Early Childhood Research Quarterly 63 (2023) 327–336

Contents lists available at ScienceDirect

Early Childhood Research Quarterly

journal homepage: www.elsevier.com/locate/ecresq

Effects of language switching frequency on inhibitory control in bilingual preschool children: Different roles of expressive and receptive language abilities

Jin Chen[a,1], Yiwei Zhao[a,1], Xinpei Xu[c], Junsheng Liu[a,b,*], Ciping Deng[a,b,*]

[a] Shanghai Key Laboratory of Brain Functional Genomics, Affiliated Mental Health Centre (ECNU), School of Psychology and Cognitive Science, East China Normal University, Shanghai 200062, China
[b] Shanghai Changning Mental Health Center, Shanghai 200062, China
[c] Shanghai Institute of Early Childhood Education, Shanghai Normal University, 200234, China

ARTICLE INFO

Keywords:
Language switching frequency
Inhibitory control
Expressive language ability
Receptive language ability

ABSTRACT

Although research has indicated the contribution of bilinguals' language switching frequency and language abilities to their inhibitory control, the mechanism of how they work together to influence inhibitory control is unclear. This study examined the moderating role of expressive and receptive language abilities on the relationship between language switching frequency and inhibitory control. Participants were 229 Uyghur-Mandarin bilingual preschoolers aged 4.5 to 6.5 years. They were individually tested on expressive language ability (ELA), receptive language ability (RLA), and inhibitory control. Their frequency of language switching was collected from parents' and teachers' reports. The results showed that language switching frequency was positively associated with inhibitory control in children with high Uyghur ELA and low Mandarin ELA, and vice versa. Moreover, language switching frequency was negatively associated with inhibitory control in children with both low Uyghur and Mandarin ELA, but not significantly associated with inhibitory control in children with both high Uyghur and Mandarin ELA. Additionally, this moderating effect of language abilities was not found in receptive language abilities. The significant moderating effect of ELA, but not RLA, suggests the active role of children in their early executive function development; this extends the current understanding of how and when language switching frequency impacts bilinguals' inhibitory control.

1. Introduction

Different cultural communities provide distinct developmental pathways for children within diverse ecocultural contexts (Bronfenbrenner & Morris, 2007). Cultural pathways are composed of daily routines that comprise cultural activities requiring language skills. Through routine interactions with their parents and other established community members, children are socialized to use particular languages (Garrett & Baquedano-López, 2002; Schieffelin & Ochs, 1986). According to the ecocultural (Bronfenbrenner & Morris, 2007) and language socialization models (Garrett & Baquedano-López, 2002; Schieffelin & Ochs, 1986), bilingual children have a cognitive advantage that can be partly attributed to their language context, where young bilinguals must intentionally utilize multiple language resources to create meaning. In this study, we investigated the specific roles of translanguaging practice and language abilities in bilingual children's inhibitory control.

A typical argument presented by many researchers on the effect of language switching context on inhibition control (e.g., Abutalebi & Green, 2008; D'Souza et al., 2020; Green & Abutalebi, 2013), is that bilinguals' experience in managing conflict between competing phonetic and lexical representations may prompt inhibitory control (Green, 1998). Most studies found a positive correlation between language switching frequency and inhibitory control in bilinguals (e.g., Abutalebi & Green, 2008; Green, 1998; Green & Abutalebi, 2013); however, others questioned whether language switching frequency was associated with enhanced inhibition control (e.g., Kalamala et al., 2020). Recent studies have proposed that second language ability might affect the relationship between language switching frequency and inhibition control (Bonfieni et al., 2019; Thanissery et al., 2020). However, these studies (e.g., Bonfieni et al., 2019) did not consider both the roles of proficiency in the two languages and the differences between expressive language ability (ELA) and receptive language ability (RLA).

* Corresponding authors at: Shanghai Key Laboratory of Brain Functional Genomics, Affiliated Mental Health Centre (ECNU), School of Psychology and Cognitive Science, East China Normal University, 407 Junxiu Building, 3663 North Zhongshan Road, Shanghai 200062, China
E-mail addresses: jsliu@psy.ecnu.edu.cn (J. Liu), cpdeng@psy.ecnu.edu.cn (C. Deng).
[1] Jin Chen and Yiwei Zhao contributed equally to this work.

https://doi.org/10.1016/j.ecresq.2023.01.002
Received 19 March 2021; Received in revised form 18 December 2022; Accepted 4 January 2023
0885-2006/© 2023 Elsevier Inc. All rights reserved.

Moreover, such studies only recruited adult bilinguals as participants and did not examine language ability in bilingual children's cognitive development. Thus, we aimed to address this gap by examining the relationship between language switching frequency, language abilities (Mandarin/Uyghur ELA and RLA), and inhibitory control in Uyghur-Mandarin bilingual children.

1.1. Language switching frequency and inhibitory control in bilinguals

Language switching refers to bilinguals alternating between languages according to the language used by an interlocutor in a bilingual conversation (Green & Abutalebi, 2013), which reflects the cross-linguistic activation and systematic control of the two languages (Lai & O'Brien, 2020). Language switching frequency is the frequency at which an individual switches between languages in daily life (Verreyt et al., 2016). Inhibitory control refers to the ability to control one's tendency to respond automatically or impulsively and to inhibit presenting irrelevant information. This is a core component of executive function (Salwei & de Diego-Lazaro, 2021; Treffers-Daller et al., 2020) and might be the "common factor" underlying its different elements (Valian, 2015).

Theoretically, language switching frequency positively affects inhibitory control. The inhibitory control model (Green, 1998) states that bilinguals have a cognitive advantage over monolinguals because they need to restrict access to the irrelevant language that was simultaneously activated with the relevant language, which may lead to strengthened inhibitory control. The adaptive control hypothesis (Abutalebi & Green, 2016) further proposes that bilinguals are often required to engage in adaptive language switching according to different language contexts (i.e., single, dual, and dense code-switching). Single-language context refers to the use of one language in one context. Dual language context is one where bilinguals alternate between languages according to the language used by an interlocutor in a conversation. Dense code-switching language context refers to the mixing of languages in an utterance or sentence. Among these contexts, language switching in a dual-language context requires more inhibitory control than in a single-language or dense code-switching language context. Bilinguals perform better on inhibitory control tasks because of their experience of frequently switching languages in a bilingual environment (e.g., Sanchez-Azanza et al., 2020).

Many studies have supported the positive relationship between language switching frequency and inhibitory control in bilinguals. For example, Sanchez-Azanza et al. (2020) found that the frequency of language switching in daily life was positively associated with executive control performance in Spanish-Catalan bilinguals (19–44 years old). Liu et al. (2019) found that language switching training may enhance bilinguals' inhibitory control; however, some recent empirical studies suggested that the association between language switching frequency in daily life and inhibitory control does not always exist. For example, Kalamala et al. (2020) demonstrated that dual-language context intensity did not predict performance on response-inhibition tasks. Based on a review of several recent studies, Paap et al. (2021) indicated that bilinguals' performance on executive functioning tasks did not reflect the expected advantage of a language switching context. Pliatsikas et al. (2021) suggested a dynamic restructuring model to explain this inconsistency, in which bilingualism is considered a dynamic experience where the adaptive brain structure and cognitive functions develop dynamically together with changes in language abilities and switching needs. Similarly, Paap (2018) proposed a controlled-dose hypothesis assuming that the early stages of second language acquisition require domain-general inhibition; only as fluency is gained and ubiquitous practice accrues can bilingual-language control become increasingly automated and the demand for domain-general inhibition is lowered. Taken together, these perspectives emphasize that the relationship between language switching frequency and inhibitory control is dynamic and may be influenced by language abilities. We review this issue in detail in the following paragraph.

