Relationship between Bilingual Experience and Cognitive Control of Bilingual Children*

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ABSTRACT: There has been growing interest in how different dimensions of bilingual experience relate to cognitive abilities within the bilingual group. However, this interest rarely targeted data from young bilingual children who lack sufficient language production. The current study includes a variety of bilingual experience-related factors, such as language proficiency, language use, and code-switching frequency, to investigate 30- to 48-month-old bilingual children as well as their parents. Results showed that children's age, rather than any of the bilingual-experience-related variables from neither children nor parents, predicted children's cognitive control abilities. This study is one of the few that looked at the bilingual effects by including three bilingual-experience-related dimensions as well as parental factors. The implications of applying the bilingual experience dimension-based approach and including environmental

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factors while studying young bilingual age groups with limited language production were discussed.

Keywords: bilingual experience-related variables, cognitive control abilities, environmental factors, code-switching frequency, young bilingual speakers

İkidillilik deneyimi ile iki dilli çocukların bilişsel kontrolü arasındaki ilişki

ÖZ: İkidilli kişilerin çeşitli bilişsel yetileri ile İkidillilik deneyiminin farklı boyutları arasında nasıl ilişkili olduğuna dair giderek artan bir ilgi bulunmaktadır. Ancak, bu ilginin yeterli dil gelişimi olmayan küçük yaştaki ikidilli çocuklardan veri elde etme konusunda sınırlı kaldığı görülmüştür. Mevcut çalışma, 30-48 aylık ikidilli çocukların ve ebeveynlerinin dil yeterliği, dil kullanımı, ve kod değiştirme sıklığı gibi çeşitli ikidillilik deneyimine dair faktörleri incelemektedir. Sonuçlar, çocukların bilişsel kontrol yeteneklerini, çocuklardan veya ebeveynlerden gelen ikidilli deneyim değişkenlerinden ziyade, çocukların yaşının yordadığını göstermiştir. Bu çalışma, üçlü ikidillilik deneyimi boyutlarını ve ebeveyn faktörlerini de içererek ikidilliğin etkileri inceleyen az sayıdaki çalışmadan biridir. Sınırlı dil üretimine sahip küçük yaştaki ikidilli çocuklar incelenirken, ikidilli deneyimin getirdiği tüm boyutları içeren bir yaklaşım uygulamanın ve çevresel faktörleri dahil etmenin alanyazın özelindeki çıkarımları tartışılmıştır.

Anahtar sözcükler: iki dilli deneyimle ilgili değişkenler, bilişsel kontrol yetenekleri, çevresel faktörler, kod değiştirme sıklığı, genç iki dilli konuşmacılar

1 Introduction

The global bilingual/multilingual population is growing as the world becomes more interconnected. It was reported that there are about 7000 languages within all 200 countries in the world (Cenoz, 2013; UNESCO, & UNICEF, 2020), and two-thirds of the world's children are raised in environments that speak more than one language (Crystal, 2003). Therefore, researchers are increasingly interested in the potential association between this unique linguistic capacity and human cognitive abilities. Nonetheless, for the past decades, whether bilingual speakers have a cognitive advantage over monolingual speakers has been the subject of heated debate up to the present day (Gunnerud et al., 2020; Lowe et al., 2021; van den Noort et al., 2019). Because of the complex and controversial nature of bilingualism and cognition studies, some researchers proposed that “bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances” (Paap et al., 2015).

The current study was designed to address the challenges that researchers face when studying the effects of bilingualism on cognition, as well as literature gaps in terms of age group. Instead of using the popular group comparison between monolingual and bilingual speakers, the focus of this study is to treat bilingual experience related variables of both children and parents as potential indicators of the bilingual effect on children's cognitive control abilities. We aimed to disentangle the effect of bilingualism by applying a gradient measure of bilingual experience related factors, including language proficiency, language usage, and code-switching frequency. We also hope to focus on the relatively understudied age group, which is young bilingual children without sufficient language production, and pay attention to parental factors that constitute their home language environments. The goal of the current study is twofold: 1) to examine whether there is a relationship between bilingual experience related factors (e.g., language proficiency, language use and code-switching frequency) and children's cognitive control ability; and 2) to examine whether environmental factors, namely parental factors, could potentially account for the variation of young bilingual children's cognitive control abilities.

1.1 Overview

The debate of whether the "bilingual effect" exists has continued for decades in the field of bilingualism and cognitive abilities. Scholars suggested that the reasons for lacking consensus within scholars is the underdeveloped typology of bilingualism (e.g., life-long balanced vs. later-onset or infrequent use of the non-dominate language) as well as the measurement of bilingual related experience not being consistently reported across studies (Bialystok, 2017; De Cat et al., 2018; Lowe et al., 2021). As a result, researchers called for a more rigorous approach based on theoretically-motivated hypotheses instead of the widely used between-group quasi-experimental comparison design to address the potential cause of null findings.

