that their CS behaviors at home and school could not be reduced to a single variable. This was further backed by an exploratory factor analysis, which identified three distinct factors: school language mixing and switching (combined), home language mixing, and home language switching. Table 5 presents means, standard deviations, and correlations between the various measures of children's CS behavior.

Home code-switching practices. We had two different sources of data regarding children's language switching and mixing at home: the 7-day diary study and the follow-up survey. Overall, we found that the two types of home CS behaviors were not significantly correlated (Table 5, Variables 1 & 4, and 2 & 5). Findings also showed that results from the diary study and follow-up survey were significantly correlated (Table 5, Variables 1 & 2, and 4 & 5).

Diary study (Variables 1 and 4 in Table 5)**.** Of the 248 CS utterances recorded by parents, 20.56% were coded as language switching, 66.13% were coded as language mixing, 7.26% were both language switching and mixing, and 6.05% were not CS. After excluding utterances that were not CS, 29.61% were language switching and 78.11% were language mixing (7.73% out of each type were both switching and mixing).

Of the 26 families who participated in the diary study, 15 (57.69%) reported at least one instance of language **switching** (*M* = 2.91 times in one week,[23] *SD* = 4.68). There was wide variation in the frequency of children's language switching at home: 42.31% of children did not engage in any language switching, 46.15% switched languages less than once a day, and 11.54% did so at least once a day.

In contrast, all but one family (96.15%) reported at least one instance of language **mixing** (*M* = 7.76 times in one week, *SD* = 6.25). Again, children varied in how frequently they engaged in language mixing at home: 3.85% of children did not engage in any language mixing, 50% mixed languages less than once a day, and 46.15% mixed languages at least once a day.

Histograms of children's language switching (Figure 3) and language mixing (Figure 4) display notable differences in their distributions. Language switching frequency was positively skewed, with many children (n = 11) never switching languages over the course of the diary study. On the other hand, language mixing frequency was more regularly distributed, with a peak at 5 to 6 times in one week.

We conducted Pearson's correlation analyses to examine the extent to which children's rates of language mixing and language switching were associated.[24] We found no significant correlation between children's frequencies of language mixing and

[23] As some parents did not complete diary study entries for all seven days, we calculated average rates of children's language switching and mixing per day, and then multiplied by seven to create an overall frequency over the week.
[24] For this analysis, we excluded utterances that were simultaneously intra- and inter-sentential and were thus categorized as both language mixing and language switching.

language switching at home based on diary study data ($r(26) = .12$, $p = .55$). Based on parents' reports in the diary study, children mixed languages more often than they switched languages ($t(25) = 3.97$, $p = .001$).

We also found no significant correlations between children's age (in months) and language switching and mixing at home ($r(26) = .16$, $p = .42$ and $r(26) = -.25$, $p = .23$, respectively).

Follow-up survey (Variables 2 and 5 in Table 5)**.** Based on parents' responses to the follow-up survey, 61.54% of children engaged in language switching at least "sometimes," and about one-third (34.62%) did so "often" or "very often." Roughly 3 in 4 children (73.08%) engaged in language mixing at least "sometimes," and 53.85% did so "often" or "very often." The mean frequencies of children's language switching and mixing were 2.07 and 2.30 (on a scale of 0 to 4), respectively. We again found no significant correlation between children's frequencies of language mixing and switching at home based on the follow-up survey ($r(27) = .30$, $p = .13$), and no significant correlation between these two CS behaviors and children's age in months ($r(27) = .32$, $p = .11$ and $r(27) = -.10$, $p = .64$). In contrast to diary study data, parents' reports on the follow-up survey indicated that children's rates of language mixing and switching were not significantly different ($t(26) = .77$, $p = .45$).

Alignment between diary study and follow-up survey results. We conducted Pearson's correlation analyses to check whether results from the diary study (Table 5, Variables 1 & 4) were consistent with results from the follow-up survey (Table 5, Variables 2 & 5). We found that for both language switching and mixing at home, the frequency reported in the diary study was significantly correlated with the frequency reported in the follow-up survey ($r(25) = .53$, $p < .01$ and $r(25) = .67$, $p < .001$, respectively).

School code-switching practices (Variables 3 & 6 in Table 5)**.** Children's language switching and mixing practices at school were measured via a teacher survey. There were two measures of each child's language switching and mixing: one from each bilingual teacher. First, we conducted Pearson's correlation analyses to check whether the two teachers' ratings of children's CS were consistent with one another. Teachers' ratings of the frequency of children's language switching were significantly correlated ($r(31) = .60$, $p = .001$), as were their ratings of the frequency of children's language mixing ($r(31) = .47$, $p < .01$).

Based on mean teacher ratings of children's CS behaviors, nearly two-thirds (64.52%) of the children engaged in language switching at least "sometimes," and 41.90% did so "often" or "very often." About two-thirds (67.74%) engaged in language mixing at least "sometimes," but only 22.58% did so "often," and none "very often." The mean frequencies of children's language switching and mixing were 1.90 and 1.66 (on a scale of 0 to 4), respectively; this difference was marginally significant ($t(29) = 1.79$, $p = .09$).

We found a strong positive correlation between teachers' reports of children's language mixing and switching at school ($r(31) = .80$, $p < .001$).

Children's language switching and mixing at school were both significantly correlated with age in months ($r(31) = .50$, $p < .01$ and $r(31) = .40$, $p = .03$, respectively).

Comparing code-switching practices at home and school. Children's CS behaviors at home and school were not correlated (Table 5, Variables 1 & 3, 2 & 3, 4 & 6, and 5 & 6); in other words, children who engaged in more language switching at home (based on diary study and follow-up survey results) did not necessarily switch languages more or less at school, and children who engaged in more language mixing at home did not necessarily mix languages more or less at school. For example, of the nine children who were reported to engage "often" or "very often" in language switching at home (based on the follow-up survey), only four (44.44%) were reported to switch languages "often" or "very often" at school.

Moreover, links between children's language mixing and switching differed based on whether they were at home or at school. At home, children who switched languages more often did not mix languages more often. However, at school, children who switched languages more often also mixed languages more often. Bubble charts of children's language mixing and switching at home (Figure 5, in blue) and school (Figure 6, in orange) display these differences. Specifically, in Figure 6, there is a clear positive linear relation between language mixing and switching at school ($r(31) = .80$, $p < .001$), while in Figure 5, there is notably more variation in how language mixing and switching are related at home ($r(27) = .30$, $p = .13$).

Paired *t*-tests comparing follow-up study data and teacher survey data showed that parents reported significantly higher rates of language mixing than teachers did ($t(26) = 2.25$, $p = .03$). However, parents and teachers' reports of children's rates of language switching were not significantly different ($t(26) = .12$, $p = .91$).

Factor analysis. We conducted an exploratory factor analysis (EFA) to determine the structure underlying children's CS behaviors at home and school. This EFA included eight indicators of children's CS behaviors: four were measures of their language mixing (as reported in the diary study, follow-up survey, and two teacher surveys), and four were measures of their language switching (as reported in the same measures).

We conducted a principal components analysis, and retained factors based on (a) Kaiser's (1960) criterion of retaining all factors above the eigenvalue of one, (b) the scree test (Cattell, 1966), and (c) Loewen and Gonula's (2015) recommendation that the cumulative percentage of variance extracted should be at least 60%. Given that our findings indicated correlations between these six indicators (see Table 5), direct oblimin rotation was used to allow for correlations between the factors and enhance simplicity of the final factor structure (Yong & Pearce, 2013).

The EFA generated three factors of children's CS behaviors: overall CS (language mixing and switching combined) at school, language mixing at home, and language switching at home (see Table 7). Combined, the three factors accounted for a total variance of 77.79%, with overall school CS accounting for 39.71% of the variance, home language mixing accounting for 24.88%, and home language switching accounting for 13.20%. Scree plot results supported the three-factor solution (see Figure 7), and all factors had eigenvalues greater than one (Factor 1 = 3.18, Factor 2 = 1.99, Factor 3 = 1.06).

The component correlation matrix (see Table 8) showed that there were no significant correlations between any of the factors, suggesting that CS at school, language mixing at home, and language switching at home are conceptually distinct contexts for CS. Findings from reliability analyses[25] showed that the indicators within CS at school and language mixing at home demonstrated good internal consistency (Cronbach's alphas = .84 and .80, respectively), while language switching at home demonstrated acceptable internal consistency (Cronbach's alpha = .69).

Results from the factor analysis suggested that it was appropriate to calculate composite scores for each of the three CS factors and treat them as independent predictors of TS abilities. We thus created three new variables: 1) School CS (both teachers' ratings of children's language mixing and switching at school), 2) Home Mixing (parents' ratings of children's language mixing at home based on diary study and follow-up survey data), and 3) Home Switching (parents' ratings of children's switching at home based on diary study and follow-up survey data). Each of these new variables was calculated by averaging the relevant standardized CS measures.

Children's Task-switching Performance

In this section, we present general findings on children's TS performance, as measured by accuracy, speed, and efficiency. For speed and efficiency, we calculated three different indicators of performance typically used in the TS literature (Park et al., 2018): *shift cost* (ability to overcome perseveration and switch to a new rule), *mix cost*

[25] Reliability analyses for children's CS behaviors at home were conducted using standardized scores to account for differences in units (instances per week vs. 5-point Likert scale).

(ability to hold two rules in mind), and *switch cost* (ability to move flexibly between different rules). Table 6 presents means and standard deviations of children's accuracy, speed, and efficiency in the five tasks.

Accuracy. We measured accuracy by calculating the proportion of correct post-switch trials out of the number of attended trials for each of the five tasks. The mean score across all post-switch trials of the five TS tasks was .82 (*SD* = .16), with scores ranging from .96 correct in the Reverse Categorization task to .71 correct in switch trials of the Advanced DCCS.

As expected, scores generally decreased as children progressed through the tasks, and children were less accurate in the post-switch phase than in the pre-switch phase (in the first four tasks), and less accurate in switch trials than non-switch trials (in the Advanced DCCS). A 5 × 2 (task × phase) repeated-measures ANOVA[26] revealed significant main effects of both task ($F(2.73, 70.90) = 16.52$, $p < .001$, $\eta_p^2 = .39$) and phase ($F(1, 26) = 16.01$, $p < .001$, $\eta_p^2 = .38$), and no significant interaction effect. Children were significantly less accurate in the Opposite Worlds task compared to the Reverse Categorization task (95% CI of mean difference = [0.01, .08], $p = .01$). They were also significantly less accurate in the Advanced DCCS compared to the Reverse Categorization (95% CI of mean difference = [.12, .37], $p < .001$), Opposite Worlds (95% CI of mean difference = [.08, .31], $p = .001$), Easy DCCS (95% CI of mean difference =

[26] Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(9) = 47.36$, p < .001); therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε = .68).

[.10, .31], $p < .001$), and Standard DCCS (95% CI of mean difference = [.07, .29], $p = .001$) tasks. Children were significantly less accurate in the post-switch than pre-switch phase (95% CI of mean difference = [.04, .12], $p < .001$). Figure 8 displays mean accuracy scores across the five tasks.

Given that children performed at ceiling in the Reverse Categorization task (.96 correct in post-switch phase), we omitted this task from our analyses. The final mean accuracy score over the four remaining tasks (post-switch phases only) was .79 (SD = .20).

Speed. We calculated three indicators of children's speed in the TS tasks: shift cost, mix cost, and switch cost. *Shift costs* compared response latencies in post-switch trials to pre-switch trials, *mix costs* compared response latencies in non-switch trials in mixed blocks (Advanced DCCS) to trials in unmixed blocks (Standard DCCS), and *switch costs* compared response latencies in switch trials to non-switch trials within mixed blocks (Advanced DCCS). For each of the nonlinguistic TS tasks, we included only children's response latencies from correct trials. In the Opposite Worlds task only, we measured total task duration rather than response latency (as in Bialystok & Shapero, 2005); as a result, these task durations included incorrect trials.

Shift costs. Shift costs, which compare speed in post-switch trials to pre-switch trials, served as our measure of children's ability to overcome perseveration and switch to a new rule. We calculated shift costs in the linguistic TS task (Opposite Worlds), as well as in two of the four nonlinguistic tasks (Easy DCCS and Standard DCCS).

Linguistic shift costs. In the Opposite Worlds task, the mean shift cost was .33 (*SD* = .42); in other words, on average, children took 33% longer to complete the post-switch phase than the pre-switch phase ($t(29) = 4.17$, $p < .001$).