1.2. Moderating effects of language proficiency

From the inhibitory control model perspective (Green, 1998), the bilingual inhibitory control advantage is derived from the competition between bilinguals' activation of both target and non-target languages simultaneously. The co-activation of two languages requires mobilizing inhibitory control to suppress non-target language interference, which may contribute to developing inhibitory control. This assumption presupposes that bilinguals may simultaneously activate their two languages in two-language contexts (Thierry & Wu, 2007), which requires control mechanisms to resolve the competition between the two languages. However, Costa et al. (2017) found that bilinguals can selectively activate second language vocabulary without activating the corresponding first language representations when they reach high proficiency in their second language. This suggests that bilinguals with different language proficiencies have different inhibitory costs to language switching. For unbalanced bilinguals, switching from a weaker to a more dominant language is more difficult than the other way around, showing asymmetric inhibitory costs (Meuter & Allport, 1999). The smaller the difference between languages proficiencies, the smaller the asymmetric cost (Monsell et al., 2000). Casado et al. (2022) also demonstrated that the more balanced the proficiency in the two languages, the lower the control elicited by second language production. Thus, different bilingual proficiencies may require different control mechanisms to resolve language competition and exhibit adaptive influences on executive control.

Several studies have indicated that second language ability plays an important role in language control and modulating the dependency of bilingual processing on domain-general cognitive control (e.g., Abutalebi et al., 2013; Bonfieni et al., 2019; Jiao et al., 2019). When second language proficiency is low, individuals need more cognitive resources to suppress the influence of the first language. The effect of language switching on inhibitory control weakened as second language proficiency increased. Since the participants in these studies were adults who were already proficient in their first language and were learning a second language, research only focused on the moderating effects of second language ability. However, for bilingual preschool children, both of their languages are in a period of rapid development, and the ability development status of the two languages may jointly determine the effect of language switching on inhibitory control.

Based on the above analysis, we speculated that the two language abilities of bilingual children would moderate the association between language switching frequency and inhibitory control. The more balanced the abilities of the two languages, the weaker the positive effect of language switching on inhibitory control.

1.3. Different roles of expressive and receptive language abilities

Language ability is assumed to comprise ELA and RLA. According to the self-organizing model of language processing (Curtin et al., 2011), ELA and RLA are independent but interrelated language abilities (Pickering & Garrod, 2013). ELA refers to an individual's ability to express and convey information to another person, which helps children use language information directly to select the right object by explicitly generating tags and activating related concepts internally (Feldman, 2019). RLA refers to the ability to recognize and understand the language of others, using linguistic information to activate related concepts (Cheung et al., 2022).

Early on in development, children comprehend more vocabulary than they produce (Ibbotson, 2022), which may be because language comprehension is generally considered easier than language expression. This reception-expression gap is more evident in bilingual preschool children (Gibson et al., 2014a). In contrast to language comprehension, language expression requires children to activate the appropriate words to convey ideas. The limited lexical experience of bilingual children results in a weaker connection between the semantic and phonological representations of these words. From the weak link hypothesis,

weak semantic-phonological representations can accomplish receptive language tasks but not word generation tasks (Gibson et al., 2020). Considering the asymmetry in the development of preschool children's expressive and receptive language abilities, we separately examined the moderating role of ELA and RLA in bilingual populations.

Furthermore, because cognitive demands differ between expressive and receptive language tasks, the repressed or relatively inactive representations are sufficient for the less demanding receptive tasks but not for the more demanding expressive tasks. Thus, compared to RLA, ELA requires stronger mental links between the pronunciation of a word and its meaning (Gollan et al., 2008). Meanwhile, the inhibitory control model holds that the degree of inhibition in bilingual children is proportional to the degree of parallel activation (Hilchey & Klein, 2011). If this is the case, then the expression task requires high activation and corresponding high inhibition demands. Bilinguals' cognitive control skills are enhanced as a result of their increased need for language control. Based on the above analysis, we further expected that the moderating effect of ELA would be more pronounced than that of RLA.

1.4. Bilingual context of young Uyghur children in China

The Xinjiang Uygur Autonomous Region of China is the major bilingual region in the world where both Uyghur and Mandarin are used (Chen et al., 2018). Historically, this area has always been a multi-ethnic region with many coexisting cultures. The long-term coexistence of various ethnic groups and cultures, along with the high prevalence of multilanguage and multilingual press, publications, radio, and television, has created a bilingual environment where diversity is respected and embraced. Both the Uyghur and Mandarin languages are frequently used in daily life. Uyghur is one of the regional language while Mandarin is the national common language in China which plays a dominant role in the economy, social and educational development.

Uyghur and Mandarin belong to the Altaic and Sino-Tibetan language groups, respectively. Mandarin is an isolating language, while Uyghur is an agglutinative language (Mang, 2003), and significant differences exist between the two (Wang, 2012). However, Uyghur has a long history of contact and mutual influence with the Chinese language. The grammatical morphology, structure, and word formation rules of the two languages have many commonalities (Mang, 2003). The commonalities and differences between the two languages present specific challenges for Uyghur-Chinese bilingual children.

Young Uyghur children in China often use the two languages interchangeably as part of normal communication in their daily lives, but the diversity and richness of the language environment means that their languages develop at different rates. Therefore, there are children with balanced bilingual development—those with Mandarin as their dominant language, those with Uyghur as their dominant language, and those with weaker development of both languages. Moreover, children's dominant and non-dominant language patterns may change based on their experience of a language environment as bilinguals may be more proficient in their heritage language (the language spoken at home with their parents) early in life, while Mandarin becomes their dominant language at the preschool/school age. As a bilingual population with little research, Uyghur-Mandarin bilingualism provides a relatively new natural bilingual context for investigating complex associations between language switching frequency, language ability, and inhibitory control. This study can thus reveal some new information about the moderating effect of language abilities on the relationship between language switching frequency and inhibitory control.

1.5. The present study

To summarize, the foregoing review of literature shows that the high frequency of language switching in a bilingual context is expected to promote bilingual children's inhibitory control because it involves frequent invocation of cognitive control mechanisms (e.g., Green & Abutalebi, 2013; Verhagen et al., 2017). Previous research on this association has shown mixed results. Some studies with adult bilinguals suggest that the association may depend on second language ability (e.g., Jiao et al., 2019). A common explanation for this association is that, with the improvement of second language ability, cognition associated with second language processing evolves from that requiring cognitive control to that involving automated processing (e.g., Abutalebi, 2008; Costa & Sebastián-Gallés, 2004). However, the association for young bilinguals may be more complex, since both first and second languages are in the learning phase, and bilingual language abilities jointly affect the level of activation and control of the two languages (e.g., Costa et al., 2017). More development research is therefore needed for the outstanding issue.

This study provides an explanatory mechanism for the association between language switching frequency and inhibitory control by testing the moderating effects of young children's Uyghur and Mandarin language abilities (see Fig. 1). We examined both the main effects of language switching frequency on inhibitory control and how language switching and bilingual children's abilities work together in affecting inhibitory control. Furthermore, we explored hypothetical models for the moderating roles of ELA and RLA on the relationship between language switching frequency and inhibitory control.