One of the more recent approaches that has received increased attention is to take individual bilingual differences into consideration and locate underlying working mechanisms that could potentially contribute to the presence (or absence) of bilingual advantages in executive functions (Bialystok & Craik, 2022; Yang et al., 2016). Consequently, there is a growing body of literature that emphasizes the source of different cognitive performances between monolingual and bilingual groups by investigating the influence of distinct bilingual experiences (Kang & Lust, 2019; Kheder & Kaan, 2021; Sulpizio et al., 2020; Yow & Li, 2015). Language proficiency and language usage appeared to be two of the aspects that could be extracted from multiple self-reported and standardized measures. They were also reported to be the most frequently examined features in studies in recent years regarding bilingualism and cognition (Luk & Bialystok, 2013; Surrain & Luk, 2019).

Code-switching on the other hand, has gained growing attention in terms of building transparent, consistent, and comprehensive reporting of bilingualism's characteristics (Kałamała et al., 2023; Marian & Hayakawa, 2021). It was suggested that the core of the "bilingual advantage" lies in bilinguals' language-switching behavior, which generates the monitoring and inhibiting processes that command the effort of cognitive control (Costa et al., 2009). Nonetheless, studies that include multiple abovementioned dimensions of bilingualism in this line of research were limited, and the results appeared to be rather inconsistent (Giguere et al., 2022; Kheder & Kaan, 2021). Therefore, to account for the full range of bilingual experience, researchers are advocating for the integration of analyses that consider the variability of bilingual experience (De Cat et al., 2018).

Furthermore, studies about bilingualism and cognition almost exclusively draw evidence from school-age children and adults. Young simultaneous bilingual individuals with insufficient language production rarely become the target age group (Verhagen et al., 2020). Nonetheless, differences between monolingual and bilingual infants and toddlers regarding selective attention, visual habituation, cognitive flexibility, and generic executive function have been repeatedly discovered (Comishen et al., 2019; Kovács & Mehler, 2009a, 2009b; Poulin-Dubois et al., 2011; Singh et al., 2015; Verhagen et al., 2020). These discoveries indicated that, other than being generated from direct language production, the bilingual effect could also be due to mere exposure and processing of two languages, namely, language comprehension under the bilingual context (Dijkstra et al., 1998). Therefore, the parental factors that form the bilingual environment for simultaneous bilingual children should be included if we aim at young age groups and take individual bilingual variabilities into consideration. So far, very few studies have considered parental factors such as parental language proficiency and parental language usage as indicators for bilingual children's cognitive performance (Verhagen et al., 2020). To our knowledge, other facets of bilingualism, such as parental code-switching frequency, have never been investigated in terms of parental variables.

1.2 Bilingual Individual Variability and Cognitive Control

During the language production process of a bilingual speaker, both languages are activated simultaneously in the bilingual brain (Costa et al., 1999; Kroll et al., 2014). It is commonly accepted that inhibition is critical in allowing bilingual speakers to exclude inferences from non-targeted languages (Martin-Rhee & Bialystok, 2008; Philipp & Koch, 2009). Several bilingual language and cognitive models are based on this inhibition assumption. Green (1998) depicted the bilingual language production process in his Inhibitory Control Model, from conceptual idea formation to language task schema activation, and then inhibition of non-targeted lexical-semantic representations and activation of targeted linguistic systems. By the same token, the Bilingual Interactive-

Activation (BIA) Model suggested a top-down control mechanism for decision and response selection when choosing between activated lexical representations (Dijkstra et al., 1998). With the foundation of bilingual language processing theories, there is growing consensus that the bilingual language control process has recruited domain-general cognitive control, providing strong support for the importance of cognitive control in the language production of bilingual individuals (Hartanto & Yang, 2016; Timmermeister et al., 2020).

To differentiate the effect of individual bilingual variations on cognition, language proficiency, language usage, and code-switching frequency were used as major indicators when applying the within-group design. Abutalebi and Green (2007) proposed that the proficiency level of a second language results in varied activation of the bilingual brain. They attribute this variability to the ongoing active monitoring, selection, and inhibition processes during bilingual language processing. Studies also found that for both monolingual and bilingual preschool children, there is an association between language proficiency, inhibition, and shifting abilities (Iluz-Cohen & Armon-Lotem, 2013). Specifically, it was discovered that students who had mastered their second language performed significantly better at shifting than those still learning the new language. Meanwhile, language usage, as another dimension of the bilingual experience, focused on the potential effect of the bilingual speakers' language mixing throughout the day on cognitive ability. The more frequently they mix their languages in their daily lives, the more practices they will receive implemented in monitoring, selecting, and inhibitory processes (Costa et al., 2009; Soveri & Laine, 2011).

Code-switching as the more fine-grained factor compared to language proficiency and usage received increasing interest. Green and Abutalebi (2013) in their Adaptive Control Hypothesis (henceforth ACH), proposed that code-switching behavior initiates various cognitive control processes. Researchers who followed the ACH model in their studies suggested that cognitive control challenges during bilingual speakers' code-switching behaviors lead to better cognitive performance. Nonetheless, compared to language proficiency and language usage, studies on code-switching and its effect on cognition are fairly limited (Surrain & Luk, 2019), especially the ones that targeting children.

To the best of our knowledge, only two studies have examined the possible effects of code-switching behavior on executive functions of bilingual children. One of them discovered that contrary to previous work on adults, code-switching performance did not significantly predict EF performance for eight-year-old children; however, bilingual language proficiency did (Kang & Lust, 2019). The other one is a longitudinal study, and the findings indicated that the frequency of children's code-switching behavior, in fact, is negatively related to their inhibitory control during the preschool period (Kuzyk et al., 2020). This result might be because the function of code-switching behaviors for children, especially when they are in the preverbal stage, is different compared to adults.