Nonlinguistic shift costs. Shift costs were close to zero in the Easy DCCS and Standard DCCS (see Table 6), indicating that children's mean response latencies in post-switch trials were not significantly different from those in pre-switch trials (Easy DCCS: $t(28) = .01$, $p = .99$; Standard DCCS: $t(27) = .40$, $p = .70$).

Mix costs. Mix costs, which compare speed in Advanced DCCS non-switch trials to Standard DCCS pre-switch trials, served as our measure of children's ability to hold two rules in mind. Across all participants, the mean mix cost was .43 (*SD* = .90); in other words, response latencies in non-switch trials of the Advanced DCCS were an average of 43% longer than response latencies in pre-switch trials of the Standard DCCS ($t(26) = 2.35$, $p = .03$).

Switch costs.[27] Switch costs, which compare speed in Advanced DCCS switch trials to non-switch trials, served as our measure of children's ability to move flexibly between different rules. Across all participants, the mean switch cost was .20 (*SD* = .95). Response latencies in switch trials of the Advanced DCCS were an average of 20% longer than in non-switch trials, but this difference was not statistically significant ($t(25) = .76$, $p = .45$).

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[27] We omitted one child due to their mean response latency in the Advanced DCCS switch trials being more than four standard deviations higher than the sample mean.

Efficiency. As we did for speed, we calculated three indicators of children's efficiency in the TS tasks: shift cost, mix cost, and switch cost. Instead of comparing children's response latencies, we compared their rate of correct responses (number of seconds per correct response), thus simultaneously taking into account speed and accuracy.

Shift costs. Shift costs, which compare efficiency (number of seconds per correct response) in post-switch trials to pre-switch trials, served as our measure of children's ability to overcome perseveration and switch to a new rule. We measured shift costs in the linguistic TS task (Opposite Worlds), as well as in two of the four nonlinguistic tasks (Easy DCCS and Standard DCCS).

Linguistic shift costs. In the Opposite Worlds task, the mean shift cost was 0.69 (SD = 0.87): children took an average of 69% longer per correct response in the post-switch than pre-switch phase ($t(29) = 4.00$, $p < .001$).

Nonlinguistic shift costs. The average efficiency score shift costs for the Easy DCCS and Standard DCCS were 0.49 (SD = 1.09) and 0.74 (SD = 1.98), respectively. In the Easy DCCS task, each correct post-switch response took an average of 49% longer to generate than each correct pre-switch response ($t(27) = 2.13$, $p = .04$). In the Standard DCCS, each correct post-switch response took an average of 74% longer to generate than each correct pre-switch response ($t(26) = 1.68$, $p = .10$), but this difference was not statistically significant.

Mix cost.[28] Mix costs, which compare efficiency in Advanced DCCS non-switch trials to Standard DCCS pre-switch trials, served as our measure of children's ability to hold two rules in mind. Across all participants, the mean mix cost in efficiency scores was 1.65 (SD = 1.53); in other words, each correct response took an average of 165% longer to generate in Advanced DCCS non-switch trials than in Standard DCCS pre-switch trials ($t(25) = 5.60$, $p < .001$).

Switch cost.[29] Switch costs, which compare efficiency in Advanced DCCS switch trials to non-switch trials, served as our measure of children's ability to move flexibly between different rules. The mean switch cost in efficiency scores was .81 (SD = 1.45); in other words, each correct response took an average of 81% longer to generate in switch trials compared to non-switch trials in the Advanced DCCS ($t(21) = 1.93$, $p = .07$), but this difference was marginally significant.

Final TS measures. Given our relatively small sample size, it was important to limit the number of regression models to test, as α levels would need to be adjusted in order to account for inflation in the probability of Type I errors (i.e., false positives) due to multiple comparisons (Streiner, 2015). We opted to omit measures solely related to children's speed in favor of measures of their efficiency, which incorporated both speed and accuracy and demonstrated more variability. There were six different indicators of

[28] We omitted from this analysis children who scored at chance or below in Standard DCCS pre-switch trials (indicating that they did not understand the task rules), as well as one child whose efficiency score in the Advanced DCCS non-switch trials was nearly ten standard deviations higher than the sample mean (total omitted: 13% of sample).
[29] We omitted from this analysis children who scored at chance or below in Advanced DCCS non-switch trials, as well as one child whose efficiency score in the Advanced DCCS non-switch trials was nearly ten standard deviations higher than the sample mean (total omitted: 27% of sample).

efficiency: shift costs for the linguistic task, shift costs for each of the three nonlinguistic tasks, mix costs, and switch costs. Of these six efficiency measures, we decided to include four dependent variables: 1) *shift costs* in the linguistic TS task (Opposite Worlds), 2) *shift costs* in the most difficult nonlinguistic task (Standard DCCS), 3) *mix costs* (Standard DCCS pre-switch trials vs. Advanced DCCS non-switch trials), and 4) *switch costs* (Advanced DCCS switch vs. non-switch trials). We also included children's overall *accuracy*[30] as a fifth dependent variable.

In the end, we selected five TS measures: *overall accuracy* (proportion correct across all tasks), efficiency *shift costs* in the Opposite Worlds (linguistic) and Standard DCCS (nonlinguistic) tasks, efficiency score *mix costs*, and efficiency score *switch costs*.

Links between Code-switching and Task-switching

The current study aimed to identify links between specific CS practices and TS performance. Our analyses of children's CS behaviors at home and school revealed three distinct types and contexts of CS: language **switching** at home, language **mixing** at home, and overall CS (language mixing and switching **combined**) at school. To explore how these CS behaviors at home and school would predict children's TS abilities, we conducted multiple hierarchical regressions with each of the three CS factors (Home Switching, Home Mixing, and School CS) as separate predictors. We also included age,

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[30] As mentioned earlier in this section, this composite measure included children's accuracy scores from four TS tasks: Opposite Worlds, Easy DCCS, Standard DCCS, and Advanced DCCS. We excluded children's accuracy scores from the Reverse Categorization task because children performed at ceiling in this task.

working memory score, language balance proficiency, and overall language proficiency as control variables in our models.

We investigated how each of the CS factors contributed to five different measures of children's TS performance: *overall accuracy* (proportion correct across all tasks), linguistic TS *shift costs*, nonlinguistic TS *shift costs*, *mix costs*, and *switch costs*. Therefore, we ultimately conducted 15 separate hierarchical regressions:[31] five with Home Switching as the predictor of interest, five with Home Mixing as the predictor of interest, and five with School CS as the predictor of interest. Tables 9 and 10 present results from these multiple hierarchical regression analyses. In the remainder of this section, we describe these results, organized by CS predictor.

Home switching. We had hypothesized that language switching would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children who switched languages more often at home would be more accurate and experience smaller losses in efficiency compared to children who did so less often).

Our results did not support this hypothesis; language switching at home did not predict *overall accuracy, shift costs, mix costs,* or *switch costs* in the TS tasks. Although home language switching appeared to negatively predict *shift costs* in the linguistic TS task ($\beta = -0.78$, $p < .01$, see Table 9, "Home Switching Model" for linguistic TS shift costs) and explained an additional 21% of the variance in linguistic TS *shift cost* beyond

[31] We used the Holm method (Holm, 1979) with a Dunn-Šidák correction (Šidák, 1967) to correct for inflation in the rate of Type I errors due to multiple comparisons. This method is more powerful than the Bonferroni adjustment, which tends to over-correct in hypothesis-testing applications (Streiner, 2015).

the control variables alone (Adjusted R^2 = .17 vs. -.04), the overall model did not reach statistical significance (p = .11).

Home mixing. We had expected that language mixing would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children who mixed languages more often at home would be more accurate and experience smaller losses in efficiency compared to children who did so less often), but to a lesser extent than language switching.

Our results partially supported this hypothesis. In line with our expectations, language mixing at home significantly predicted *overall accuracy* (β = 0.53, p < .01) and *mix costs* (β = -0.72, p < .01): children who mixed languages more frequently at home were more accurate and experienced smaller losses in efficiency due to holding two rules in mind versus one when controlling for age, working memory, language proficiency balance, and overall language proficiency (see Table 9, “Home Mixing Model” for overall accuracy; and Table 10, “Home Mixing Model” for mix costs).

However, contrary to our expectations, language mixing at home predicted TS performance to a greater extent than did language switching. The Home Mixing model explained an additional 22% of the variance in *overall accuracy* beyond the control variables alone (Adjusted R^2 = .57 vs. .35), while the Home Switching model explained an additional 5% of the variance in *overall accuracy* (Adjusted R^2 = .40 vs. .35). When predicting *mix cost*, the Home Mixing model explained an additional 32% of the variance in *mix cost* beyond the control variables alone (Adjusted R^2 = .49 vs. .17), while the

Home Switching model did not explain any additional variance in *mix cost* (Adjusted R^2 = .15 vs. .17).

Counter to our hypothesis, language mixing at home was not a significant predictor of *shift costs* or *switch costs*.

School switching and mixing. We had expected that both language switching and language mixing would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children who switched and mixed languages more often at school would be more accurate and experience smaller losses in efficiency than children who switched and mixed languages less often).

Our results did not support this hypothesis; language switching and mixing at school did not predict *overall accuracy*, *shift costs*, *mix costs*, or *switch costs* in the TS tasks. Although the School CS model significantly predicted *overall accuracy* in the TS tasks, the model only explained an additional 1% of the variance in *overall accuracy* beyond the control variables alone (Adjusted R^2 = .36 vs. .35).

Control variables.

Age. In line with other developmental research on children's TS abilities, we had expected that age would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., older children would be more accurate and experience smaller losses in efficiency).

Our results partially supported past findings: age significantly predicted *overall accuracy* in the Home Mixing model ($\beta = 0.48$, $p < .01$) in the expected direction, as well as *mix costs* in the Home Mixing model (β = -0.75, p < .001). In other words, older children were more accurate and experienced smaller losses in efficiency due to holding two rules in mind versus one specifically when controlling for frequency of language mixing at home, working memory, language proficiency balance, and overall language proficiency.

However, contrary to our expectations, age did not significantly predict *shift costs* or *switch costs*.

Working memory. We had expected that working memory would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children with better working memory would be more accurate and experience smaller losses in efficiency).

Our results partially supported these hypotheses: working memory significantly predicted *overall accuracy* in the expected direction, but only in the Home Switching model (β = 0.36, p = .04): children with better working memory were more accurate in the TS tasks when controlling for frequency of language switching at home, age, working memory, language proficiency balance, and overall language proficiency.

Contrary to our expectations, working memory did not significantly predict *shift*, *mix*, or *switch costs*.

Language proficiency balance. We had expected that language proficiency balance would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children with more balanced language proficiencies would be more accurate and experience smaller losses in efficiency).

Our results did not support these hypotheses. Language proficiency balance significantly predicted *overall accuracy* in the Home Mixing model ($\beta = -0.61$, $p < .01$) and Home Switching model ($\beta = -0.52$, $p = .04$), but in the opposite direction: children with more balanced language proficiencies were less accurate in the TS tasks when controlling for frequencies of language mixing and language switching at home, age, working memory, and overall language proficiency. Furthermore, language proficiency balance significantly predicted *mix costs* in the Home Mixing model ($\beta = 0.61$, $p = .01$), but again in the opposite direction: children with more balanced language proficiencies experienced larger losses in efficiency due to holding two rules in mind versus one when controlling for frequency of language mixing at home, age, working memory, and overall language proficiency.

Counter to our expectations, language balance proficiency was not a significant predictor of *shift costs* or *switch costs*.

Overall language proficiency. We had expected that overall language proficiency would positively predict overall accuracy and negatively predict efficiency score shift, mix, and switch costs (i.e., children with higher language proficiencies would be more accurate and experience smaller losses in efficiency).

Our results partially supported our hypotheses. Overall language proficiency significantly predicted *overall accuracy* in the Home Mixing model ($\beta = 0.45$, $p < .01$)

and Home Switching model ($\beta = 0.36$, $p = .03$) in the expected direction: children with higher language proficiencies were more accurate in the TS tasks when controlling for frequencies of language mixing and language switching at home, age, working memory, and language proficiency balance. In addition, overall language proficiency significantly predicted *mix costs* in the expected direction in the Home Mixing model ($\beta = 0.61$, $p = .04$): children with higher language proficiencies experienced smaller losses in efficiency due to holding two rules in mind versus one when controlling for frequency of language mixing at home, age, working memory, and language proficiency balance.