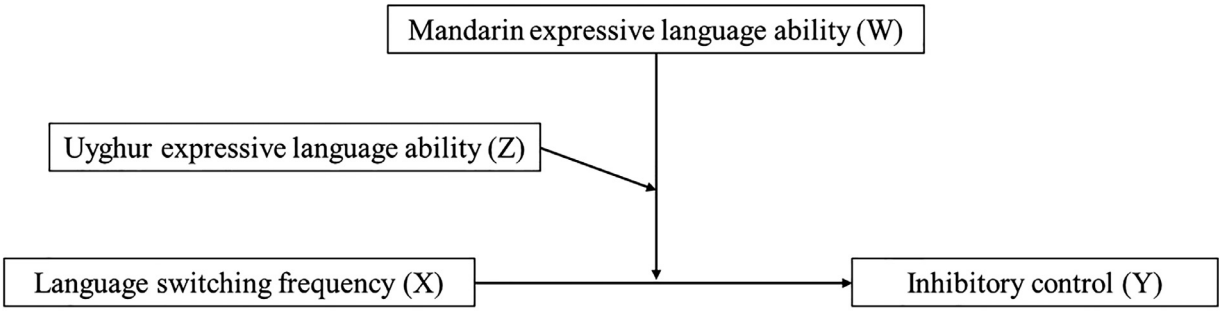
Based on previous studies and theories, this study hypothesized that (a) the effect of language-switching frequency on inhibitory control may be positively significant or nonsignificant; (b) bilingual children's language abilities moderate the relationship between language switching frequency and inhibitory control. There may be three-way interactions between Mandarin- and Uyghur-language abilities and language switching frequency in predicting inhibitory control. We hypothesized that the more unbalanced the language abilities of Mandarin and Uyghur, the stronger the positive effect of language switching on inhibitory control; (c) expressive language is the more cognitive loading form of language communication, and we hypothesize that the moderating effect of language ability between language switching frequency and inhibitory ability is more pronounced in expressive than in receptive language.

Furthermore, in early childhood, inhibitory control and working memory, as subcomponents of executive function, are still in the initial stage of functional differentiation. Children's performance on inhibitory control tasks may be strongly influenced by working memory (Ponitz et al., 2008) as they need to memorize the requirements and rules for completing tasks within a short period. Therefore, we control for the effect of working memory on inhibitory control when examining the hypothetical model.

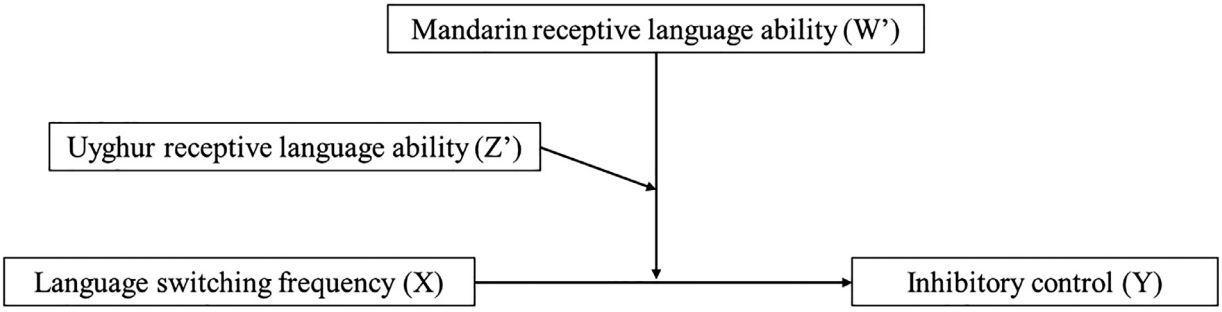
2. Method

2.1. Participants

We recruited 229 Uyghur-Mandarin bilingual preschool children (4.5–6.5 years old, 109 girls and 120 boys, M_{age} = 63.27 ± 5.97 months, $M_{age\ of\ acquisition\ Mandarin}$ = 31.42 ± 12.22 months) from five kindergartens in Urumqi, Xinjiang Uygur Autonomous Region of China. The recruitment criteria were set as: (1) normal intellectual development; (2) normal language development; (3) normal or corrected-to-normal hearing and vision; (4) both parents are Uyghur-Mandarin bilinguals; (5) received at least one school year of bilingual education in kindergarten. All children and families who met the inclusion criteria filled out informed consent forms before participating. Following previous research (Yoshida et al., 2011), the study used parental education as an indicator of socioeconomic status. Parental education was categorized into five levels (1 = *junior high school and below*, 2 = *high school*, 3 = *professional or technical school*, 4 = *undergraduate*, 5 = *graduate and above)*. The mean value of SES was 3.47 (*SD* = 0.80).



(a) Testing the three-way interaction effect of language switching frequency, Uyghur expressive language ability and Mandarin expressive language ability on inhibitory control in Uyghur-Mandarin bilingual children.



(b) Testing the three-way interaction effect of language switching frequency, Uyghur receptive language ability and Mandarin receptive language ability on inhibitory control in Uyghur-Mandarin bilingual children.

Fig. 1. Moderated moderation model of the relationship between language switching and inhibitory control.

2.2. Measures

2.2.1. Language switching frequency

Language switching frequency was assessed by a measure adapted from the Language and Social Background Questionnaire, Item 22 (Anderson et al., 2018; Luk & Bialystok, 2013; see Appendix A). As with most studies on young children's language development, the assessment of language switching frequency relies on reports from caregivers because children are often unable to complete reports by themselves. For bilingual preschoolers, which language to use often depends on the current language environment and conversational needs (Marian & Hayakawa, 2021). Therefore, we used parents' and teachers' reports to measure children's language-switching experiences in everyday life. Parents and teachers were asked to report how often they engage in language switching with the child at home and school, respectively. Teachers were also asked to report the frequency of language switching between the child and their classmates. All items were rated based on a 5-point Likert scale (1 = *never* to 5 = *always*). The range of possible scores was 0–15. Here, scores were significantly correlated between the three items for language switching frequency between children and parents, teachers, and peers, r = .26–.58, ps < .001, and thus were summed to form a single index of children's language switching frequency in their daily lives. The Cronbach's alpha coefficient was .86.

2.2.2. The Head-Toes-Knees-Shoulders task

The Head-Toes-Knees-Shoulders (HTKS) task is a brief game designed to assess inhibitory control ability in children aged four to six (Burrage et al., 2008; Mcclelland et al., 2007). The HTKS task has been used to measure inhibitory control or response inhibition in many studies (e.g., Fuhs & Day, 2011; Gandotra et al., 2021; Lan et al., 2011) and is particularly considered an appropriate measure of inhibitory control in preschoolers. It is easy to conduct with minimal time and material requirements since children are already familiar with the aspects of the game (Ponitz et al., 2008, 2009). The task requires children to inhibit a dominant response and produce a non-dominant response, and consists of two parts. Part I included two paired behavioral commands. When the researcher said, "touch your head," the children were required to touch their toes; when the researcher said, "touch your toes," the children were required to touch their head. Part II included four paired behavioral commands that the research assistant presented to each child: "touch your head," "touch your toes," "touch your shoulders," and "touch your knees." Similarly, the children were asked to respond to the command and do the opposite of it (e.g., touch their knees when they heard the instruction to "touch your shoulders"). A child scored a "2" if they responded immediately and correctly, a "1" if they self-corrected their response, and a "0" if they responded incorrectly. The task included 20 items (with a total score range of 0–40). The Cronbach's alpha of the HTKS test was .92.

2.2.3. Expressive Vocabulary Test-Mandarin/Uyghur version

The Expressive Vocabulary Test (EVT) by Williams (2007) is a standardized test for assessing ELA in children. We used the revised Mandarin version of EVT (Li, 2018) to test Mandarin ELA in children. After a one-week interval, we measured the children's Uyghur ELA using the

Uyghur version revised by Zhou et al. (2015). The child and research assistant sat facing each other with the EVT booklet placed between them. After presenting a colored picture to the child, the research assistant asked standard questions (e.g., the names and synonyms for various objects or actions depicted in the picture). The test ended when the child gave five wrong answers within seven consecutive questions. Each question had a score of 1 for a correct answer or 0 otherwise. The range of possible scores was 0–130. All item scores were summed to get the total score. The Cronbach's alpha of the EVT for the Mandarin and Uyghur versions were .95 and .91, respectively.