Therefore, it might not be a valid indicator for judging the changes in their cognitive abilities, which supported the necessity of including factors other than young children's bilingual experience as potential predictors that we will be discussing in the following chapter.

Moreover, we will also take the opportunity to look into the intercorrelations among all three bilingualism dimensions as well as between children and their parents. Given that researchers have only recently begun to place a greater emphasis on developing a more accurate and consistent description of bilingualism, language proficiency, language usage, and code-switching frequency were extracted from self-reported and standardized measures as relatively more consensual dimensions of bilingualism (Kałamała et al., 2023; Luk & Bialystok, 2013). It has been discovered that people who use both languages equally also have the same level of mastery of the two languages (Yow & Li, 2015). They also concluded that participants who are equally proficient in both languages tend to switch languages more frequently. It was also reported that the more frequently people use their second language, the higher the code-switching frequency observed (Kang & Lust, 2019). Nonetheless, there are also studies reported that the level of language proficiency is not related to the frequency of code-switching (Kheder & Kaan, 2021), The only study that included both children's and parents' factors reported that there was not only a correlation between children's language use and their language proficiency, but also between children's language use and parents' language use (Verhagen et al., 2020). We hope to investigate this question among all of the children and parental variables included in our study.

1.3 Dual Language Home Environment and Cognitive Control of Young Bilingual Children

Bilingual children switch their choice of languages constantly based on interlocutors and current situations (Kremin et al., 2022; Kootstra et al., 2020). In fact, for bilingual children who grow up in dual-language families the language acquisition processes - language perception and comprehension - start long before they can produce their first word (Werker & Byers-Heinlein, 2008). The updated version of the Bilingual Interactive-Activation Model (BIA+ model) suggests that language production and comprehension both result in language-switching effects during bilingual language processing (Dijkstra & van Heuven, 2002). Therefore, according to the model, language comprehension is also cognitively demanding and might affect the cognitive functioning of preverbal infants or young children who grow up in a dual-language home environment.

Yet, applying bilingual experience-related indicators when studying bilingual effect does not apply to young bilingual children with limited language production since sufficient language production is the precondition of investigation (Poulin-Dubois et al., 2022). Nonetheless, whether or not the

bilingual effect exists in young age groups has always been an interest of researchers, and between-group comparisons were usually applied to detect differences. In a habitual response to visual rewards study, compared to 7- and 12-months-old monolingual infants, who primarily focused on the original location regardless of the presence of rewards or not, bilingually raised infants were able to switch their eye gaze to the new location where the reward appeared (Kovács & Mehler, 2009a, 2009b). Another visual habituation task also demonstrated better encoding and recognition memory abilities for 6-month-old infants with bilingual home language environments compared to monolingual counterparts (Singh et al., 2015). These findings call into question the widely accepted assumption that bilingual experience only influences cognitive performance through actual language production. Furthermore, to apply within-group instead of between-group comparison to identify the potential association between bilingualism and cognitive abilities for very young age groups, environmental factors should be the ones that call for more attention.

Consequently, parents' bilingual experience should be considered and investigated as the indices that predict the cognitive performance of young bilingual individuals, because they are directly associated with young children's language output (Branum-Martin et al., 2014; Hoff & Core, 2013). However, very limited studies examine the effect of bilingual home language environments. Verhagen et al. (2017) conducted the first study that included predictors of bilingual experience from both parents and children, then discovered that 24-month-old bilingual children with parents who spoke different languages demonstrated better performance on both the conflict task and a delay of gratification task when compared to their counterparts with parents who spoke the same language. In another study following the previous one (Verhagen et al., 2017), Verhagen et al. (2020) took the language use and language proficiency of both children and parents into consideration regarding their possible effects on children's cognitive abilities. The results verified the effect of parental factors, whereas no effect from the factors of children. So far, the above-mentioned two studies are the only ones that included parental factors of bilingual experience as indicators that were demonstrated to have an effect on their children's cognitive performance; meanwhile, parental code-switching behavior has never been included as one of those parental factors yet. Direct measurements of the frequency of language switching and observational studies instead of questionnaires are needed to uncover the relationship between bilingualism and cognition.

1.4 The Present Study

The previous literature has dominantly relied on quasi-experimental designs where bilingual groups were compared to monolingual groups; however, bilingual speakers vary greatly from the proficiency of each language they use to

the sequence of their language learning. Therefore, the typological issue of bilingualism has always been criticized. More researchers suggested treating bilingualism as a spectrum instead of a category to reduce confounding factors. Moreover, the targeted age group in this line of research has mainly focused on bilingual individuals with sufficient language production. However, the environmental factors that could potentially relate to very young bilingual children were rarely investigated. In the present study, we applied within-group design instead of between-group design, to look into the possible relationship between three bilingual experience-related variables and children's cognitive control task performance. We also want to look into the factors from not only children but also their parents. The main research questions of the current study are as follows:

a) Whether different facets of bilingual experience, including language proficiency, language usage, and code-switching frequency of both young bilingual children and parents, may be associated with children's cognitive control ability, as well as with one another?
b) To take the analysis one step further, we asked whether bilingual experience-related variables predict children's cognitive performance, specifically the group of parental factors.