Contrary to our expectations, overall language proficiency did not significantly predict *shift* or *switch costs*.

Discussion

The purpose of our study was twofold. First, we wanted to document the types of CS behaviors that bilingual preschoolers engage in at home and at school. Second, we wanted to understand how these CS behaviors link to children's TS abilities.

RQ #1: Code-switching at Home and School

Our findings showed that children engaged in a variety of CS practices at home and school. At home, nearly all children **mixed** languages (e.g., "妈妈我想去 [Mandarin: I want to go] swing!"), but comparatively fewer **switched** languages (e.g., "Papa, je veux jouer avec ton telephone [French: Daddy, I want to play with your phone. 妈妈,我可以玩你的手机吗 [Mandarin: Mommy, can I play with your cell phone]?"). In contrast, most of these children engaged in both language mixing and switching at least sometimes at school. Children's CS practices were different at home and school: those who mixed or switched languages more often at home did not necessarily mix or switch languages more often at school. Moreover, we found interesting differences in how language mixing and switching behaviors were related within each of these contexts. Based on teachers' reports, children who mixed languages more often at school also tended to switch languages more, but this was not true of parent-reported CS behaviors at home. The variation within this small sample of young children speaks to the importance of considering individual and contextual differences when assessing the existence of the bilingual advantage in EF (Yang, Hartanto, & Yang, 2016b).

Our findings also suggest distinct developmental trajectories of children's bilingual language abilities at home versus at school. At school, older children tended to mix and switch languages more frequently than younger children. This is likely due to the fact that many (57%) entered preschool with no prior experience with Mandarin, but became increasingly competent in Mandarin as they got older and spent more time in the program. Although the program did not abide by a strict language policy (e.g., Mandarin only on certain days of the week), children were expected to produce and understand everyday vocabulary and conversational phrases in Mandarin. As a result, children's Mandarin language abilities generally improved over time. Moreover, teachers regularly encouraged all children to engage in both language switching and language mixing, and engaged frequently themselves in both types of CS behaviors in the classroom. Our results suggest that in this school context where CS was regularly modeled and encouraged by teachers, children also engaged more often in language switching and mixing over time. Indeed, studies have shown that bilingual children as young as two years old adjust their CS behaviors to match the language practices of bilingual strangers (Comeau, Genesee, & Lapaquette, 2003). Given that older children had more CS exposure and experience at the preschool compared to younger children, it is unsurprising that they also engaged more often in language switching and mixing compared to younger children.

At home, on the other hand, neither language mixing nor switching appeared to increase consistently with age. This may be because patterns in children's home language usage did not generally change over time; during the semi-structured interview, parents often spoke about their household language policies as stable rules governing children's bilingual language use. Household language policies varied widely by family—some parents shared that they tried to discourage their children from mixing languages, while others mentioned regularly reminding their children to switch languages when talking to specific people (e.g., grandparents). However, there was no anecdotal evidence to suggest that household language policies changed as children grew older. Research from the field of bilingual language socialization has shown that parents' CS behaviors and attitudes toward CS shape their children's own CS practices at home (Bayley & Schecter, 2003; Jaffe, 2007). Given that children had been participating in their family language practices since birth, and that household language policies varied widely by family but demonstrated no consistent developmental arc, it is unsurprising that we found no reliable links between children's age and home CS practices. Together, these results suggest that even at this young age, the development of preschoolers' CS practices is sensitive to differences in context.

These descriptive findings were further supported by results of the factor analysis, which indicated that distinctions between CS types are context-dependent. While children's language switching and language mixing were disparate constructs within the home context, they were one unified construct within the school context. This new finding suggests that children adjust their CS practices based on the expectations of each context. At preschool, teachers welcomed, modeled, and encouraged *both* language switching and mixing as means of developing bilingual fluency; children therefore switched *and* mixed languages more often as they grew older and had more exposure to the program. Parents, on the other hand, ranged widely in their language policies: some parents ascribed to a strict "one parent, one language" approach, other parents encouraged their children to mix languages freely, and still others expected their children to speak only their heritage language at home. In other words, parents tended to view language switching and language mixing as distinct behaviors, and often had opinions about whether each type of CS was beneficial to their child's development. Given that young children adjust their language use based on family language practices (Quay, 2008), it is likely that the children in our study adjusted their CS behaviors in response to their parents' preferences. Our findings highlight the importance of moving away from considering CS to be a stable behavior that can be measured via a general question (i.e., "How often do you mix/switch languages?") towards understanding it as a dynamic behavior that is responsive to changes in context—even in children as young as three and four years old.

RQ #2: Links between Code-switching and Task-switching

Language switching and task-switching. Contrary to our hypotheses, we did not find any links between children's language **switching** at home and their TS performance. Our findings did not support the Adaptive Control Hypothesis (Green & Abutalebi, 2013) or Control Process Model (Green & Wei, 2014), both of which propose that language switching exercises the same cognitive control processes implicated in TS tasks. In our group of young emerging bilinguals, children who switched languages more often did not outperform those who switched languages less often.

This null finding may be partially due to our small sample size (n = 31); our study may have been underpowered for the potentially small effect size of language switching on TS performance. In Hartanto and Yang's (2016) study, which found that language switching significantly predicted switch costs in bilingual young adults, the sample was notably larger than ours (n = 113), but the effect size of language switching on switch costs was still relatively small (η_p^2 = .034). If the effect size of language switching on switch costs with bilingual young children is similar to the effect size found with bilingual young adults, future studies with bilingual young children should include a larger sample size in order to detect the relationship between language switching frequency and TS performance.

In our study, home language switching frequency appeared to negatively predict *shift* costs in one task: the Opposite Worlds task, which required children to call animals by their "upside-down names" (i.e., pigs were called cows, and cows were called pigs). Given that children who switch languages very often (e.g., those in one-parent, one-language households) must regularly overcome language perseveration with each change in conversational partner, it is reasonable to expect that they might experience smaller losses in efficiency due to linguistic perseveration in this task. However, the overall model predicting linguistic shift costs did not reach statistical significance (p = .11), likely because the p-value of the F-test considers the average contribution of the entire set of predictors, and the control variables entered in the first step of the hierarchical regression (age, working memory, language proficiency balance, overall language proficiency) were effectively unrelated to linguistic shift costs (adjusted R^2 = -.04). This suggests not only that these control variables were imprecise predictors of linguistic shift costs; it also suggests that they may have obscured the true relationship between language switching and linguistic shift costs by overfitting the model (Hawkins, 2004). Future studies exploring links between language switching and linguistic TS with more relevant control variables might yield more reliable results, particularly as other studies have found linguistic TS advantages in bilingual young children (Bialystok et al., 2010; Bialystok & Shapero, 2005), as well as in bilingual adults who engage frequently in CS (Adamou & Shen, 2019).

Another explanation for this null finding is that there may have been insufficient variability in the rates of home language switching among our sample. Very few children were reported to engage in frequent language switching at home; indeed, our diary study results suggested that the vast majority of children switched languages fewer than once a day. Other studies that found links specifically between language switching and TS involved adult populations who lived in bilingual cultures and reported extensive experience with language switching in their daily lives (Hartanto & Yang, 2016). To examine these links in young bilingual children, it may be necessary to focus on cultural groups and settings where language switching among children is common practice. Studies have shown that bilingual 2- to 4-year-olds in multilingual cultural contexts switch languages flexibly to enact different roles during imaginary play (Paugh, 2005). While the children in our study came from homes with diverse language environments, they were embedded within a larger American cultural context that was essentially monolingual; this likely limited the extent to which they were exposed to and practiced language switching. To further explore this question, future studies could compare the TS performance of bilingual children who live in communities where language switching is common to that of bilingual children who live in communities where it is less common.

Language mixing and task-switching. While we did not find links between children's language **switching** and their TS performance, we found that more frequent language **mixing** at home significantly predicted TS advantages in two areas: accuracy and mix cost efficiency. In other words, children who mixed languages more often at home were more accurate across the TS tasks and able to generate correct responses more quickly when holding two rules in mind (monitoring) compared to children who did not mix languages as often at home. These findings supported our hypothesis that language mixing would positively predict TS performance, and may help to explain the source of the bilingual advantage in mix costs that has been found in various other studies (Barac & Bialystok, 2012; Park et al., 2018; Yang, Hartanto, & Yang, 2018). However, these findings did not support our hypothesis that language mixing would predict TS performance to a lesser extent than language switching: instead, we found that language mixing predicted TS performance more reliably than did language switching.

This pattern was unexpected, as the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model of Code-switching (Green & Wei, 2014) both posited that language **switching** is more cognitively taxing than language **mixing** and therefore is more likely to contribute to TS abilities. Our results suggest that perhaps specifically for children, language mixing may be more cognitively demanding than is implied by these two theories: given that language mixing requires that children simultaneously hold two languages in mind in order to draw elements from both, it may be that this type of CS exercises a general ability to monitor and manage multiple rule sets. Anecdotal evidence from parent interviews suggested that the vast majority of children did not mix languages at random; instead, parents reported that children tended to mix languages in one of two situations: 1) if they did not know the word in the other language, or 2) if they were accustomed to using that particular word/concept in that language. This suggests children were not drawing words randomly from multiple language systems, but instead engaging cognitive control processes relevant to monitoring and managing multiple languages—a different picture is described by the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model of

Code-switching (Green & Wei, 2014). According to these two theories, language mixing implies a cooperative relationship between language schemas, where both languages are simultaneously activated and creatively interwoven. However, this also implies a level of competence in both languages; it is possible that the bilingual children in our study had not yet reached the level of linguistic competence necessary to establish this type of cooperative language structure.

In other words, there may be developmental differences in how language mixing operates in bilingual children versus bilingual adults. For bilingual children who are in the process of acquiring multiple languages, language mixing may, for example, draw upon cognitive control processes such as conflict monitoring (to determine that they do not know a particular word in a language) and goal maintenance (to shift back to the other language after inserting the unknown word). On the other hand, bilingual adults who have ample experience with language mixing and high proficiencies in both languages may no longer need to draw upon conflict monitoring or goal maintenance processes when mixing languages, and instead draw upon other cognitive control processes such as opportunistic planning (Green & Abutalebi, 2013). Our results suggest that the cognitive demands of language mixing may change over the lifespan, further underscoring the importance of bringing a developmental perspective to this area of research.

School code-switching and task-switching. Contrary to our expectations, school CS practices did not significantly predict TS performance in our study. There are several explanations for why we did not find a relationship between children's CS behaviors at school and their TS abilities. First, they may not have reached the threshold of school CS experience necessary to yield benefits in TS.[32] Studies investigating the effect of bilingual education on TS performance have found advantages in adolescents with at least three full years of bilingual education (Christoffels, de Haan, Steenbergen, van den Wildenberg, & Colzato, 2015), but not in 5- to 7-year-olds (Kaushanskaya, Gross, & Buac, 2014), some of whom had less than a year of bilingual classroom experience. In our sample, there was wide variation in the amount of time that children had been enrolled at the bilingual preschool: the newest student had been attending the school for only two months, while the oldest student had been there for nearly three years. It is possible that advantages in EF emerge only after a specified amount of exposure and experience with CS at school (De Cat, Gusnanto, & Serratrice, 2018). Future studies could compare the TS performance of children with varying degrees of bilingual classroom experience.

In addition, there may have been issues with how we measured school CS behaviors. In our study, we relied on teachers' reports of children's language switching and mixing in the classroom. In everyday classroom activities, both bilingual teachers encouraged children to use both Mandarin and English. However, the majority of children's time at school is spent not in one-on-one interactions with teachers, but with other children, and these peer interactions have implications for their bilingual language

[32] In our sample, children's age (in months) and the time they had been enrolled at the preschool were highly correlated ($r(30) = .83$, $p < .001$). Given concerns regarding collinearity, we did not include time enrolled at the preschool as a separate control variable in our analyses.

practices (Chesterfield, Chesterfield, & Chávez, 1982). Although teachers regularly prompted children to code-switch between English and Mandarin during classroom activities and thus may have observed relatively frequent language switching and mixing, anecdotal evidence from both parents and teachers indicated that children used mostly English when engaging with their friends and playmates. If children spent comparatively more time with their classmates than with their teachers, and did not mix or switch languages often in these peer interactions, it is likely that their true rates of overall CS in the classroom were lower than were reported by the teachers. Future studies of CS within bilingual school contexts could benefit from the inclusion of direct observational methods to support teachers' reports.