2.2.4. Peabody Picture Vocabulary Test (PPVT)–Mandarin/Uyghur version

PPVT is an effective tool for assessing RLA in children (Hill et al., 2015). We used the Mandarin (Lu & Liu, 2005) and Uyghur (Chen et al., 2018) versions of the test. In a quiet room, the child and the research assistant sat facing each other with the PPVT booklet between them. The starting question was based on the child's age. The research assistant presented a page with four pictures and said aloud the word representing one of the four pictures. The child was asked to point to the picture corresponding to the word. Each question had a score of 1 for the correct answer or 0 otherwise. The test ended when the child gave six wrong answers within eight consecutive questions. The range of possible total scores was 0–125. The Cronbach's alpha of the PPVT was .92 and .91 for the Mandarin and Uyghur versions, respectively.

2.2.5. Nonverbal intelligence

Intelligence was assessed using nonverbal matrices from the Das-Naglieri Cognitive Assessment System-Version 2 (D-N CAS-2) by Naglieri and Das (1997). Each page contained six different shapes and geometric designs. The children were asked to identify a spatial or logical relationship among the figures on a given page by selecting the best answer from six options. Each question had a score of 1 for a correct answer or 0 otherwise. The test ended when the child gave four consecutive wrong answers. The range of possible total scores was 0–43. Deng et al. (2011) reported high test-retest reliability for the D-N CAS-2 in Chinese children (r = .72–.90, $ps < 0.01$). The Cronbach's alpha for this test was .90.

2.2.6. Working memory

We used the Forward Digit Span Task (Wechsler, 1974) to investigate working memory in children. The research assistant read one number per second. The span of the numbers increased from three to eleven. The child was asked to repeat the numbers they heard. Two trials were performed for each digit length. The child received 1 point if the answer is correct and 0 otherwise. The test ended when the child failed to repeat two identical digit lengths. The range of the total scores was 0–16. Raw scores were converted into standard scores for analysis. The Cronbach's alpha for this test was .92.

2.3. Procedure

This study was approved by the institutional review board of the university. Trained Uyghur-Mandarin bilingual research assistants conducted the research tasks. Cognitive tasks (inhibitory control, nonverbal intelligence, and working memory) were tested in the children's dominant language to reduce the influence of language itself. To ensure the effectiveness and standardization of the test implementation, the research assistants completed training and passed a one-to-one assessment prior to the study. Child assessments were conducted one-to-one in a quiet room within approximately 30–40 min. The research assistants were instructed to test the children in one session if possible, or divide the session into smaller segments if the children showed signs of fatigue.

2.4. Data analysis

The statistical analyses comprised two steps. In the preliminary analyses, the distributions of all study variables were tested for violations of normality, linearity, and homogeneity of variance (Hayes, 2013). Then, we calculated the means, standardized deviations, and inter-correlations among the variables. In the second step, we used Hayes's (2013) PROCESS macro (Model 3) to test the moderating effects. All continuous variables were standardized. Effects were estimated using bootstrapping techniques with 5,000 bootstrapped samples and were considered significant when 95% bias-corrected confidence intervals (95% CI) did not include zero (Preacher & Hayes, 2008).

3. Results

3.1. Descriptive statistics

Descriptive statistics and correlations among the variables are presented in Table 1. The results showed that language switching frequency was significantly negatively associated with Mandarin ELA, but not with Mandarin RLA, Uyghur ELA and RLA, and inhibitory control. Moreover, Uyghur ELA and RLA, Mandarin ELA and RLA, nonverbal intelligence, age, and working memory were significantly positively associated with inhibitory control. Moreover, child age was significantly negatively associated with language switching frequency, but significantly positively associated with inhibitory control, Uyghur ELA and RLA, Mandarin ELA and RLA, nonverbal intelligence, and working memory. Nonverbal intelligence and working memory were significantly associated with all variables of interest except language switching frequency. Thus, in the following analyses, child age, nonverbal intelligence, and working memory were statistically controlled. In addition, to distinguish the roles of ELA and RLA, the receptive language ability of Mandarin and Uyghur were covariates in the model for ELA while expressive language ability of Mandarin and Uyghur were covariates in the model for RLA.

3.2. Testing for the moderating role of language abilities

Model 3 in the PROCESS macro was performed to examine the moderating role of language proficiency in the relationship between language switching frequency and inhibitory control. We first explored hypothetical models for the moderating role of expressive language abilities, controlling for child age, nonverbal intelligence, working memory, Uyghur RLA, and Mandarin RLA. The results are shown in Table 2. The results showed that language switching frequency did not significantly predict inhibitory control, β = 0.04, SE = 0.06, 95% CI = [-0.09, 0.16]. Moreover, neither Uyghur ELA nor Mandarin ELA was associated with inhibitory control, β = 0.10, SE = 0.07, 95% CI = [-0.04, 0.25]; β = 0.16, SE = 0.10, 95% CI = [-0.03, 0.35]. Furthermore, the interactions of language switching frequency with Uyghur and Mandarin ELA were not significant in predicting inhibitory control, β = 0.10, SE = 0.07, 95% CI = [-0.04, 0.24]; β = -0.01, SE = 0.07, 95% CI = [-0.14, 0.13]. However, language switching frequency × Uyghur ELA × Mandarin ELA showed a significant three-way interaction effect in predicting inhibitory control, β = -0.32, SE = 0.08, 95% CI = [-0.48, -0.16].

To understand the nature of the interaction, we used simple slope analyses (Dawson & Richter, 2006) considering the conditional effect of language switching frequency on inhibitory control. We computed high- and low-Mandarin ELA/Uyghur ELA at +1 and -1 SD scores. As shown in Fig. 2, language switching frequency was positively associated with inhibitory control in children with high Uyghur ELA and low Mandarin ELA, β = 0.47, SE = 0.15, t = 3.23, p = .001, as well as in children with low Uyghur ELA and high Mandarin ELA, β = 0.25, SE = 0.12, t = 2.08, p = .04. Moreover, language switching frequency was negatively associated with inhibitory control in children with both

Table 1
Descriptive statistics and correlations for study variables.

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
1 Child gender	0.52	0.50	1										
2 Child age	63.27	5.97	.03	1									
3 family SES	3.47	0.80	-0.07	.04	1								
4 Nonverbal intelligence	12.22	4.39	.09	.30***	.04	1							
5 Working memory	4.57	2.28	.01	.14*	.09	.29***	1						
6 Language switching frequency	8.86	2.91	-.08	-.18**	-.06	-.11	-.06	1					
7 Inhibitory control	29.18	8.57	.03	.21**	-.11	.27***	.29***	.00	1				
8 Uyghur ELA	33.31	19.32	-.12	.29***	-.04	.14*	-.06	-.00	.15*	1			
9 Mandarin ELA	32.45	18.22	.09	.30***	.13	.48***	.43***	-.14*	.32***	.02	1		
10 Uyghur RLA	24.61	17.95	-.04	.31***	.00	.13*	-.02	-.03	.15*	.51***	.11	1	
11 Mandarin RLA	28.62	16.36	.04	.38***	.11	.41***	.23***	-.11	.28***	.05	.69***	.16*	1

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; ELA = expressive language ability; RLA = receptive language ability.

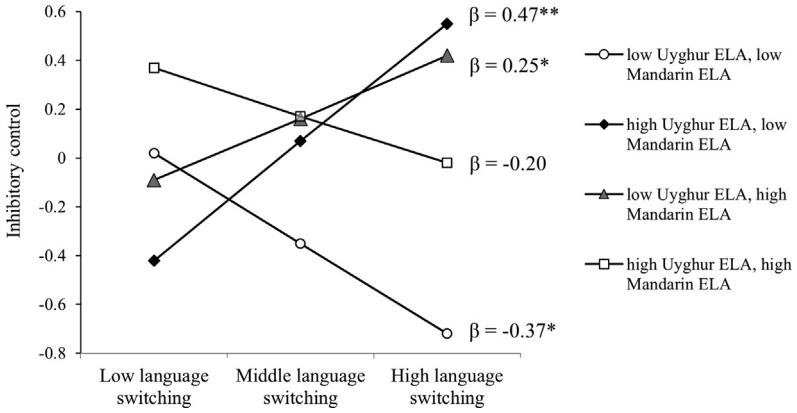


Fig. 2. The simple slope indicating the moderation effects.