Regarding the first research question, we anticipated that there would be intercorrelations among bilingual-experience related variables and also with children's cognitive control abilities. Regarding the second research question, based on previous literature (Kang & Lust, 2019; Kuzyk et al., 2020), we anticipated that language proficiency and language usage of both children and parents, but not children's code-switching frequency would predict their cognitive performance. We explored the possible effect of parents' code-switching frequency because it has never been investigated before. We also expected that compared to children's bilingualism variables, parental factors would contribute relatively more to the variation of children's cognitive abilities when performing executive function tasks, which is based on previous findings (Verhagen et al., 2017, 2020) as well as the fact that young children do not produce enough language to reflect the cognitively demanding environment to which they are exposed on a daily basis.

2 Method

2.1 Participants

The sample consists of 24 multilingual families, which include both sides of the parents and their children. Children who participated in the study were between 3 and 4 years old (twelve females; M_{age} = 3;6; SD_{age} = 0.43; *Age Range* = 2;7–4;2). The participants in this study are from families in which at least one parent spoke more than one language with their children on a daily basis. Both parents

and children are participants in the study. Data from one additional child and three additional adults were excluded for the following reasons: failure to submit the audio recording (n = 2), problem with internet connection (n = 1), and disruption during the online testing sessions (n = 1). We also checked outliers regarding cognitive task scores, and all data were within the scope of three deviations from the mean.

All families speak more than one language at home daily, albeit the proportion of different language usage for all parents varies. Language use in the family is limited to Turkish and one more language, or Turkish and English and one more language, decided by the language configuration of the researchers. The languages used in the household were English (n = 21), Turkish (n = 15), and one of the following languages: Chinese (n = 6), German (n = 3), French (n = 2), Arabic (n = 1), Russian (n = 1), Spanish (n = 1), Cantonese (n = 1), Serbian (n = 1), Bengali (n = 1). Trilingual families that speak more than one language, neither English nor Turkish, were not included in the sample. The proportion of different language usage between parents varies from 100% (one parent, one language) to 20% (parents speak the same language 80% of the time in a day).

Seventy-one percent of families have more than one child, and 50% have other adults interact with their children daily. Twenty-one out of all 24 families enrolled their children into daycare, with an average 14-month duration in total at the time of testing (SD = 11.64). The socioeconomic status of the participating families is from middle to high, with 88% of families' income level above 20,000 TL per month at the time of testing. Regarding maternal education levels, 96% of mothers owned a bachelor's degree or higher.

2.2 Procedure

Families were contacted through social media and snowball sampling and mainly consisted of international families in Turkey. Before data collection, a consent letter was collected from every family through an online meeting. Cognitive control abilities were tested during the online meeting with the researcher. Parents' and children's language proficiency, usage and other demographic information were collected through the simplified version of the Bilingual Language Experience Calculator (BiLEC) (Unsworth, 2013) online survey. Lastly, parents were instructed to record a 15-minute audio recording of their family's daily interaction (including mother, father, and child). Most families recorded the conversations during mealtime or play sessions. After all the tasks were finished, the family received an online Amazon gift card of 150 Turkish Lira, and their child received a certificate for their task performance.

2.3 Measurements

2.3.1 Bilingual language experience calculator (BiLEC)

The BiLEC questionnaire was applied to examine children's and parents' language proficiency and language use. Although this scale is designed to obtain a composite measure of language dynamics in bilingual and multilingual families overall, for our research design, we will only calculate the raw scores on language proficiency and language use for children and parents separately. The BiLEC assessed how children and parents spoke and understood each language on a 6-point scale ranging from 0 ("almost no speaking/understanding") to 5 ("native-like speaking/understanding"). For the measurement of the children, parents were instructed to use estimation by comparing their children's language abilities to those of typical monolingual children of the same age.

2.3.2 Bilingual experience related variables

Six bilingual experience related variables (language proficiency, language use, and code-switching frequency) were created for bilingual children and parents based on the BiLEC questionnaire and audio recordings. A full list of descriptions of all variables can be found on the Open Science Framework (https://osf.io/uhkx7/?view_only=c88b1c4f116a430c8d0ccc9e0452102c)

2.3.3 Code-switching frequency for children and parents

The recordings were divided into 30-second segments and coded by either English or Turkish-English bilingual research assistants. The 30-second segment follows a common practice for transcribing and coding day-long recordings (Ramírez-Esparza et al., 2014), which ensures the reliability of research assistants when they are required to pay close attention between languages. The research assistants were ensured to have the capacity to comprehend one out of two or two out of three languages documented in the recordings; therefore, the code-switching behavior could be identified and calculated. The research assistants listened to every segment and tagged every time a language change took place as code-switching. Transcriptions contain a great amount of parents' code switches between utterances, as in (1), when parent 1 uttered a sentence in one language, and parent 2 made an utterance in another language/

(1) P1 (Turkish): *Ela peynir istiyor.*

Ela cheese want

'Ela wants cheese.'

P2 (English): You want cheese?

C (English): Yeah I want cheese.