Summary. Taken together, our findings provide a new perspective on the bilingual advantage debate in a group of participants younger than previously studied. Some theories have proposed that different types of CS exercise different constellations of cognitive control processes and thus differ in cognitive demand and impact on EF (Green & Abutalebi, 2013; Green & Wei, 2014). In contrast to our hypotheses, we found that language **switching** was not a significant predictor of children's TS abilities. Instead, our results suggest that language **mixing** may play a role in the development of certain cognitive control processes implicated in TS, such as conflict monitoring and goal maintenance.

Our study findings parallel those of one recent study with bilingual adults that found that those who **mixed** languages often showed EF advantages specifically in conditions involving higher demands in conflict monitoring (Hofweber, Marinis, &

Treffers-Daller, 2016). However, contrary to our expectations, our findings do not provide support for Green and Wei's (2014) Control Process Model of Code-switching, which posits that language **mixing** involves a cooperative rather than competitive relationship between languages, and thus is not likely to enhance TS abilities. Instead, we found that young children who mixed languages more often demonstrated advantages in TS. It may be that the Control Process Model operates differently at different points of the developmental trajectory; perhaps this distinction between competitive and cooperative language schemas is not as clear in young emerging bilinguals. There may also be individual differences at play: some parents mentioned in the interview that their child did not appear to distinguish between their two languages and would often select the wrong language to speak to an interlocutor, while others said that their child was highly aware of language differences from a young age and never selected the wrong language. In sum, our results suggest that there might be both competitive and cooperative cognitive processes involved in TS, and that future investigations of the Control Process Model could benefit from a developmental perspective.

Finally, we had expected that children's CS behaviors would predict their switch costs, which provide a measure of the ability to move flexibly between different rules. In particular, we had expected that children who **switched** languages more often would demonstrate smaller losses in efficiency, given that language switching is posited to draw upon the same cognitive control processes necessary for shifting rule sets (Green & Abutelabi, 2013; Green & Wei, 2014). Hartanto and Yang (2016) found that bilingual adults who **switched** languages frequently exhibited smaller switch costs, while those who **mixed** languages frequently exhibited larger switch costs. However, findings from our regression analyses indicated that none of our models (language switching or mixing) significantly predicted children's switch costs. Although a couple of studies have found bilingual advantages in this particular area of TS performance (Prior & Gollan, 2011; Prior & MacWhinney, 2010), the vast majority of studies have found no difference between bilingual and monolingual children (Barac & Bialystok, 2012; Park et al., 2018) or adults (Hernández, Martin, Barceló, & Costa, 2013; Paap & Greenberg, 2013; Paap et al., 2017). Our results add further nuance by suggesting that if there is a difference in how bilinguals and monolinguals move flexibly between different rules (Prior & Gollan, 2011), and if this difference is indeed driven by bilinguals' experience specifically with language switching (Hartanto & Yang, 2016), there may be a threshold of experience necessary for these benefits to appear. Specifically, Hartanto and Yang's (2016) study involved bilingual young adults who had grown up in a bilingual culture and had extensive experience switching and mixing languages. In contrast, the children in our study were still in the process of acquiring bilingual language skills, and had at most two years of experience engaging in regular language switching (assuming they began to speak at the age of two). Moreover, many of our children had very little experience with language switching. It is possible that differences in switch costs might emerge only after several additional years of language switching experience; future research could explore the longitudinal effects of consistent language switching on bilingual children's switch costs.

Other Predictors in Task-switching Performance

As expected, age significantly predicted TS performance: older children were more accurate across the tasks and demonstrated smaller mix costs. This replicates results from other studies that have identified age-related improvements in children's TS abilities from the age of two to five (Bialystok et al., 2010; Carlson, 2005; Doebel & Zelazo, 2015).

We had expected that working memory would significantly predict TS performance, given that some theorists have proposed that EF (comprised of TS, working memory, and inhibitory control) is a unitary construct (Garon, Bryson, & Smith, 2008). However, in our study, working memory emerged as a significant predictor of TS performance in only one out of 15 models. This was surprising, as studies have shown that people with stronger working memory capacity also demonstrate advantages in TS (Kane, Bleckley, Conway, & Engle, 2001). At the same time, recent work on working memory has highlighted the existence of substantial intra-individual variability in working memory task performance, particularly in people with weaker working memory capacity (Wiemers & Redick, 2018), younger children (Dirk & Schmiedek, 2016), and older adults (Mella, Fagot, Lecerf, & de Ribaupierre, 2015). In fact, studies suggest that children's working memory performance varies not only from day to day, but also between different occasions on the same day, different trials within the same occasion, and different items within the same trial (Galeano Weber, Dirk, & Schmiedek, 2018). Together, these findings call for a closer look at possible links between working memory and TS, perhaps investigating working memory *variability* rather than *one-time performance* as a potential predictor of TS.

We found that language proficiency balance predicted TS performance, but not in the expected direction. Specifically, children with more balanced language proficiencies were less accurate and demonstrated larger mix costs. Other studies have found the opposite pattern in bilingual preschoolers (Iluz-Cohen & Armon-Lotem, 2013), young adults (Rosselli et al., 2016; Yow & Li, 2015), and the elderly (Houtzager, Lowie, & de Bot, 2014). However, our sample was unusual in that half of the children were trilingual. Some work on trilingualism has argued that it is effectively impossible that three languages can be truly balanced, and thus theories involving balanced bilingualism cannot simply be transferred to balanced trilingualism (Barron-Hauwaert, 2000). Our sample size was too small to compare the impact of language proficiency balance on TS performance in bilingual versus trilingual children. Future studies can explore how language proficiency balance may differentially impact EF abilities in bilingual versus trilingual children.

In our models, overall language proficiency predicted overall accuracy and mix costs in the expected direction. Children who were more proficient were more accurate across the TS tasks and exhibited smaller losses in efficiency due to holding two rules in mind. These results replicate other findings that highly proficient bilinguals outperform less proficient bilinguals in TS (Iluz-Cohen & Armon-Lotem, 2013) as well as a host of other verbal and nonverbal EF measures (Rosselli et al., 2016). Variations in language proficiency could thus help explain some of the inconsistencies in the literature on bilingual advantages in EF.

Limitations

This study had several methodological limitations. First, given that this was the first study to our knowledge to measure preschoolers' language switching and language mixing in multiple contexts, there were a few issues that arose in the process of measuring young children's CS behaviors at home and school.

Parents reported children's CS behaviors at home through two different measures: a 7-day diary study and a follow-up survey. The two measures should have been strongly correlated given their proximity in time of administration. However, correlations for both language switching and language mixing were moderate rather than strong, indicating that parents' final overall estimates of their children's CS behaviors were not completely aligned with their diary study observations. Without collecting home observational data, we did not have a direct measure of children's CS behaviors to compare with parents' reports. For example, it is likely that some parents may not have made diary study entries for every instance of their child's language switching or mixing.

Underreporting children's CS behaviors in the diary study may have been particularly problematic speciically with regards to language switching, for which diary study and follow-up survey data demonstrated only acceptable internal consistency (Cronbach's $\alpha = .69$). While language mixing is generally noticeable because it involves a sudden shift in language in the middle of a sentence, language switching may be less noticeable, especially if it is embedded within the family's normal interaction patterns (i.e., in one-parent, one-language situations). Indeed, at least several parents who anecdotally reported that their children were required to switch languages constantly in everyday interactions with family members did not ultimately make many language switching entries in the diary study. This discrepancy suggests that for bilingual language practices that are extremely common and therefore more difficult for parents to individually document, it could be useful to include an observational measure, such as audio-recording family dinner conversations (Quay, 2008).

One CS context that we did not capture in our study was children's interactions with their peers. Research has shown that bilingual children engage in CS intentionally and strategically with their peers to achieve various social goals (Bengochea, Sembiante, & Gort, 2018; Cromdal, 2001; Cromdal & Aronsson, 2000; Paugh, 2005). Given that all children at the preschool shared both English and Mandarin in common but varied in their usage of the two languages, it is likely that some language switching and mixing occurred in the classroom and/or on the playground. Including a more direct measure of children's CS behaviors with their classmates at the bilingual preschool would have added an important dimension to our understanding of their everyday CS practices.

Aside from these limitations related to measuring CS, there are limitations to the generalizability of our findings due to the small sample size and unique characteristics of our sample. The Mandarin-English bilingual preschool involved in this study was private and located in the San Francisco Bay area. As a result, the vast majority of the children in our study came from highly educated, high-income, Chinese-speaking families. There is ample research documenting the link between children's EF abilities and socioeconomic status (Hughes, Ensor, Wilson, & Graham, 2009; Raver, Blair, & Willoughby, 2013; Sarsour et al., 2011), as well as EF advantages in Chinese versus American preschoolers (Lan, Legare, Ponitz, Li, & Morrison, 2011; Sabbagh, Xu, Carlson, Moses, & Lee, 2006). It is likely that the children in our study are among the top percentile in their age group in terms of TS performance. Therefore, results from our study should not be generalized to children from other groups. Instead, we hope that our findings will be considered a starting point for further research exploring the CS practices of children within other socioeconomic, linguistic, and cultural groups.

Future Studies

We found links between young bilingual children's TS performance and their CS behaviors at home (based on parent report), but we did not find this link with their CS behaviors at school (based on teacher report). Future studies could investigate children's CS behaviors through observation, an experimental task, or a combination of methods. Although some work has shown that different measures of CS do not necessarily align (Gumperz, 1977), research in this area has rarely included triangulation across methods (Cox et al., 2019). Given the nature of CS, it is especially important to approach it not as a single construct, but a complex behavior that shifts dynamically based on contextual factors.

One contextual factor that likely shapes children' CS practices is language policy, or the extent to which each type of CS is encouraged and/or modeled by surrounding adults. Our findings regarding age-related changes in CS behaviors at school but not at home suggest that children adapt their bilingual language usage to the expectations of each context. Given anecdotal evidence that parents endorsed language switching and language mixing to different extents, it would be informative to explore possible links between family language policies and children's CS practices. Empirical evidence suggests that young children's language mixing is sensitive to the language usage and preferences of their parents (Juan-Garau & Pérez-Vidal, 2001). Therefore, it is likely that parents' stated policies regarding the two types of CS could predict the frequency of children's language switching and mixing. Studies investigating this potential connection could be an important step forward in identifying precisely which contextual factors impact children's everyday CS behaviors.

Future research could also explore links between children's TS abilities and bilingual language practices beyond language switching and mixing. Many immigrant families settle in communities where their home language is not the language of everyday interaction. Within these families, children often take on the role of translating, interpreting, and communicating on behalf of their parents across a wide range of situations (Valdés, Chavez, & Angelelli, 2003). These young interpreters, or language brokers, code-switch regularly to assist their families with a host of legal, financial, educational, and work-related demands (Haneda & Monobe, 2009; Orellana, 2001; Tse, 1996). Language brokering represents a uniquely demanding CS context, as children need to not only shift between language, but between different "spheres," such as child language/adult language, majority/minority culture, and working class/middle class values (Rainey, Flores-Lamb, & Gjorgieva, 2017; Reynolds & Orellana, 2009).

Moreover, it requires regular navigation of *dual-language*, *single-language*, and *dense CS* contexts. One recent study found that 8- to 10-year-olds who served as language brokers for their families demonstrated advantages in cognitive flexibility (as measured in a trail-making task) over both monolingual children and bilingual children who did not serve as language brokers for their families (Rainey, Davidson, & Li-Grining, 2016). Further exploration of the contributions of language brokering to TS performance would not only add additional nuance to the debate surrounding the bilingual advantage in EF; it would also provide a new angle from which to test the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model (Green & Wei, 2014).

Our study suggests that young children who mix and switch languages more often may demonstrate advantages in TS. Future work could implement manipulations or interventions to experimentally test for these advantages. Although induced CS is not the same as in vivo CS (Cox et al., 2019), these results could inform teaching in bilingual classrooms. In the United States, bilingual education takes many forms. Some programs are explicitly intended to transition non-native English speakers into mainstream English-only classrooms; others are aimed at helping monolingual English speakers develop fluency in a second language. Still others are designed to develop bilingualism and biliteracy in both native and non-native English speakers. Each of these programs has distinct goals and policies regarding language mixing and language switching. If CS interventions indeed boost children's TS abilities, bilingual education programs could further support their students' EF development by modeling and encouraging language switching and mixing in the classroom.