Table 2
Effects of language switching frequency and expressive language ability (Uyghur and Mandarin) on predicting inhibitory control.

	β	*SE*	*t*	95% CI
Constant	0.01	0.06	0.14	[-0.11, 0.12]
Child age (months)	0.07	0.07	0.91	[-0.07, 0.20]
Nonverbal intelligence	0.05	0.07	0.71	[-0.09, 0.19]
Working memory	0.19	0.07	2.82**	[0.06, 0.32]
Uyghur RLA	0.07	0.07	0.96	[-0.07, 0.21]
Mandarin RLA	0.04	0.09	0.45	[-0.13, 0.21]
LSF	0.04	0.06	0.60	[-0.09, 0.16]
Uyghur ELA	0.10	0.07	1.41	[-0.04, 0.25]
Mandarin ELA	0.16	0.10	1.68	[-0.03, 0.35]
LSF × Uyghur ELA	0.10	0.07	1.41	[-0.04, 0.24]
LSF × Mandarin ELA	-0.01	0.07	-0.12	[-0.14, 0.13]
Uyghur ELA × Mandarin ELA	-0.11	0.07	-1.61	[-0.24, 0.02]
LSF × Uyghur ELA × Mandarin ELA	-0.32	0.08	-4.01***	[-0.48, -0.16]
R^2	0.24			
F	5.69***			

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; LSF = language switching frequency; RLA = receptive language ability; ELA = expressive language ability; CI = confidence interval.

Table 3
Effects of language switching frequency and receptive language ability (Uyghur and Mandarin) on predicting inhibitory control.

	β	*SE*	*t*	95% CI
Constant	0.01	0.06	0.20	[-0.11, 0.14]
Child age (months)	0.07	0.07	0.93	[-0.08, 0.21]
Nonverbal intelligence	0.09	0.07	2.17	[-0.06, 0.24]
Working memory	0.21	0.07	2.97**	[0.07, 0.35]
Uyghur ELA	0.09	0.07	1.20	[-0.06, 0.23]
Mandarin ELA	0.09	0.10	0.91	[-0.10, 0.28]
LSF	0.06	0.07	0.95	[-0.07, 0.19]
Uyghur RLA	0.10	0.08	1.21	[-0.06, 0.26]
Mandarin RLA	0.08	0.09	0.90	[-0.10, 0.26]
LSF × Uyghur RLA	0.08	0.06	1.21	[-0.05, 0.21]
LSF × Mandarin RLA	-0.07	0.06	-1.21	[-0.19, 0.05]
Uyghur RLA × Mandarin RLA	-0.04	0.06	-0.69	[-0.15, 0.07]
LSF × Uyghur RLA × Mandarin RLA	-0.08	0.06	-1.34	[-0.19, 0.04]
R^2	0.19			
F	4.15***			

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; LSF = language switching frequency; RLA = receptive language ability; ELA = expressive language ability; CI = confidence interval.

low Uyghur and Mandarin ELA, $\beta = -0.37$, $SE = 0.14$, $t = -2.55$, $p = .01$, but not significantly associated with inhibitory control in children with both high Uyghur and Mandarin ELA, $\beta = -0.20$, $SE = 0.16$, $t = -1.26$, $p = .21$.

Next, we explored hypothetical models for the moderating role of receptive language abilities (Uyghur and Mandarin RLA) on the relationship between language switching frequency and inhibitory control, controlling for child age, nonverbal intelligence, working memory, Uyghur ELA, and Mandarin ELA. The results are shown in Table 3. No significant two- or three-way interactions were found, suggesting that the moderating effect of language abilities on the relationship between language switching frequency and inhibitory control does not hold in receptive language abilities.

4. Discussion

The preschool years are a critical period for developing language and inhibitory control (Best & Miller, 2010). Such development often benefits from the interactions between environment, language, and complex cognitive systems. We examined the moderating roles of ELA and RLA in preschoolers on the association between language switching frequency and inhibitory control. The results showed that the effect of language

switching frequency on inhibitory control was only moderated by ELA. Specifically, language switching frequency was not significantly associated with inhibitory control in children with both high Uyghur and Mandarin ELA, but positively associated with inhibitory control in children with high Uyghur ELA and low Mandarin ELA and children with low Uyghur ELA and high Mandarin ELA. Moreover, language switching frequency was negatively associated with inhibitory control in children with both low Uyghur and Mandarin ELA. These findings can facilitate our understanding of the extent to which language switching frequency affects bilingual children's inhibitory control.

4.1. Effects of language switching frequency on inhibitory control

The effect of language switching frequency on inhibitory control was not significant, which suggests that the cognitive advantage provided by language switching frequency does not apply to all bilingual children. This non-significant result is consistent with the findings of some recent studies (e.g., Kalamala et al., 2020; Paap et al., 2021), but inconsistent with those of Hartanto et al. (2020) and Lai et al. (2020). An explanation behind the inconsistent results across studies is the existence of other variables that can moderate the association between language switching frequency and inhibitory control. We found that the effect of language switching frequency on inhibitory control was moderated by language abilities, supporting the claim that bilingual language proficiencies may lead to differences in language switching cost among bilingual children (DeLuca et al., 2019).

4.2. Moderating roles of Uyghur ELA and Mandarin ELA

This study identified the three-way interaction effect of language switching frequency, Uyghur ELA, and Mandarin ELA on inhibitory control, indicating their importance regarding the effects of language switching frequency on inhibitory control in Uyghur-Mandarin bilingual children. As an indicator of language production, ELA reflects the degree of connection between cognitive processing at the conceptual and lexical levels. Two proposals have attempted to explain the moderating effects of ELA. First, from the level of activation and control, language proficiency affects the degree of activation of the two languages, which may lead to the recruitment of different control mechanisms to resolve language competition and have adaptive influences on executive control (Kroll et al., 2015). Second, from language switching cost perspectives, building on the inhibitory control model (Green, 1998), the degree of language control applied depends on the relative balance between the current activation of the two languages. The model indicated that the higher the first language activation level and the lower the second language activation level, the greater the second language aftereffect. The results also revealed an enduring down-regulation of the first language activation level in more language-balanced speakers (Casado et al., 2022).

Further analysis of the simple effect showed that the effect of language switching frequency on inhibitory control was different in Uyghur and Mandarin ELA at various levels. First, language switching frequency was unrelated to inhibitory control in children with high language abilities in both Uyghur and Mandarin, consistent with previous studies (Costa & Sebastián-Gallés, 2004; Paap et al., 2014). According to the computational model proposed by Costa et al. (2017), activation is restricted to one language when two languages reach a given level of proficiency. This means that bilinguals do not need control mechanisms to resolve the competition between the two languages. Alternatively, with language proficiency development, bilinguals may have developed and automated language-specific control mechanisms (Paap et al., 2014; Segalowitz & Freed, 2004), which might render inhibitory control unnecessary. That is, in children with high ELA in both languages, inhibitory control is "less affected" by language switching frequency.

Second, language switching showed a significantly positive effect on inhibitory control in the group of bilingual children with high Uyghur and low Mandarin ELA, as well as in children with low Uyghur and high Mandarin ELA. Our findings show that unbalanced bilinguals benefit from the experience of suppressing the dominant language during language switching. Bilinguals with unbalanced languages required more additional cognitive control when switching between languages (Declerck et al., 2020; Jiao et al., 2020). In addition, the results showed that the positive correlation between language switching and inhibitory control in Uyghur dominant bilinguals was higher than in Mandarin dominant bilinguals. Based on the inhibitory control model, the degree of activation/inhibition of the two languages was related to language ability and determined the switching cost (Costa, 2017; Green, 1998). When bilingual children use their non-dominant language, they need to maximize the activation of the non-dominant language and suppress the interference of the dominant language; when switching to their dominant language, they need to suppress the high activation of the non-dominant language and activate the suppressed dominant language. In our study population, the children spent more time in the Mandarin context (in kindergarten) than in the Uyghur context (at home). Thus, the Uyghur dominant bilinguals might have had a higher language switching cost. There have been similar discussions about different switching costs for first versus second language contexts (Timmer et al., 2019). Thus, Uyghur dominant children are likely to need more inhibitory control to switch between languages compared with Mandarin dominant children.