Transcriptions also contain children's code switches, as in (2), which children switch language from one to another/

(2) C (Turkish): *Hayır, hayır, su…Daha su var.*

No, no, water…more water there is

'No no water…There is more water.'

P1 (English): You want more water?

C (Turkish): No I don't want pee.

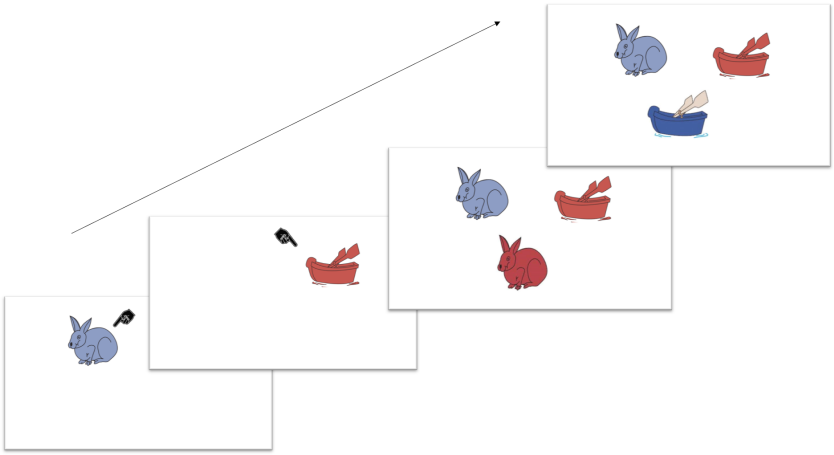
The code-switching frequency was calculated based on the number of code-switches per hour of speech for all families and per 1000 utterances for 13 out of 24 families due to the language capacities of the researchers[1].

2.3.4 Cognitive performance tasks

Dimensional Change Card Sort (DCCS) Task. DCCS is a conflict task frequently used to examine the flexibility, switching, and monitoring of attention in Children (Zelazo et al., 2013). Children were required to sort objects with two-dimensional attributes (e.g., red rabbit) based on one of the two dimensions (color or shape) (See Figure 1). The task is conducted with PowerPoint slides through online Zoom meetings. Children were in front of the camera and their parents were next to or behind them. Upon parents' permission, we first displayed two objects on the screen (blue rabbit and red boat) and described them to children based on either color (e.g., "Look, here is something red, and here is something blue") or shape (e.g., "Look, here is a rabbit, and here is a boat"). We then asked them to group the newly appeared objects (red rabbit or blue boat) based on color or shape by pointing to the previously appeared two objects on the screen. Children accomplished two practice trials and 12 trials in total. In the first six trials children were required to use color for categorization. After the first six trials, the categorization dimension switched to shape for the rest of the trials. Scores were calculated by dividing the total number of correct trials by the total number of completed trials then multiplying by100.

[1] Our research assistants are fluent in either Turkish, English, or Chinese. We transcribed all utterances from families that used two or three of the abovementioned languages. For the families that speak an additional language other than the above three, only code-switching frequencies were calculated.

Figure 1. Example of the Dimensional Change Card Sort Task. During the first six trials, children were asked to sort the emerging red rabbit and blue boat based on color (blue or red). For the later six trials, they were asked to sort based on shape (rabbit or boat)



Visual Search Task. A visual search task is a task that examines selective attention ability (Mulder et al., 2014). Children were requested to identify the targeted animal image out of 48 images in total per slide. There were three slides in total, with 48 animal images for the first two slides and 72 animal images for the last slide (See Figure 2). Images of elephants, bears, and donkeys that were similar in size and color served as stimuli. During test sessions, children were given 40 seconds to point to as many targets (elephants) as they could while ignoring distractions (bears and donkeys). Parents were required to help the researcher locate the images that the children pointed at. All rolls and columns in the slides were numbered for easy recognition of the images' location, and the researcher crossed off the images that were located by the children. Scores were counted by dividing the number of accurately identified targets by the total number of targeted animal images within all slides.

Figure 2. Example of the Visual Search Task. The elephants were crossed off once they were identified by children

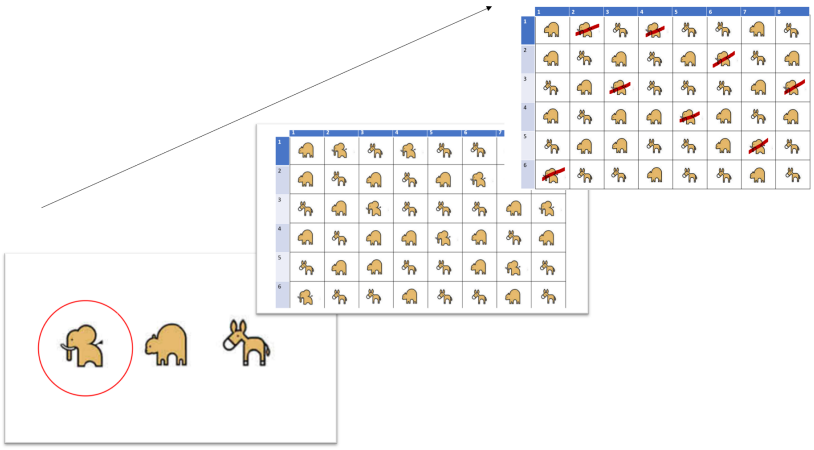


Figure 2. Example of the Visual Search Task. The elephants were crossed off once they were identified by children.