Conclusions

Our study is the first to our knowledge that links 3- and 4-year-olds' task-switching performance with specific code-switching practices in multiple contexts. Our findings suggest that, even at this young age, preschoolers participate in different interactional contexts that involve engaging in different types of CS that consequently develop different aspects of cognitive control. By focusing on these within-group differences, we move away from treating bilingualism as a categorical variable (Luk & Bialystok, 2013) and towards identifying specific elements of bilingual experience that may enhance specific components of EF (Paap & Greenberg, 2013). Building upon the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and the Control Process Model of Code-switching (Green & Wei, 2014), we illuminate links between bilinguals' language mixing in their everyday lives and particular facets of TS ability (accuracy and mix cost).

Our findings highlight the importance of exploring these questions through a developmental lens. Studies comparing TS accuracy in bilinguals and monolinguals have yielded inconsistent results that appear to differ based on the age of participants: in general, studies involving children have found a bilingual advantage (Bialystok et al., 2010; Bialystok & Shapero, 2005; Okanda et al., 2010), while studies involving adults have not (Prior & Gollan, 2011; Prior & MacWhinney, 2010). Our findings linking TS performance and home language mixing in bilingual preschoolers provide additional support for the theory that the cognitive benefits of bilingualism vary along a U-shaped function, with clearer advantages in childhood and old age than in young adulthood (Bialystok et al., 2012; Cepeda et al., 2001).

Our study also contributes methodologically to the literature by identifying a measure of TS ability that may be particularly useful in studies involving young children. Following recent work by Paap and colleagues (2017), we analyzed children's performance in terms of their efficiency, or rate at which they produced correct responses, thus simultaneously capturing speed and accuracy. The vast majority of prior TS research has examined participants' accuracy and speed separately, and operationalized shift, mix, and switch costs based on differences in participants' response latencies in correct trials. However, measuring costs in this way assumes the existence of the speed-accuracy trade-off, the idea that participants adjust their speed based on the difficulty of the task (i.e., slow down when the task is harder). However, in our study, we found that children's response latencies did not change notably between pre-switch and post-switch phases, even if their accuracy did. This suggests that 3- and 4-year-olds may not be as adept at monitoring task difficulty and adjusting their speed, thus the speed-accuracy trade-off may not operate the same way in this age group as in adults. Our findings back other research that has found a developmental progression in the speed-accuracy trade-off, where compared to 6-year-olds, older children (8- and 10-year-olds) and adults demonstrated a temporal deficit in tasks requiring more accuracy (Rival, Olivier, & Ceyte, 2003). In other words, older children slowed down when they needed to be more accurate, whereas younger children did not. In the context of our study, looking at speed alone was likely not a reliable indicator of 3- and 4-year-old children's TS abilities. For these reasons, efficiency scores may be a more appropriate way to capture TS shift, mix, and switch costs in young children.

Finally, our results can potentially inform the language policies of schools in the United States, where the student population is growing increasingly diverse (U.S. Census Bureau, 2017), yet a substantial portion of children learn English at the expense of their heritage language (Cohen & Wickens, 2015; Fillmore, 1991). Although studies have shown that CS in the classroom is perceived by language learners as helpful (Jingxia, 2010) and enhances their academic achievement (Simasiku, Kasanda, & Smit, 2015), many teachers remain ambivalent about its use even in bilingual classrooms (Yao, 2011), possibly due to prevailing attitudes that the ideal language learning environment is one that is pure and free of CS (Chaudron, 1988; Lightbown, 2001). These attitudes mirror those in many mainstream classrooms, where linguistic diversity is often constructed as problematic, difficult, and requiring extra work compared to "normal" classrooms (Dooly, 2007; Gkaintartzi & Tsokalidou, 2011). Highlighting various forms of CS as beneficial to children's cognitive development could not only help to create learning environments that are more inclusive of linguistic diversity; it could also aid in the maintenance of children's heritage languages.

Nearly 30 years ago, Kagan and Garcia (1991) called for a shift in how we educate culturally and linguistically diverse preschoolers. They advocated for more connections between research on early childhood programs, research on childhood bilingualism, and legislative practices, to challenge the English-only policies in most preschools and child care centers in the United States. They argued that more communication and collaboration between researchers, practitioners, and families would have positive implications for language-minority children's academic adjustment and achievement. These sentiments have been echoed by other researchers, who have underscored collaboration as a crucial component of reversing the longtime trend of heritage language loss in America (Fillmore, 2000). Our hope is that, by broadening awareness of bilingual practices that may support children's cognitive development, this study can serve as a step towards achieving these larger goals of widening access to educational opportunity for all children and honoring the diversity that enriches our society.

Tables

Table 1

Demographic profile of participants (n = 30)

	%	*n*
Age *(M = 45.73 months)*		
3 years old	63%	19
4 years old	37%	11
Gender		
Female	57%	17
Male	43%	13
Siblings		
None	50%	15
Has younger sibling	40%	12
Has older sibling	10%	3
Parental education (*n* = 60)		
Did not complete high school	2%	1
High school/GED	0%	0
Some college	3%	2
Associate's degree	3%	2
Bachelor's degree	55%	33
Master's degree	27%	16
Graduate/Professional degree	8%	5
Prefer not to say	2%	1
Household income		
$0 to 34,999	0%	0
$35,000 to 49,999	3%	1
$50,000 to 74,999	0%	0
$75,000 to 99,999	0%	0
$100,000 to 149,999	3%	1
$150,000 to 199,999	17%	5
$200,000 or more	53%	16
Prefer not to say	23%	7

Table 2

Home language background of participants (n = 30)

	%	*n*
Number of household languages		
1 language	20%	6
2 languages	50%	15
3 languages	27%	8
4 languages	3%	1
Household languages spoken		
English	97%	29
Mandarin	43%	13
Cantonese	40%	12
French	10%	3
Japanese	3%	1
Marathi	3%	1
Shanghainese	3%	1
Spanish	3%	1
Tagalog	3%	1
Toisanese	3%	1
Telugu	3%	1
Percentage of time in English		
0 to 25%	20%	6
26 to 50%	17%	5
51 to 75%	30%	9
76 to 100%	33%	10
Household language balance (Range: 0 to 1)		
Balanced (.76 to 1)	33%	10
Somewhat balanced (.51 to .75)	33%	10
Somewhat unbalanced (.26 to .50)	17%	5
Unbalanced (0 to .25)	17%	5

Table 3

Participants' language use at school (n = 30)

	%	*n*
Percentage of time in English		
0 to 25%	23%	7
26 to 50%	40%	12
51 to 75%	23%	7
76 to 100%	13%	4
School language balance (Range: 0 to 1)		
Balanced (.76 to 1)	17%	5
Somewhat balanced (.51 to .75)	43%	13
Somewhat unbalanced (.26 to .50)	27%	8
Unbalanced (0 to .25)	13%	4

Table 4

Language proficiencies of participants (n = 30)

	Poor	Fair	Average	Good	Excellent	Excellent or Good
Overall English proficiency (*n* = 30)	**3%**	**7%**	**7%**	**23%**	**60%**	**83%**
Receptive proficiency	3%	7%	3%	27%	60%	87%
Productive proficiency	7%	10%	10%	23%	50%	73%
Overall L2 proficiency (*n* = 27)	**11%**	**15%**	**22%**	**33%**	**19%**	**52%**
Receptive proficiency	11%	7%	19%	41%	22%	63%
Productive proficiency	30%	19%	11%	37%	4%	41%
Overall L3 proficiency (*n* = 15)	**20%**	**33%**	**20%**	**20%**	**7%**	**27%**
Receptive proficiency	27%	27%	7%	33%	7%	40%
Productive proficiency	40%	33%	7%	13%	7%	20%

Table 5

Means, standard deviations, and correlations of code-switching behaviors and language proficiency variables with 95% confidence intervals

Variable	*M*	*SD*	1	2	3	4	5	6	7
Language switching									
1. Home: Instances per week *(Diary study)*	2.91	4.68	–						
2. Home: Overall frequency[1] *(Follow-up survey)*	2.07	1.33	.53** [.17, .76]	–					
3. School: Overall frequency[1]	1.90	1.19	.25 [-.14, .58]	.2 [-.19, .53]	–				
Language mixing									
4. Home: Instances per week *(Diary study)*	7.76	6.25	.12 [-.27, .48]	.22 [-.19, .56]	.08 [-.32, .44]	–			
5. Home: Overall frequency[1] *(Follow-up survey)*	2.30	1.20	.19 [-.22, .54]	.30 [.09, .60]	.17 [-.22, .51]	.67*** [37, .84]	–		
6. School: Overall frequency[1]	1.66	0.93	.09 [-.28, .47]	.06 [-.32, .43]	.80*** [.59, .89]	.05 [-.35, .41]	.21 [-.18, .54]	–	
Language proficiency									
7. Balance[2]	0.54	0.31	.42* [.04, .69]	.60** [.28, .79]	0.24 [-.13, .55]	.57** [.23, .78]	.48* [.12, .72]	.14 [-.23, .47]	–
8. Overall[3]	4.37	0.81	.07 [-.32, .43]	.10 [-29, .45]	.13 [-24, .46]	-.13 [-.49, .27]	-.12 [-.47, .27]	19 [-.18, .50]	.18 [-.19, .50]

Table 6

Means and standard deviations of attention, accuracy, speed, and efficiency scores in task-switching tasks

	Attended (% of trials)		Accuracy (% correct of attended trials) Score		Speed[1] (% change in sec) Shift costs[2]		Speed[1] (% change in sec) Mix/Switch costs[3]		Efficiency[1] (% change in sec/correct response) Shift costs[2]		Efficiency[1] (% change in sec/correct response) Mix/Switch costs[3]	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Reverse Categorization												
Pre-switch	1.00	0.00	.98	.07	.01	.35			.08	.46		
Post-switch	1.00	0.00	.96	.13								
Opposite Worlds												
Pre-switch	1.00	0.00	.97	.06	.33	.42			.69	.87		
Post-switch	1.00	.02	.85	.19								
Easy DCCS												
Pre-switch	.99	.03	.99	.04	.14	.51			.49	1.09		
Post-switch	.96	.18	.88	.23								
Standard DCCS												
Pre-switch	.94	.18	.96	.10	.02	.44			.74	1.98		
Post-switch	.95	.10	.85	.27								
Advanced DCCS												
Non-switch	.91	.19	.75	.20			.43	.90			1.65	1.53
Switch	.93	.16	.71	.23			.20	.95			.81	1.45

[1]Only children who scored above chance in the pre-switch phase of each task were included. We also excluded children whose efficiency scores were more than four standard deviations above the sample mean.

[2]Shift costs for the Reverse Categorization, Easy DCCS, and Standard DCCS tasks compare mean post-switch response latencies to mean pre-switch response latencies, while shift costs for the Opposite Worlds task compare mean pre-switch task duration to mean post-switch task duration.

[3]Mix costs (comparing non-switch trials in the Advanced DCCS to pre-switch trials of the Standard DCCS) are presented in the top row; switch costs (comparing Advanced DCCS switch to non-switch trials) are presented in the bottom row.