Finally, the results suggest that for children with lower ability in both languages, more frequent language switching resulted in lower inhibitory control. One possible explanation for this is that high activation of the non-target language in low-proficiency bilinguals would cause more interference when switching. The comprehension and production of the target language also require greater cognitive effort. This kind of excessive cognitive load may bring cognitive costs. According to the limited-resource model (Eysenck et al., 2007), low-proficiency bilinguals have difficulty adapting to a language switching context because their cognitive resources are consumed by language processing, which leaves fewer resources available for suppressing the interference from the non-target language (Paap et al., 2019). Taken together, the resource-related pattern of adaptation provides evidence of individual-environment interactions (Pluess et al., 2018). Another possible reason is that a higher cognitive load may cause low-proficiency bilingual children to give up control and processing of the language, which may hamper cognitive development and learning (Mücke et al., 2020) as well as inhibitory control development. Thus, for children with weaker developmental abilities in both languages, a bilingual environment with high frequency of language switching may not be conducive to the development of their inhibitory control.

4.3. Moderating roles of Uyghur RLA and Mandarin RLA

The results showed that RLA in bilingual children had no moderating effect on the association between language switching frequency and inhibitory control. ELA is associated with high neural activation and requires conscious attention and task-related cognitive effort (Cheung et al., 2022). In contrast, RLA is associated with automatic attention, which requires a relatively lower level of language domain knowledge and cognitive domain ability. This language processing requires less language activation or inhibition than expressive language processing, and thus consumes fewer resources (Mosca & de Bot, 2017). Additionally, based on the weak link hypothesis (Gollan et al., 2008), weak phonological representations in second language might be sufficient for meeting the task requirements of receptive vocabulary but insufficient for the task requirements of expressive vocabulary (Gibson et al., 2014b). In the context of language switching, target language activation and inhibitory control are low and insufficient for producing a moderating effect.

4.4. Limitations and implications

This study has some limitations that should be considered when interpreting the results. First, this study was cross-sectional, precluding the examination of causality or directionality. Future studies should examine developmental changes in this association. Second, we used a parent questionnaire to assess language switching frequency in children. However, the real-world complexity of bilingualism requires a more detailed assessment of the context and process of language switching, which can be considered as topics for future study (Blanco-Elorrieta & Pylkkanen, 2018). A study in which observational methods are used to assess both language switching in children and the amount of exposure to language switching performed by other people may produce helpful information. Third, we do not consider the direction of language switching (i.e., Mandarin to Uyghur and Uyghur to Mandarin). Distinguishing between these two types of language switching is important to link the relative strengths of both. Future research can further consider the frequency of the two switches.

Despite the limitations, this study significantly contributes to our understanding of how language experiences shape the development of inhibitory control in bilingual preschoolers. The study may have some practical implications. First, the findings can help us better understand the relationship between language switching frequency, language abilities, and inhibitory control in bilingual preschoolers, which in turn can help parents and educators create a more supportive environment for the cognitive development of children with different language abilities. Children with high language ability are less affected by language environment, while children with unbalanced or poor language ability may be more affected by their language environment. Language switching environment cannot simply be regarded as positive or negative. Children with different language abilities adapt to their environment in various ways, which can affect their cognition differently. Additionally, the findings suggest that expressive and receptive language abilities play different roles in the relationship between language switching frequency and inhibitory control. For bilingual children, ELA may utilize more complex cognitive processes, and thus may be superior to RLA as an indicator of general language ability in bilingual preschoolers.

5. Conclusion

This study investigated two aspects of language ability (ELA and RLA) in bilingual children, as well as the associations among language switching frequency, language ability (ELA and RLA), and inhibitory control. The findings suggest that only ELA plays a moderating role in the association between language switching frequency and inhibitory control in bilingual preschoolers. Specifically, language switching frequency was positively associated with inhibitory control in children with high Uyghur ELA and low Mandarin ELA, as well as children with low Uyghur ELA and high Mandarin ELA. Moreover, language switching frequency was negatively associated with inhibitory control in children with both low Uyghur and Mandarin ELA, but not significantly associated with inhibitory control in children with both high Uyghur and Mandarin ELA.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

Jin Chen: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Yiwei Zhao:** Validation, Writing – original draft. **Xinpei Xu:** Writing – review & editing. **Junsheng Liu:** Writing – review & editing, Supervision. **Ciping Deng:** Supervision, Project administration.

Data Availability

The authors do not have permission to share data.

Acknowledgments

This study has been supported by the STI 2030—Major Projects 2021ZD0200500. The authors would like to thank the children and their parents for participating in this study as well as all the experimenters' help in collecting data.

Appendix A. Language switching Frequency Questionnaire

1 Please indicate how often parents and family members engage in language switching with the child.

☐ Never ☐ Rarely ☐ Sometimes ☐ Frequently ☐ Always

2 Please indicate how often teachers communicate with the child using language switching.

☐ Never ☐ Rarely ☐ Sometimes ☐ Frequently ☐ Always

3 Please indicate how often friends engage in language switching with the child.

☐ Never ☐ Rarely ☐ Sometimes ☐ Frequently ☐ Always

The questionnaire consisted of three questions concerning language switching regarding children and their family members, teachers, and peers. Parents reported the language switching frequency at home (Item 1). Teachers reported the language switching frequency between teachers and the child at school (Item 2) and between the child and his/her classmates (Item 3). In the questionnaire, parents and teachers served as different information sources to help researchers evaluate the frequency of language switching instances encountered by the young children.

References

Abutalebi, J. (2008). Neural aspects of second language representation and language control. *Acta Psychologica (Amst), 128*(3), 466–478. 10.1016/j.actpsy.2008.03.014.

Abutalebi, J., Della Rosa, P. A., Ding, G., Weekes, B., Costa, A., & Green, D. W. (2013). Language proficiency modulates the engagement of cognitive control areas in multilinguals. *Cortex, 49*(3), 905–911. 10.1016/j.cortex.2012.08.018.

Abutalebi, J., & Green, D. (2008). Control mechanisms in bilingual language production: Neural evidence from language switching studies. *Language and Cognitive Processes, 23*(4), 557–582. 10.1080/01690960801920602.

Abutalebi, J., & Green, D. W. (2016). Neuroimaging of language control in bilinguals: Neural adaptation and reserve. *Bilingualism: Language and Cognition, 19*(4), 689–698. 10.1017/s1366728916000225.

Anderson, J. A. E., Mak, L., Keyvani Chahi, A., & Bialystok, E. (2018). The language and social background questionnaire: Assessing degree of bilingualism in a diverse population. *Behavior Research Methods, 50*(1), 250–263. 10.3758/s13428-017-0867-9.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660. 10.1111/j.1467-8624.2010.01499.x.

Blanco-Elorrieta, E., & Pylkkanen, L. (2018). Ecological validity in bilingualism research and the bilingual advantage. *Trends in Cognitive Sciences, 22*(12), 1117–1126. 10.1016/j.tics.2018.10.001.

Bonfieni, M., Branigan, H. P., Pickering, M. J., & Sorace, A. (2019). Language experience modulates bilingual language control: The effect of proficiency, age of acquisition, and exposure on language switching. *Acta Psychologica (Amst), 193*(2), 160–170. 10.1016/j.actpsy.2018.11.004.