2.4 Design & Data Analysis

The current research considered the variation within bilingual children by adopting language proficiency, language use, and code-switching frequency as continuous variables. We first performed correlation analysis to examine the intercorrelation among all variables. Then, we conducted a hierarchical regression analysis to investigate how different facets of bilingual experience, including language proficiency, language usage, and code-switching frequency of both young bilingual children and their parents, may influence children's cognitive control ability. We want to see specifically whether parental factors act as more dominant indicators compared to children's factors. For that, we controlled age and the children's bilingual-related variables through the three steps hierarchical regression model.

2.5 Results

In total, we collected 324 minutes and 28 seconds of audio recordings from all families who participated and transcribed 4434 utterances for 13 families out of 24. For all families on average, parents code-switch behaviors occurred 148 times per hour (*SD* = 81.70, *Range* = 24 - 329), while children code-switched 52 times per hour (*SD* = 46.70, *Range* = 0 - 162). For the 13 families that we also

calculated code-switching frequency based on utterances, parents code-switched 96 times per 1000 utterances (*SD* = 49.50, *Range* = 32 - 228), while children code-switched 32 times per 1000 utterances (*SD* = 46.70, *Range* = 0 – 104).

We conducted correlation analysis for those families whose code switches were measured in two of the abovementioned ways (per hour and 1000 utterances). We found out that for both parents and children, those two types of frequency were highly correlated ($r_{parents}$ = .96, p <.001, $r_{children}$= .91, p < .001). Based on the high correlation between code-switching frequency per hour and code-switching frequency per 1000 utterance, we performed the rest of the analysis by using code-switching frequency per hour for both parents and children (see Kremin et al., 2022 for a similar procedure).

2.5.1 Relationship between bilingualism related variables

We first conducted correlation analysis to detect possible associations among children's and parents' code-switching frequency, children's and parents' language proficiency, children's and parents' language use, cognitive task scores, and age (See Table 1). Results showed that children's code-switching frequency was positively associated with children's language use (r = .402, p = .051) and negatively associated with age (r = -.438, p = .032) and parent's language proficiency (r = -.480, p = .018). Parents' language proficiency was negatively associated with parents' language usage (r = -.437, p = .033). Children's language usage was positively associated with parents' language usage (r = .460, p = .024) and children's language proficiency (r = .419, p = .042). Lastly, children's cognitive task performance was strongly correlated with age (r_{DCCS} = .559, p = .004, $r_{VisualSearch}$ = .585, p = .003) but not with any of the bilingual-experience-related variables from both children and parents (all p's > 0.05). Descriptive statistics of all bilingual experience variables and children's cognitive control performance can be found on the Open Science Framework (https://osf.io/uhkx7/?view_only=c88b1c4f116a430c8d0ccc9e0452102c).

Table 1. Correlation Among All Variables

		Cognitive Task (DCCS)	Cognitive Task (Visual)	Children's CS frequency	Children's language proficiency	Children's language usage	Parent's CS frequency	Parents' language proficiency	Parents' language usage	Age
Cognitive Task (DCCS)	Pearson's r	—								
	p-value	—								
Cognitive Task (Visual)	Pearson's r	0.632 ***	—							
	p-value	< .001	—							
Children's CS frequency	Pearson's r	0.014	-0.189	—						
	p-value	0.949	0.376	—						
Children's language proficiency	Pearson's r	-0.108	-0.138	0.059	—					
	p-value	0.617	0.519	0.784	—					
Children's language usage	Pearson's r	0.002	0.036	0.402	0.419 *	—				
	p-value	0.994	0.867	0.051	0.042	—				
Parent's CS frequency	Pearson's r	0.036	0.017	0.113	0.059	0.293	—			
	p-value	0.868	0.936	0.601	0.783	0.164	—			
Parents' language proficiency	Pearson's r	-0.127	-0.095	-0.480 *	0.167	-0.178	0.008	—		
	p-value	0.555	0.658	0.018	0.436	0.405	0.971	—		
Parents' language usage	Pearson's r	-0.322	-0.250	0.288	0.100	0.460 *	0.323	-0.437 *	—	
	p-value	0.125	0.239	0.173	0.641	0.024	0.123	0.033	—	
Age	Pearson's r	0.559 **	0.585 **	-0.438 *	-0.110	-0.132	-0.216	0.001	-0.383	—
	p-value	0.004	0.003	0.032	0.608	0.540	0.311	0.998	0.064	—

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

2.5.2 What predicts children's cognitive control abilities?

We then conducted further analysis on whether or not the bilingual-experience-related variables predict children's cognitive control abilities, especially parental factors, using hierarchical regression. The model consisted of three steps with the combined score of Dimensional Change Card Sort and Visual Search tasks as outcome variables. The combined score is determined as the average of the total of two task scores that have been transformed to z-scores from the original raw values. The first step of each model contained age. The second step contained child-related bilingualism factors (i.e., language proficiency, language usage, and code-switching frequency). Lastly, we inserted parent-related bilingualism factors (parents' language proficiency, language usage and code-switching frequency) as third the step.