Table 7

Results of exploratory factor analysis of code-switching measures

CS measure	Factor 1	Factor 2	Factor 3
Overall CS at school			
Language mixing frequency (Teacher 1)	.89		
Language mixing frequency (Teacher 2)	.85		
Language switching frequency (Teacher 1)	.84		
Language switching frequency (Teacher 2)	.80		
Language mixing at home			
Language mixing frequency (Follow-up survey)		.91	
Language mixing instances (Diary study)		.88	
Language switching at home			
Language switching instances (Diary study)			.87
Language switching frequency (Follow-up survey)			.84
Eigenvalues	3.18	1.99	1.06
Variance explained (%)	39.71	24.88	13.20
Cronbach's alpha	.84	.80*	.69*

*Calculated using *z*-scores to account for difference in units in diary study vs. follow-up survey

Table 8

Component correlation matrix with direct oblimin rotation method

Factor	1	2	3
Overall CS at school	–		
Language mixing at home	0.07	–	
Language switching at home	-0.20	-0.28	–

Table 9

Hierarchical regression analyses for predicting overall accuracy and efficiency score shift costs

					Shift costs							
	Overall Accuracy				Linguistic TS				Nonlinguistic TS			
Model	*B*	*SE*	β	Adj. R^2	*B*	*SE*	β	Adj. R^2	*B*	*SE*	β	Adj. R^2
Control variables				.35				-.04				.14
Age	0.01	0.01	0.31		-0.04	0.03	-0.29		-0.14	0.07	-0.43	
Working memory	0.42	0.25	0.29		-0.37	1.37	-0.06		2.71	2.96	0.19	
Language proficiency balance	-0.17	0.10	-0.26		0.13	0.55	0.05		1.69	1.27	0.26	
Overall language proficiency	0.08	0.04	0.33*		-0.01	0.21	-0.01		-0.83	0.52	-0.31	
1. Home Switching Model				**.40**				.17				.10
Age	**0.01**	**0.01**	**0.34**		-0.04	0.03	-0.29		-0.15	0.08	-0.44	
Working memory	**0.59**	**0.27**	**0.36***		-0.02	1.17	0.00		2.40	3.50	0.15	
Language proficiency balance	**-0.34**	**0.16**	**-0.52***		1.44	0.68	0.60*		1.22	2.24	0.19	
Overall language proficiency	**0.09**	**0.04**	**0.36***		-0.20	0.17	-0.22		-0.67	0.61	-0.24	
Home Switching	**0.07**	**0.06**	**0.28**		-0.76	0.27	-0.78*		0.32	0.83	0.12	
2. Home Mixing model				**.57**				.02				.11
Age	**0.02**	**0.01**	**0.48****		-0.05	0.03	-0.38		-0.19	0.09	-0.55	
Working memory	**0.36**	**0.24**	**0.22**		0.78	1.33	0.13		2.61	3.48	0.16	
Language proficiency balance	**-0.40**	**0.11**	**-0.61****		0.65	0.60	0.27		3.23	2.38	0.49	
Overall language proficiency	**0.12**	**0.04**	**0.45****		-0.21	0.19	-0.23		-0.93	0.61	-0.34	
Home Mixing	**0.12**	**0.04**	**0.53****		-0.38	0.21	-0.47		-0.55	0.80	-0.25	
3. School CS model				**.36**				-.09				.19
Age	**0.01**	**0.01**	**0.24**		-0.04	0.03	-0.30		-0.11	0.07	-0.34	
Working memory	**0.33**	**0.26**	**0.23**		-0.41	1.46	-0.07		3.88	2.98	0.28	
Language proficiency balance	**-0.20**	**0.10**	**-0.30**		0.11	0.57	0.04		2.09	1.26	0.32	
Overall language proficiency	**0.08**	**0.04**	**0.32***		-0.01	0.22	-0.01		-0.79	0.51	-0.29	
School CS	**0.06**	**0.04**	**0.23**		0.03	0.25	0.03		-0.75	0.50	-0.32	

* $p < .05$, ** $p < .01$, *** $p < .001$, bold-face: model is significant at adjusted α-level (Holm method with Dunn-Šidák correction)

Table 10

Hierarchical regression analyses for predicting efficiency score mix costs and switch costs

Model	Mix costs				Switch costs			
	B	*SE*	β	Adj. R^2	*B*	*SE*	β	Adj. R^2
Control variables				.17				-.06
Age	-0.14	0.05	-0.58*		0.04	0.06	0.17	
Working memory	0.93	2.23	0.09		-1.98	2.57	-0.20	
Language proficiency balance	0.50	1.02	0.10		-1.83	1.29	-0.36	
Overall language proficiency	-0.24	0.40	-0.12		0.49	0.49	0.26	
1. Home Switching model				.15				-.04
Age	-0.14	0.06	-0.56*		0.03	0.06	0.13	
Working memory	-0.07	2.60	-0.01		-1.05	2.92	-0.09	
Language proficiency balance	1.31	1.73	0.25		-3.36	1.99	-0.68	
Overall language proficiency	-0.41	0.46	-0.20		0.87	0.54	0.46	
Home Switching	-0.33	0.65	-0.16		0.64	0.71	0.33	
2. Home Mixing model				**.49**				-.10
Age	**-0.19**	**0.05**	**-0.75*** **		0.03	0.08	0.14	
Working memory	**1.69**	**2.02**	**0.14**		-1.21	3.07	-0.10	
Language proficiency balance	**3.14**	**1.11**	**0.61***		-2.02	2.40	-0.41	
Overall language proficiency	**-0.82**	**0.36**	**-0.40***		0.70	0.60	0.37	
Home Mixing	**-1.17**	**0.34**	**-0.72****		0.00	0.73	0.00	
3. School CS model				.13				-.09
Age	-0.13	0.06	-0.56*		0.05	0.06	0.23	
Working memory	1.14	2.38	0.11		-1.48	2.70	-0.15	
Language proficiency balance	0.59	1.08	0.11		-1.66	1.33	-0.33	
Overall language proficiency	-0.24	0.41	-0.12		0.53	0.50	0.28	
School CS	-0.13	0.42	-0.07		-0.34	0.47	-0.20	

* $p < .05$, ** $p < .01$, *** $p < .001$, bold-face: model is significant at adjusted α-level (Holm method with Dunn-Šidák correction)