Bronfenbrenner, U. and Morris, P.A. (2007). The bioecological model of human development. In *Handbook of child psychology* (eds W. Damon, R.M. Lerner and R.M. Lerner). doi:10.1002/9780470147658.chpsy0114.

Burrage, M. S., Ponitz, C. C., McCready, E. A., Shah, P., Sims, B. C., Jewkes, A. M., & Morrison, F. J. (2008). Age- and schooling-related effects on executive functions in young children: A natural experiment. *Child Neuropsychology, 14*(6), 510–524. 10.1080/09297040701756917.

Casado, A., Szewczyk, J., Wolna, A., & Wodniecka, Z. (2022). The relative balance between languages predicts the degree of engagement of global language control. *Cognition, 226*, Article 105169. 10.1016/j.cognition.2022.105169.

Chen, S., Lawrence, J. F., Zhou, J., Min, L., & Snow, C. E. (2018). The efficacy of a school-based book-reading intervention on vocabulary development of young Uyghur children: A randomized controlled trial. *Early Childhood Research Quarterly, 44*(3), 206–219. 10.1016/j.ecresq.2017.12.008.

Cheung, R. W., Hartley, C., & Monaghan, P. (2022). Receptive and expressive language ability differentially support symbolic understanding over time: Picture comprehension in late talking and typically developing children. *Journal of Experimental Child Psychology, 214*, Article 105305. 10.1016/j.jecp.2021.105305.

Costa, A., Pannunzi, M., Deco, G., & Pickering, M. J. (2017). Do bilinguals automatically activate their native language when they are not using it? *Cognitive Science, 41*(6), 1629–1644. 10.1111/cogs.12434.

Costa, A., & Sebastián-Gallés, N. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language, 50*(4), 491–511. 10.1016/j.jml.2004.02.002.

Curtin, S., Byers-Heinlein, K., & Werker, J. F. (2011). Bilingual beginnings as a lens for theory development: PRIMIR in focus. *Journal of Phonetics, 39*(4), 492–504. 10.1016/j.wocn.2010.12.002.

Dawson, J. F., & Richter, A. W. (2006). Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test. *Journal of Applied Psychology, 91*(4), 917–926. 10.1037/0021-9010.91.4.917.

Declerck, M., Kleinman, D., & Gollan, T. H. (2020). Which bilinguals reverse language dominance and why? *Cognition, 204*, Article 104384. 10.1016/j.cognition.2020.104384.

DeLuca, V., Rothman, J., Bialystok, E., & Pliatsikas, C. (2019). Redefining bilingualism as a spectrum of experiences that differentially affects brain structure and function. *Proceedings of the National Academy of Sciences of the United States of America, 116*(15), 7565–7574. 10.1073/pnas.1811513116.

Deng, C.-p., Liu, M., Wei, W., Chan, R. C. K., & Das, J. P. (2011). Latent factor structure of the Das-naglieri cognitive assessment system: A confirmatory factor analysis in a Chinese setting. *Research in Developmental Disabilities, 32*(5), 1988–1997. 10.1016/j.ridd.2011.04.005.

D'Souza, D., Brady, D., Haensel, J. X., & D'Souza, H (2020). Is mere exposure enough? The effects of bilingual environments on infant cognitive development. *Royal Society Open Science, 7*(2), Article 180191 180191. 10.1098/rsos.180191.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, &M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336–353. 10.1037/1528-3542.7.2.336.

Feldman, H. M. (2019). How young children learn language and speech. *Pediatrics in Review, 40*(8), 398–411. 10.1542/pir.2017-0325.

Fuhs, M. W., & Day, J. D. (2011). Verbal ability and executive functioning development in preschoolers at head start. *Developmental Psychology, 47*(2), 404–416. 10.1037/a0021065.

Gandotra, A., Cserjesi, R., Bizonics, R., & Kotyuk, E. (2021). Age differences in executive functions among Hungarian preschoolers. *European Journal of Developmental Psychology, 18*(5), 695–710. 10.1080/17405629.2020.1825289.

Garrett, P. B., & Baquedano-López, P. (2002). Language socialization: Reproduction and continuity, transformation and change. *Annual Review of Anthropology, 31*(1), 339–361. 10.1146/annurev.anthro.31.040402.085352.

Gibson, T. A., Peña, E. D., & Bedore, L. M. (2014a). The receptive-expressive gap in bilingual children with and without primary language impairment. *The Bimonthly American Journal of Speech-Language Pathology, 23*(4), 655–667. 10.1044/2014_AJSLP-12-0119.

Gibson, T. A., Peña, E. D., & Bedore, L. M. (2014b). The relation between language experience and receptive-expressive semantic gaps in bilingual children. *International* Journal of Bilingual Education and Bilingualism, *17*(1), 90–110. 10.1080/13670050.2012.743960.

Gibson, T. A., Peña, E. D., Bedore, L. M., & McCarter, K. S. (2020). A longitudinal investigation of the semantic receptive-expressive gap in Spanish-English bilingual children. *International Journal of Bilingual Education and Bilingualism, 25*(3), 819–833. 10.1080/13670050.2020.1721427.

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always a means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58*(3), 787–814. 10.1016/j.jml.2007.07.001.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1*(2), 67–81. 10.1017/S1366728998000133.

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology, 25*(5), 515–530. 10.1080/20445911.2013.796377.

Hartanto, A., & Yang, H. (2020). The role of bilingual interactional contexts in predicting interindividual variability in executive functions: A latent variable analysis. *Journal of Experimental Psychology: General, 149*(4), 609–633. 10.1037/xge0000672.

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. The Guilford Press. 10.1111/jedm.12050.

Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin & Review, 18*, 625–658. 10.3758/s13423-011-0116-7.

Hill, A. P., van Santen, J., Gorman, K., Langhorst, B. H., & Fombonne, E. (2015). Memory in language-impaired children with and without autism. *Journal of neurodevelopmental disorders, 7*(1), 19 -19. 10.1186/s11689-015-9111-z.

Ibbotson, P. (2022). *Language acquisition: The basics* (1st ed.). Routledge. 10.4324/9781003156536.

Jiao, L., Liu, C., Bruin, A., & Chen, B. (2020). Effects of language context on executive control in unbalanced bilinguals: An ERPs study. *Psychophysiology, 57*(11), e13653. 10.1111/psyp.13653.

Jiao, L., Zhang, Y., Plummer, P., Liu, C., & Chen, B. (2019). The influence of bilingual language experience on executive control: An ERPs study. *Journal of Neurolinguistics, 51*, 42–52. 10.1016/j.jneuroling.2018.12.002.

Kalamala, P., Szewczyk, J., Chuderski, A., Senderecka, M., & Wodniecka, Z. (2020). Patterns of bilingual language use and response inhibition: A test of the adaptive control hypothesis. *Cognition, 204*(1), Article 104373. 10.1016/j.cognition.2020.104373.

Kroll, J. F., Gullifer, J. W., McClain, R., Rossi, E., & Martín, M. C. (2015). Selection and control in bilingual comprehension and production. In J. W. Schwieter (Ed.), *The Cambridge handbook of bilingual processing* (pp. 485–507). Cambridge University Press. 10.1017/CBO9781107447257.021.

Lai, G., & O'Brien, B. A (2020). Examining language switching and cognitive control through the adaptive control hypothesis. *Frontiers in Psychology, 11*, 01171. 10.3389/fpsyg.2020.01171.

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology, 108*(3), 677–692. 10.1016/j.jecp.2010.11.001.

Li, C.J. (2018). *The effect of preschool bilingualism on executive function.* [Doctoral dissertation, East China Normal University]. China national knowledge infrastructure. https://kns.cnki.net/KCMS/detail/detail.aspx?filename=1018710600.nh&dbname=CDFDTEMP.