The model was significant at each step (F_{step1} (1, 22) = 14.71, $p_{step1} < 0.001$, F_{step2} (4, 19) = 3.89, $p_{step2} = 0.018$, F_{step3} (7,16) = 2.47, $p_{step3} = 0.063$) in explaining 40%, 45%, and 52% of the total variance respectively. In all steps, the only significant variable was age at the time of testing ($\beta_{step1} = 0.633$, $p_{step1} <0.001$, $\beta_{step2} = 0.715$, $p_{step2} = 0.001$, $\beta_{step3} = 0.612$, $p_{step3} = 0.019$). None of the bilingual experience related variables act as a significant predictor of children's cognitive control performance individually (see Table 2).

Table 2. Differential contributions of Age, Language Proficiency, Language Usage, and CS Frequency on the combined score of DCCS and Visual Search Performance

Outcome: Cognitive Task Performance combined					
Predictors	*B*	*SE(B)*	*B*	*p*	*R2*
Step 1				<0.001	0.401
Age at Testing	1.30	0.340	0.633	<0.001	
Step 2				0.018	0.450
Age at Testing	1.471	0.393	0.715	0.001	
Children's language usage	0.003	0.007	0.083	0.694	
Children's language proficiency	-0.038	0.071	-0.104	0.593	
Children's CS frequency	0.004	0.004	0.188	0.379	
Step 3				0.063	0.520
Age at Testing	1.258	0.483	0.612	0.019	

Children's language usage	0.005	0.008	0.151	0.547
Children's language proficiency	-0.034	0.074	-0.090	0.657
Children's CS frequency	0.002	0.005	0.097	0.712
Parents' language usage	-0.010	0.008	-0.314	0.235
Parents' language proficiency	-0.086	0.124	-0.174	0.495
Parent's CS frequency	0.002	0.002	0.214	0.277

3 Discussion

In this study, we first examined the intercorrelation of different facets of bilingualism, including language proficiency, language use, and code-switching frequency from young bilingual children and parents. Then, we analyzed whether or not the abovementioned factors are associated with children's cognitive control abilities, specifically parental factors. To our knowledge, this is the first study involving all three bilingualism dimensions with the consideration of environmental factors and calculating code-switching frequency through natural observation. Overall, results showed that bilingual experience-related variables are correlated not only among children or parents themselves (e.g., children's language proficiency correlated with language usage) but also between children and parents (e.g., children's code-switching frequency correlated with parents' language proficiency). Age, rather than bilingual experience, is highly correlated with children's cognitive control ability.

3.1 Intercorrelations Among Bilingual Experience Related Variables

Due to the need to retain a pragmatic representation of the bilingual experience, the bilingualism-related factors extracted from the existing database or specific study design are allowed to correlate with one another in the analysis. It's argued that a network model would be more applicable to the most central indices of bilingualism, such as language proficiency, language usage, and code-switching frequency, along with other factors, to form a complex pattern of relationships (Kałamała et al., 2020).

In line with the constructs of these factors, we discovered a variety of correlations among studied variables, which supported the network model instead of the factors model when defining bilingualism dimensions. Firstly, it has demonstrated that the more evenly children use their home languages, the younger the children, and the less proficient their parents' second home

language, the more frequently children switch from one language to another on a daily basis. The negative association between children's age and code-switching frequency is consistent with the previous study (Kuzyk et al., 2020), which explained that children switch between languages due to lacking proficiency instead of balanced mastery of the two languages (Ribot & Hoff, 2014). They need to "borrow" words or sentences from their dominant language to fill in the language gap while expressing with non-dominant language; therefore, the behavior of language switching is reduced once they acquire better mastery of their weaker language.

Moreover, the negative correlation between parents' second home language proficiency and children's code-switching frequency could be due to the context of the participating families in the current study. We observed that in families whose parents speak different native languages, the couple's lack of proficiency in each other's language resulted in a natural "one parent, one language" conversation setting in which children are accustomed to speaking to parents in different languages. This correlation provided strong support for a previous study's discovery that bilingual children perform better on a selective attention task when one or both of their parent(s) showed a low level of language mastery in their weaker home language compared to the parents with balanced proficiency (Verhagen et al., 2020). The authors suggested that parents' language proficiency in their home languages might act as a proxy for their young bilingual children's language switch, which is a more fine-grained factor that enhances children's cognitive abilities. This assumption has been supported in our current findings.

Another interesting finding indicated that whether or not children use their home languages in a balanced way is positively associated with whether children have equal mastery of those languages and whether parents apply the "one parent, one language" policy. Meanwhile, whether or not parents use languages differently is determined by their second home language proficiency, as well as whether or not children use both home languages evenly. Specifically, for children, the more balanced the proficiency of their two languages are, the more evenly they will use them. In contrast, for parents, the less proficient they are in their second home language, the more evenly the two home languages will be used at home. These findings suggested that the language usage patterns of both children and their parents is decided by their mastery level and their interlocutors' language usage pattern, which is consistent with what we observed during the investigation. Children and parents both initiated language switches; in either case, the interlocutors were consistent with one another in their language use during each interaction.