Figures

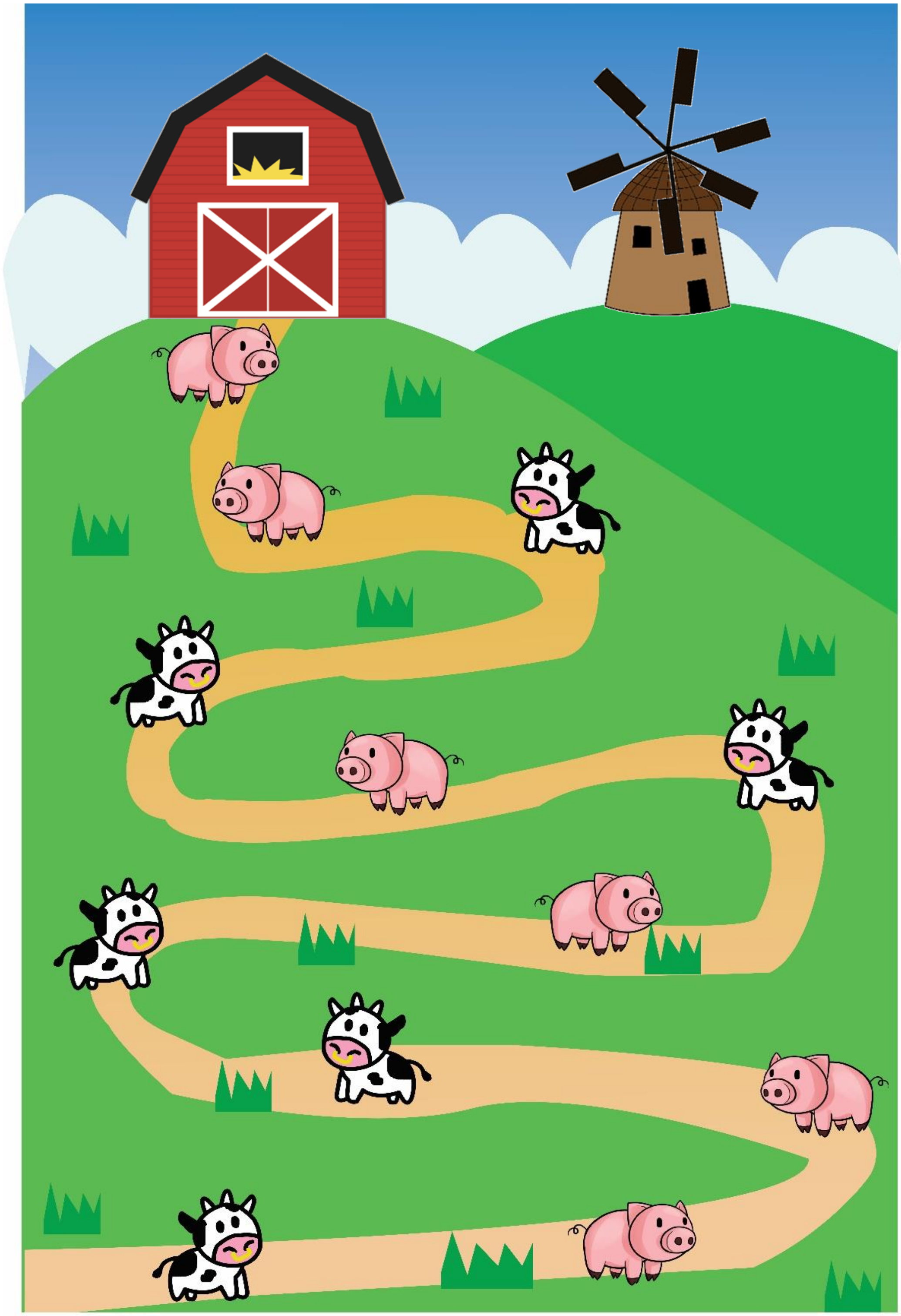

Figure 1. Scene from Opposite Worlds task

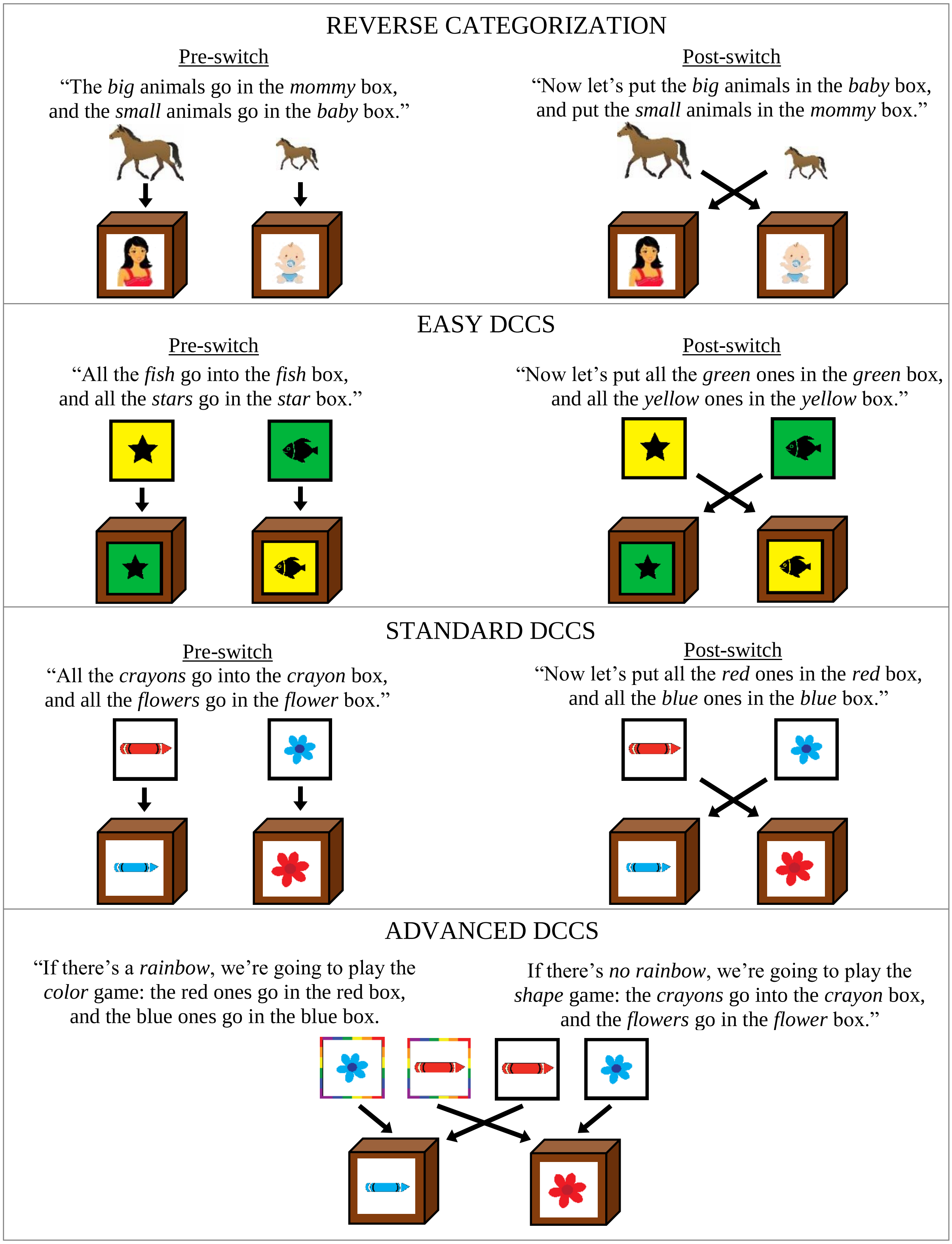

Figure 2. Nonlinguistic task-switching task procedures

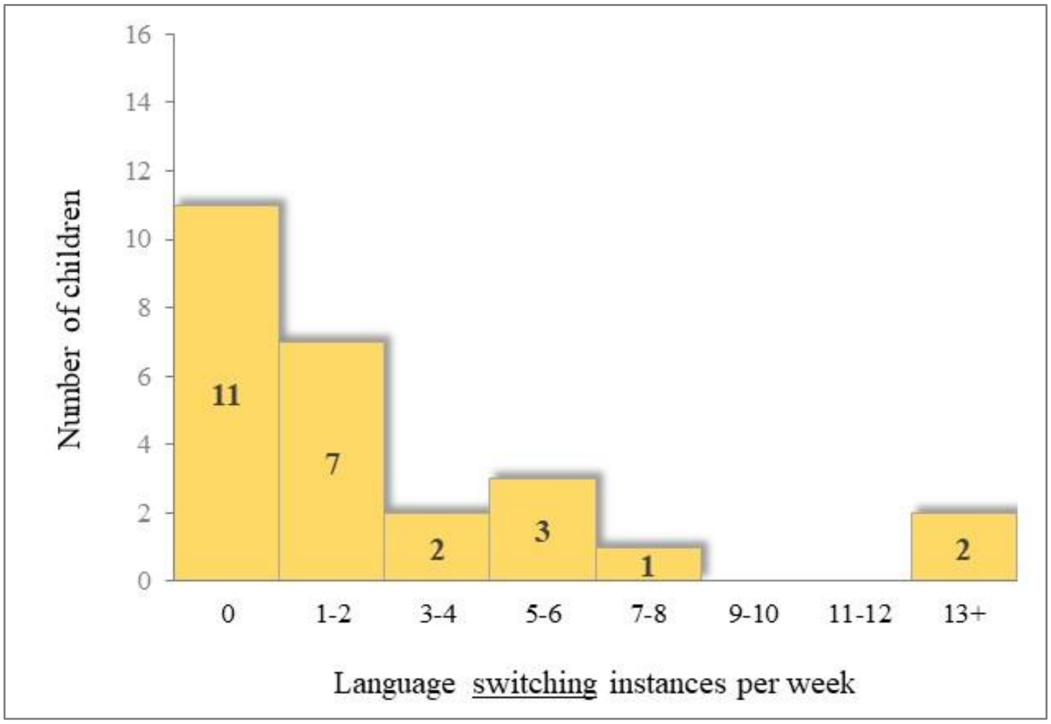

Figure 3. Children’s rates of language switching (diary study)

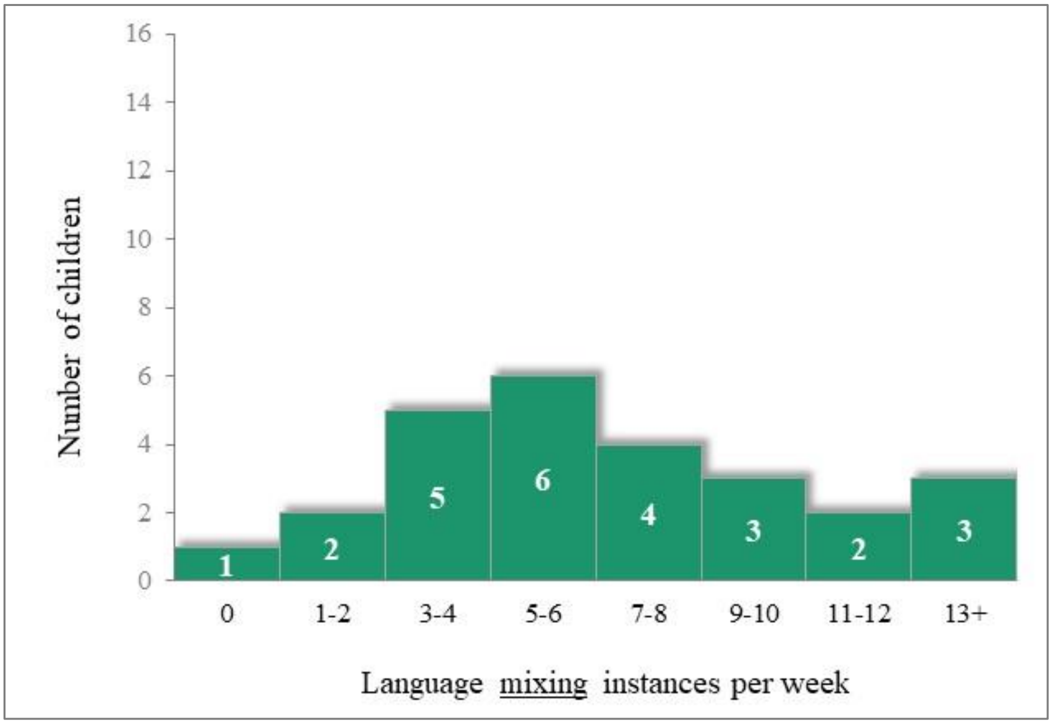

Figure 4. Children’s rates of language mixing (diary study)

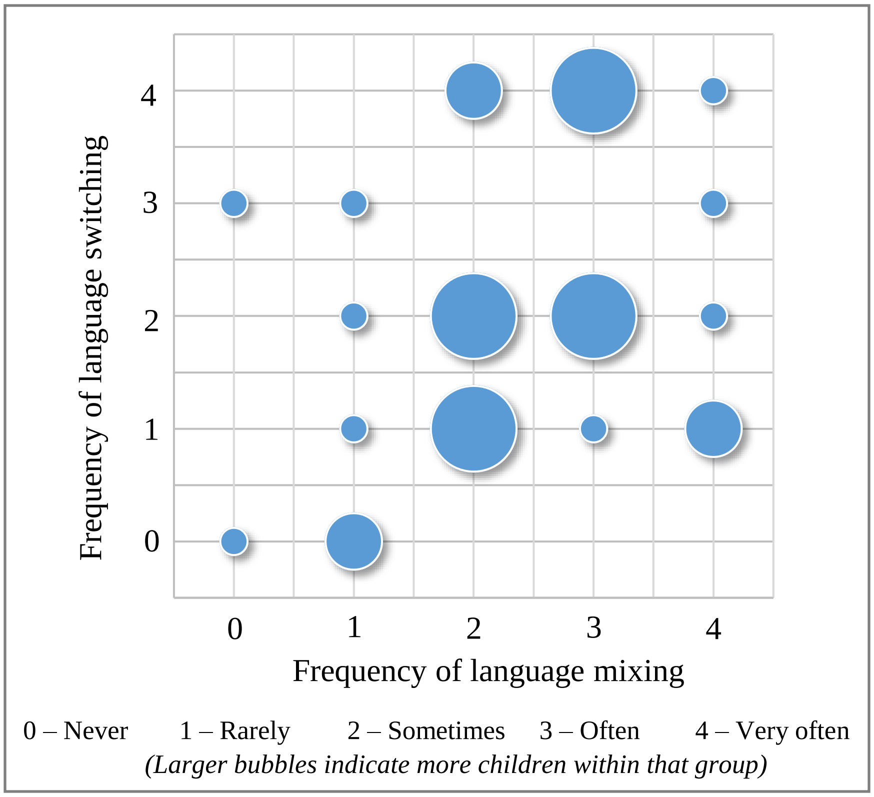

Figure 5. Relationship between children’s rates of languages switching and language mixing at home (follow-up survey)

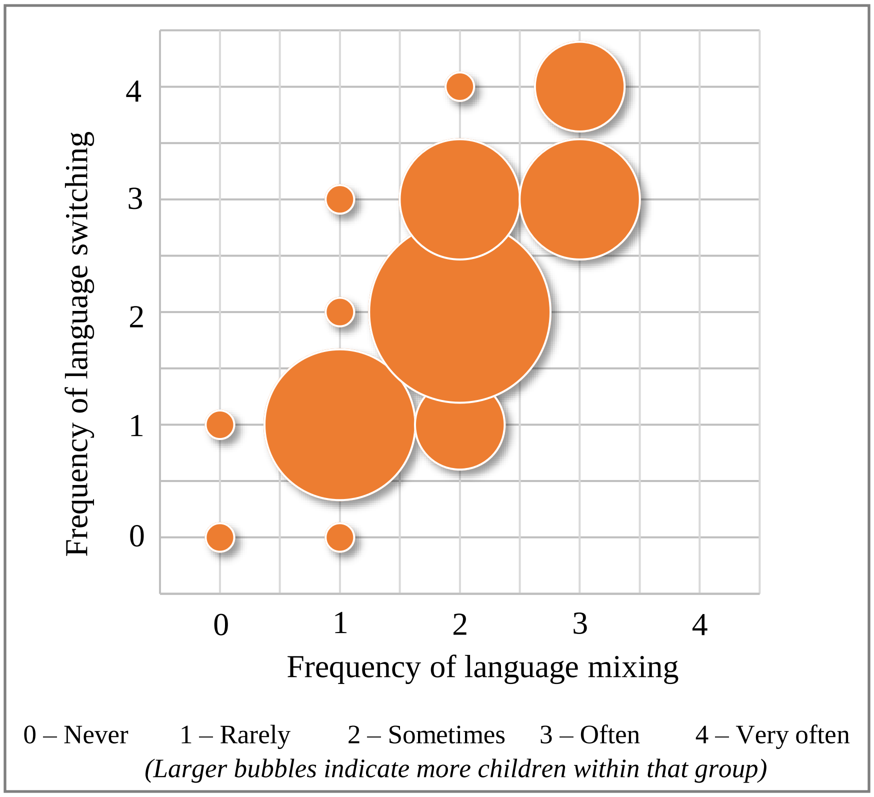

Figure 6. Relationship between children's rates of languages switching and language mixing at school (teacher survey)

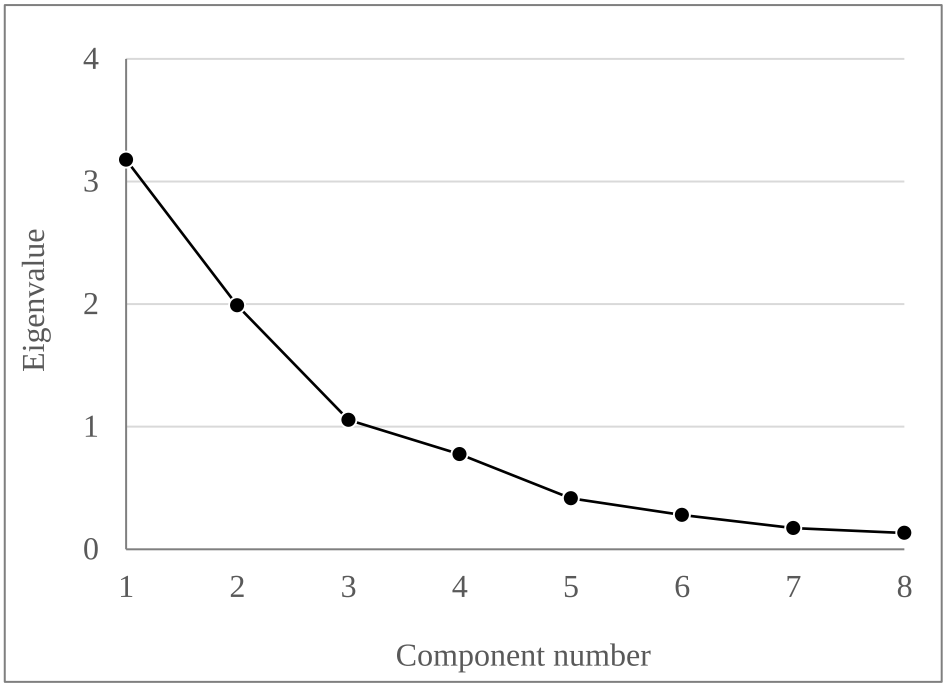

Figure 7. Scree plot results from exploratory factor analysis of CS behaviors at home and school