Liu, C., Yang, C. L., Jiao, L., Schwieter, J. W., Sun, X., & Wang, R. (2019). Training in language switching facilitates bilinguals' monitoring and inhibitory control. *Frontiers in Psychology, 10*, 01839. 10.3389/fpsyg.2019.01839.

Lu, L., & Liu, H. (2005). *Peabody picture vocabulary test-revised (Mandarin version)*. Psychological Publishing Co.

Luk, G., & Bialystok, E. (2013). Bilingualism is not a categorical variable: Interaction between language proficiency and usage. *Journal of Cognitive Psychology (Hove, England), 25*(5), 605–621. 10.1080/20445911.2013.795574.

Mang, M. L. (2003). A tentative study on the relationship between Sino-Tibetan language and Altaic languages. *Eurasian Studies*, (0), 211–256. https://kns.cnki.net/kcms/detail/detail.aspx?dbcode=ccjd&filename=oyxk200300011&dbname=ccjdlast2.

Marian, V., & Hayakawa, S. (2021). Measuring bilingualism: The quest for a "bilingualism quotient". *Applied Psycholinguist, 42*(2), 527–548 Suppl. 10.1017/s0142716420000533.

Mcclelland, M., Cameron, C., Connor, C., Farris, C., Jewkes, A., & Morrison, F. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*(4), 947–959. 10.1037/0012-1649.43.4.947.

Meuter, R. F. I., & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language, 40*(1), 25–40. 10.1006/jmla.1998.2602.

Monsell, S., Yeung, N., & Azuma, R. (2000). Reconfiguration of task-set: Is it easier to switch to the weaker task? *Psychological Research, 63*(3-4), 250–264. 10.1007/s004269900005.

Mosca, M., & de Bot, K. (2017). Bilingual language switching: Production vs. recognition. *Frontiers in Psychology, 8*(7), 934 -934. 10.3389/fpsyg.2017.00934.

Mücke, M., Ludyga, S., Colledge, F., Pühse, U., & Gerber, M. (2020). Association of exercise with inhibitory control and prefrontal brain activity under acute psychosocial stress. *Brain Sciences, 10*(7), 439. 10.3390/brainsci10070439.

Naglieri, J. A., & Das, J. P. (1997). *Cognitive assessment system*. Riverside Publishing.

Paap, K. R., Anders-Jefferson, R., Mason, L., Alvarado, K., & Zimiga, B. (2018). Bilingual advantages in inhibition or selective attention: More challenges. *Frontiers in Psychology, 9*, 01409. 10.3389/fpsyg.2018.01409.

Paap, K. R., Johnson, H. A., & Sawi, O. (2014). Are bilingual advantages dependent upon specific tasks or specific bilingual experiences? *Journal of Cognitive Psychology, 26*(6), 615–639. 10.1080/20445911.2014.944914.

Paap, K. R., Mason, L., & Anders-Jefferson, R. (2021). Predictions about the cognitive consequences of language switching on executive functioning inspired by the adaptive control hypothesis fail more often than not. *Brain Sciences, 11*(9), 1217. 10.3390/brainsci11091217.

Paap, K. R., Mason, L. A., Zimiga, B. M., Ayala-Silva, Y., Frost, M. M., Gonzalez, M., & Primero, L. (2019). Other language proficiency predicts unique variance in verbal fluency not accounted for directly by target language proficiency: Cross-language interference? *Brain Sciences, 9*(8), 0175. 10.3390/brainsci9080175.

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences, 36*(4), 329–347. 10.1017/S0140525X12001495.

Pliatsikas, C., Pereira Soares, S. M., Voits, T., Deluca, V., & Rothman, J. (2021). Bilingualism is a long-term cognitively challenging experience that modulates metabolite concentrations in the healthy brain. *Scientific Reports, 11*(1), 7090. 10.1038/s41598-021-86443-4.

Pluess, M., Assary, E., Lionetti, F., Lester, K. J., Krapohl, E., Aron, E. N., & Aron, A. (2018). Environmental sensitivity in children: Development of the highly sensitive child scale and identification of sensitivity groups. *Developmental Psychology, 54*(1), 51–70. 10.1037/dev0000406.

Ponitz, C. C., Mcclelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly, 23*(2), 141–158. 10.1016/j.ecresq.2007.01.004.

Ponitz, C. C., Mcclelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*(3), 605–619. 10.1037/a0015365.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879–891. 10.3758/brm.40.3.879.

Salwei, A. M., & de Diego-Lázaro, B. (2021). Does language make a difference? A study of language dominance and inhibitory control. *Frontiers in Psychology, 12*, Article 648100. 10.3389/fpsyg.2021.648100.

Sanchez-Azanza, V. A., López-Penadés, R., Aguilar-Mediavilla, E., & Adrover-Roig, D. (2020). Latent variable evidence on the interplay between language switching frequency and executive control in Spanish-Catalan bilinguals. *International Journal of Bilingualism, 24*(5-6), 912–930. 10.1177/1367006920902525.

Segalowitz, N., & Freed, B. F. (2004). Context, contact, and cognition in oral fluency acquisition: Learning Spanish in at home and study abroad contexts. *Studies in Second*

Language Acquisition, 26(2), 173–199. 10.1017/s0272263104262027.
Schieffelin, B., & Ochs, E. (1986). Language socialization. *Annual Review of Anthropology, 15*(1), 163–191. 10.1146/annurev.an.15.100186.001115.
Thanissery, N., Parihar, P., & Kar, B. R. (2020). Language proficiency, sociolinguistic factors and inhibitory control among bilinguals. *Journal of Cultural Cognitive Science, 4*(2), 217–241. 10.1007/s41809-020-00065-2.
Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences of the United States of America, 104*(30), 12530–12535. 10.1073/pnas.0609927104.
Timmer, K., Christoffels, I. K., & Costa, A. (2019). On the flexibility of bilingual language control: The effect of language context. *Bilingualism: Language and Cognition, 22*(3), 555–568. 10.1017/S1366728918000329.
Treffers-Daller, J., Ongun, Z., Hofweber, J., & Korenar, M. (2020). Explaining individual differences in executive functions performance in multilinguals: The impact of code-switching and alternating between multicultural identity styles. *Frontiers in Psychology, 11*(10), Article 561088. 10.3389/fpsyg.2020.561088.
Valian, V. (2015). Bilingualism and cognition. *Bilingualism: Language and Cognition, 18*(1), 3–24. 10.1017/S1366728914000522.
Verhagen, J., Mulder, H., & Leseman, P. P. M (2017). Effects of home language environment on inhibitory control in bilingual three-year-old children. *Bilingualism: Language and Cognition, 20*(1), 114–127. 10.1017/s1366728915000590.
Verreyt, N., Woumans, E., Vandelanotte, D., Szmalec, A., & Duyck, W. (2016). The influence of language-switching experience on the bilingual executive control advantage. *Bilingualism: Language and Cognition, 19*(1), 181–190. 10.1017/S1366728914000352.
Wang, Y.H. (2012). Equivalents of ancient chinese and turkic languages [*Doctoral dissertation*, NanKai University]. China national knowledge infrastructure. https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFD1214&filename=1013175122.nh.
Wechsler, D. (1974). *Wechsler intelligence scale for children* (Revised ed). The Psychological Corporation.
Williams, K. T., & Williams, K. T. (2007). *EVT-2: Expressive vocabulary test.* Pearson Assessments.
Yoshida, H., Tran, D. N., Benitez, V., & Kuwabara, M. (2011). Inhibition and adjective learning in bilingual and monolingual children. *Frontiers in Psychology, 2*, 1–14. 10.3389/fpsyg.2011.00210.
Zhou, J., Zhang, L., & &Min, L. B (2015). The relationship between bilingual semantic development and cognitive school readiness of Uygur children. *Journal of East China Normal University (Educational Sciences), 39*(2), 25–33. 10.16382/j.cnki.1000-5560.2015.02.004.