3.2 Effect of Bilingual Experience Related Variables on Children's Cognitive Control Abilities

We also investigated whether parental and children bilingual experience related factors potentially account for the variation of young bilingual children's cognitive control ability, specifically parental factors. Our results indicated that only the children's age appeared to be a strong predictor of their cognitive performance. We were able to narrow our focus by using hierarchical regression to examine the individual effects of parental factors. Yet, we still found no significant result. In other words, our assumptions that the environmental factors might act as stronger predictors compared to children's factors were not supported.

Regarding the non-significant findings, the small sample size could be one of the reasons why no effect was found other than children's age. Due to the fact that Turkey is a linguistic homogenous country and Turkish is spoken by more than 80% of the population (Konda Araştırma ve Danışmanlık, 2006), we established our target participant group within the international community in Turkey, which inevitably affected the potential sample size of our study.

Moreover, although the study has been carefully designed to avoid the confounding factors that were advocated by leading researchers in the field (Bialystok & Shorbagi, 2021; Luk & Grundy, 2023), there are still the possibilities of unmeasured variables which could affect children's cognitive performance, such as nonverbal intelligence. Although most bilingual effect research rarely reports their measure of nonverbal intelligence, some studies did control this factor by assessing participants with nonverbal spatial reasoning tasks (Bialystok & Shorbagi, 2021; Treffers-Daller et al., 2020). Additionally, although it appears to be a common, even encouraged practice to recruit participants with different linguistic and cultural contexts (Verhagen et al., 2020; De Cat et al., 2018), the cross-linguistic and cross-cultural effects have not been systematically studied in this line of research. Those potential effects could impact both parents and children's bilingual experience, which in turn would potentially affect children's cognitive performance.

It is also possible that our methods of measuring bilingual experience, which are based on natural observation, did not accurately reflect our participants' actual language practices. It was recommended in the previous literature to apply natural observation outside of the laboratory to document bilingual speakers' switch between languages in daily life (Kuzyk et al., 2020). However, in the current study, the audio recording only managed to capture a snapshot of the code-switching scenario instead of real-time documentation of a prolonged period. Specifically, due to the limitation of the preset timeframe, although parents have been informed prior to recording that the conversation should be natural and spontaneous, it has been observed that certain parents were pressured to generate topics and consciously cautiously select languages. So even though the natural observation method in the current study is an explorational step

compared to measuring code-switching frequency through survey, it might still not be sufficient enough to be considered as a valid indicator of code-switching behavior.

Therefore, the results of our study did not support the existence of a bilingual effect. A meta-analysis suggested that the overall effect size of the bilingual advantage is marginal (Gunnerud et al., 2020). It has also been reported that the potential impact of speaking more than one language on cognitive performance, if it exists, will be challenging to detect and also limited to specific circumstances (Lowe et al., 2021; Paap et al., 2015).

Additionally, the non-significant findings of this study might also be because improving cognitive control abilities requires continuous challenge (Diamond & Ling, 2016). According to the Inhibitory Control Model and Bilingual Interactive-Activation Model (Dijkstra et al., 1998; Green, 1998) the processes of inhibiting the non-targeted language or choosing from more than one activated lexical system will recruit domain-general cognitive control. However, language switching within families may become automated when the speaking pattern matures and no longer requires top-down cognitive control. If that is the case, it would be beneficial to design a longitudinal study on young bilingual children and their families to document children's language development, especially the code-switching pattern between children and their parents from emerging.

In addition, the current study contributed to the limited literature about the bilingual effect that considered the heterogeneous characteristics of bilingual speakers by including multiple dimensions of bilingualism. It added to the preliminary foundation toward disentangling the properties of an individual's bilingual experience and uncovering the underlying mechanism of the bilingual effect. The shifting of the attention in the field from group comparison to studying whether more fine-grained facets of bilingualism could predict the bilingual effect has been advocated by pioneering researchers in the field (Bialystok & Craik, 2022). By identifying the composite of bilingualism and associating those indicators to cognitive abilities through regression, we might be able to see the various potential underlying mechanisms more in-depth. Though insignificant, the result of the current study will add more reference to this line of research, which is still growing.

Furthermore, our study is one of the very few studies that included the environmental factors of young bilingual speakers with limited language production. We proposed a solution on how to investigate the bilingual groups with limited language production by applying a within-group research design and including parental factors. Though we did not detect direct connections between parental bilingualism-related factors and children's cognitive performance in this study, targeting the younger age group as well as the language environment they are exposed to instead of only considering language production of individuals with sufficient language ability as possible indicators is a complementary perspective and taps into the domain of pure environmental influence on

cognition developing system in the field of bilingualism and cognitive control abilities.

4 Conclusion

In this study, we explored the "bilingual effect" by investigating language proficiency, usage, and code-switching in young bilingual children and their parents. Despite finding correlations between these factors, we discovered that children's age, rather than their or their parents' bilingual experience, strongly predicted children's cognitive control abilities. While our results did not show a clear bilingual advantage, they highlighted the intricate relationships between bilingualism-related aspects and suggested that environmental factors should be considered for young bilingual speakers in the line of research concerning bilingualism and cognition. Our study contributes to the evolving understanding of bilingualism's impact on cognition for different age groups. It emphasizes the need for nuanced and longitudinal research to unveil the circumstances under which bilingual effects might emerge.

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Data Use: Data was used in this study. If asked, data supporting this study will be openly available.
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