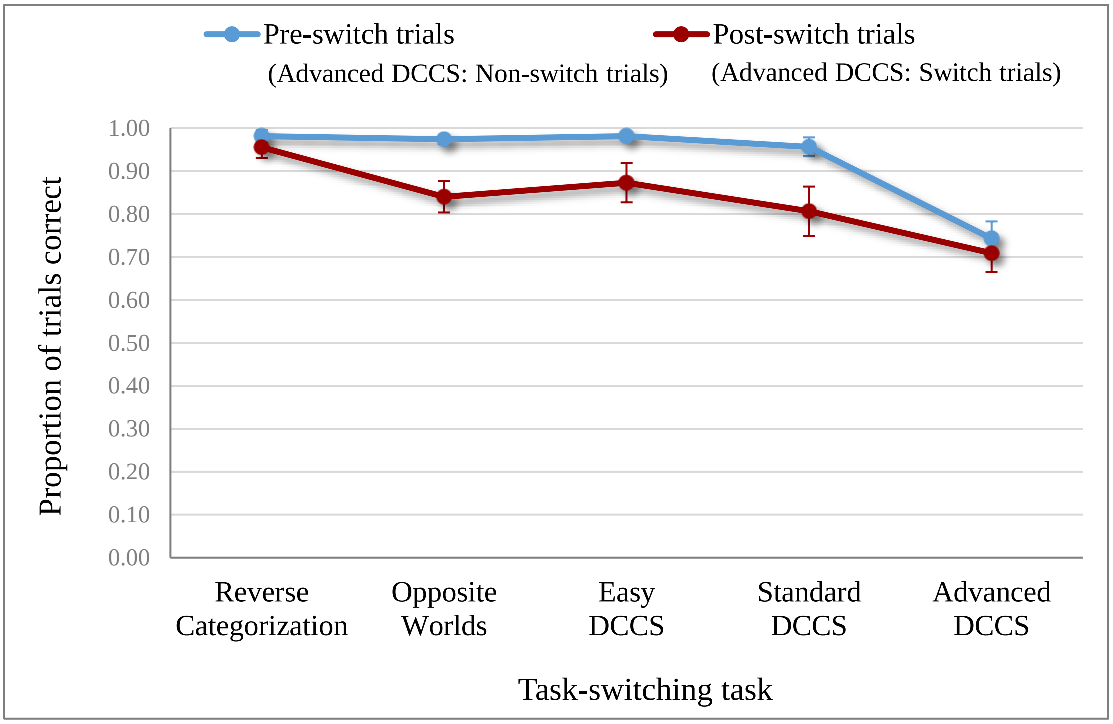

Figure 8. Mean accuracy across TS tasks, pre-switch vs. post-switch trials (proportion of trials correct)

Appendix A

Parent demographic survey

1.) Child's date of birth: _____ / _____ / _____________

2.) What is your child's gender? *(Please select one)*

❒ Female ❒ Male ❒ Prefer not to say

3.) Does your child have any siblings? If so, please indicate their gender and date of birth:

	Gender			Date of birth
1.	❒ Female	❒ Male	❒ No answer	_____ / _____ / _____________
2.	❒ Female	❒ Male	❒ No answer	_____ / _____ / _____________
3.	❒ Female	❒ Male	❒ No answer	_____ / _____ / _____________

4.) Please describe your child's race/ethnicity:

____

____

5.) What are the primary language(s) currently spoken in your home? *(Select all that apply)*

❒ Arabic	❒ Hindi	❒ Russian
❒ Chinese	❒ Japanese	❒ Spanish
❒ English	❒ Korean	❒ Tagalog
❒ French	❒ Persian	❒ Vietnamese
❒ German	❒ Portuguese	❒ Other: ____________________

6.) If multiple languages are currently spoken in your home:

a.) Briefly describe how and when you use each language:

____

____

b.) Roughly estimate the amount of time that each language is used in your home:

Language #1: ____________________ _______% of time

Language #2: ____________________ _______% of time

Language #3: ____________________ _______% of time

7.) Any additional comments about your current home language environment:

____

____

8.) How would you rate your child's current ability to **UNDERSTAND** English? *(Please circle one)*

1	**2**	**3**	**4**	**5**
Poor	**Fair**	**Average**	**Good**	**Excellent**

9.) How would you rate your child's current ability to **SPEAK** English? *(Please circle one)*

1	**2**	**3**	**4**	**5**
Poor	**Fair**	**Average**	**Good**	**Excellent**

10.) Does your child understand or speak a second language? **YES** **NO**

If YES, what language? _________________________

11.) How would you rate your child's current ability to **UNDERSTAND** this language? *(Please circle one)*

1	**2**	**3**	**4**	**5**
Poor	**Fair**	**Average**	**Good**	**Excellent**

12.) How would you rate your child's current ability to **SPEAK** this language? *(Please circle one)*

1	2	3	4	5
Poor	**Fair**	**Average**	**Good**	**Excellent**

13.) Does your child understand or speak a third language? **YES** **NO**

If YES, what language? ________________________

14.) How would you rate your child's current ability to **UNDERSTAND** this language? *(Please circle one)*

1	2	3	4	5
Poor	**Fair**	**Average**	**Good**	**Excellent**

15.) How would you rate your child's current ability to **SPEAK** this language? *(Please circle one)*

1	2	3	4	5
Poor	**Fair**	**Average**	**Good**	**Excellent**

16.) Any additional comments about your child's language proficiencies:

____

____

PARENT #1

17.) **Parent #1's** date of birth: _____ / _____ / _____________

18.) **Parent #1's** gender: *(Please select one)*

❒ Female ❒ Male ❒ Prefer not to say

19.) Please describe **Parent #1's race/ethnicity**:

____

____

20.) Which language(s) were spoken in **Parent #1's childhood home**? *(Select all that apply)*

❒ Arabic	❒ Hindi	❒ Russian
❒ Chinese	❒ Japanese	❒ Spanish
❒ English	❒ Korean	❒ Tagalog
❒ French	❒ Persian	❒ Vietnamese
❒ German	❒ Portuguese	❒ Other: ___________________

21.) What is the highest level of education completed by **Parent #1**? *(Please select one)*

- ❒ Did not complete high school
- ❒ High school/GED
- ❒ Some college
- ❒ Associate's degree
- ❒ Bachelor's degree
- ❒ Master's degree
- ❒ Graduate/Professional degree (e.g., PhD, MD, JD)

22.) What is your approximate average <u>household</u> income (combined)?

- ❒ $0 - $24,999
- ❒ $25,000 - $49,999
- ❒ $50,000 - $74,999
- ❒ $75,000 - $99,999
- ❒ $100,000 - $124,999
- ❒ $125,000 - $149,999
- ❒ $150,000 -$174,999
- ❒ $175,000 - $199,999
- ❒ $200,000 and up

PARENT #2

23.) **Parent #2's** date of birth: _____ / _____ / _____________

24.) **Parent #2's** gender: *(Please select one)*

❒ Female ❒ Male ❒ Prefer not to say

25.) Please describe **Parent #2's race/ethnicity**:

____

____

____

26.) Which primary language(s) were spoken in **Parent #2's childhood home**? *(Select all that apply)*

❒ Arabic	❒ Hindi	❒ Russian
❒ Chinese	❒ Japanese	❒ Spanish
❒ English	❒ Korean	❒ Tagalog
❒ French	❒ Persian	❒ Vietnamese
❒ German	❒ Portuguese	❒ Other: __________________

27.) What is the highest level of education completed by **Parent #2**? *(Please select one)*

❒ Did not complete high school

❒ High school/GED

❒ Some college

❒ Associate's degree

❒ Bachelor's degree

❒ Master's degree

❒ Graduate/Professional degree (e.g., PhD, MD, JD)

Appendix B

Parent interview protocol

1) Can you talk me through a day in the typical life of [child's name] on a school day?

   a. Who helps [child's name] get ready for school in the morning? What language(s) does [child's name] usually speak while he/she's getting ready for school?

   b. While [child's name] is getting ready for school in the morning, do you ever notice him/her <u>mixing</u> languages? For example, "Mommy, where is my 書包 (backpack)?"

   c. Can you give me some examples of times that [child's name] <u>mixed</u> languages when talking to the same person?

   d. While [child's name] is getting ready for school in the morning, do you ever notice him/her <u>switching</u> languages to talk to a different person? For example, "Mommy, where is my backpack? 爸爸, 看看我的鞋! [Daddy, look at my shoes]!"

   e. Can you give me some examples of times that [child's name] <u>switched</u> languages when talking to a different person?

Questions a through e will also be asked regarding the child's afternoon (after being picked up from school) and evening.

2) Can you talk me through a typical Saturday or Sunday for your family?

Again, questions a through e from the prior question will also be asked regarding the family's various activities (e.g., play dates, going to the park/museum, etc.)

Appendix C

Parent diary study Google Form

You have been invited to participate in a 7-day study of how young bilingual children use their languages in their everyday lives. During these days, we are asking you to take note of EVERY moment when [child’s name] does the following:

a. MIXES languages when talking to ONE PERSON (For example: "我要吃 frites [I want to eat fries]!")
b. SWITCHES languages when talking to DIFFERENT PEOPLE (For example: saying "妈妈, 我饿了 [Mommy, I'm hungry]!" to Mom, and then saying to Dad, "Papa, puis-je manger des frîtes [Daddy, can I eat fries]?")
c. MIXES AND SWITCHES languages at the same time (For example: saying " 妈妈, 我饿了 [Mommy, I'm hungry]!" to Mom, and then saying to Dad, "Papa, puis-je manger French fries?")

It would be most helpful if you could write down exactly what [child’s name] said. Feel free to type in whatever language feels comfortable-- just make sure to indicate which words were said in which language.

Please note that you should submit a separate entry/form for EACH instance of [child’s name]'s language mixing/switching. For example, if [child’s name] mixed 1 time and switched 3 times, please make a total of 4 entries now.

Think about ONE example of [child’s name]'s language switching/mixing from today, and answer the following questions about that example.

1) Please select one:
   a. [child’s name] MIXED languages within the SAME SENTENCE when talking to ONE PERSON
   b. [child’s name] SWITCHED between languages when talking to DIFFERENT PEOPLE
   c. [child’s name] MIXED and SWITCHED languages at the same time
   d. [child’s name] did NOT mix or switch languages at all today

2) What did [child’s name] say, exactly? (e.g., "Donnez-moi le bleu s'il vous plaît [Please give me the blue]" to Dad, then "看看我的照片 [Look at my picture]!" to Mom)

____

3) Who was involved in this interaction with [child’s name]? (e.g., Mom, Dad)

____

4) Briefly describe the situation: (e.g., [child’s name] was drawing a picture)

____

____

5) Any additional comments about this entry or any other entries?

____

Please submit this form, then click on “Submit another response” to enter additional examples of [child’s name]'s language mixing and/or switching. Thank you!

Appendix D

Parent follow-up survey

Now that you have participated in this study, how OFTEN would you say that your child does each of the following at home?

1) MIXES languages in the same sentence (e.g., “Mommy, I want 饼干 [cookies]!”)

    a. Never
    b. Rarely (once in a long while)
    c. Sometimes (once or twice a week)
    d. Often (once or twice a day)
    e. Very often (multiple times a day)

2) SWITCHES languages when talking to different people (e.g., “Mommy, I’m hungry” then to dad: “爸爸，我想吃饼干 [Daddy, I want to eat cookies]”)

    a. Never
    b. Rarely (once in a long while)
    c. Sometimes (once or twice a week)
    d. Often (once or twice a day)
    e. Very often (multiple times a day)

Appendix E

Teacher survey

Name of student: ______________________________________

Think about your interactions with this student. How much Chinese does he/she speak to you?

0% Chinese | 50% Chinese | 100% Chinese

Based on your experience, how often does he/she:

1) MIX languages when talking to ONE person? (e.g., “Miss Lilly, can I get my 水壶 [water bottle]?”)

   a. Never
   b. Rarely (once in a long while)
   c. Sometimes (once or twice a week)
   d. Often (once or twice a day)
   e. Very often (multiple times a day)

2) SWITCH languages when talking to DIFFERENT people? (e.g., “Miss Lilly, 我要拿水瓶 [I need to get my water bottle].” “Miss Carla, can I cross the line?”)

   a. Never
   b. Rarely (once in a long while)
   c. Sometimes (once or twice a week)
   d. Often (once or twice a day)
   e. Very often (multiple times a day)

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