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The role of bilingual interactional contexts in predicting interindividual variability in executive functions: A latent variable analysis

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The Role of Bilingual Interactional Contexts in Predicting Interindividual Variability in Executive Functions: A Latent Variable Analysis

by

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Submitted to School of Social Sciences in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Psychology

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ABSTRACT

Despite a huge number of studies examining bilingual advantages in executive functions (EFs), the research findings with regards to the relations between bilingualism and EFs are mostly inconsistent and mixed. In order to shed light on these inconsistent findings, the current research aimed to tackle on both conceptual and methodological limitations that are prevalent in previous studies, namely: (a) failure to consider bilingual experiences in assessing bilingual advantages, and (b) task impurity due to substantial influence of non-EFs processes on EFs task performance. Based on Adaptive Control Hypothesis and Control Process Model of Code-switching, a theory-driven multisession study coupled with a latent variable approach was conducted to systematically examine the relations between bilingual interactional contexts and EFs, measured by nine different EFs tasks. The study found that dual-language context significantly predicted latent variable of task-switching, while dense code-switching context significantly predicted latent variable of inhibitory control and goal maintenance. The findings remained robust even taking into account potential confounds of demographics, socioeconomic status, intelligence, and unintended language-switching tendency. The current study identified bilingual interactional contexts as the key language experiences that could modulate the manifestation of bilingual advantages in EFs.

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CHAPTER 1: INTRODUCTION

Research in executive functions (EFs) – a multifaceted construct of higher-order cognitive processes that are responsible for controlling and regulating thought and action to achieve a goal (Miyake et al., 2000) – has established that EFs are important to just about every aspect of life across lifespan (Diamond, 2013). For example, higher EFs have been consistently linked with better outcomes in physical health (e.g., Crescioni et al., 2011; Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010; Riggs, Spruitz-Metz, Sakuma, Chou, & Pentz, 2010), mental health (Hartanto & Yang 2016a; Lawson et al., 2015; Paelecke-Habermann, Pohl, & Leplow, 2005), pre-academic skills (Fitzpatrick, McKinnon, Blair, & Willoughby, 2014; Shaul & Schwartz, 2014), school achievement (e.g., Bull, Espy, & Wiebe, 2008; Hartanto, Yang, & Yang, 2018; St Clair-Thompson & Gathercole, 2006), job success (e.g., Bailey, 2007; Fisher, Chaffee, Tetrick, Davalos, & Potter, 2017; Schmidt, Neubach, & Heuer, 2007), and even in social relationship (e.g., Eakin et al., 2004; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006).

Due to the importance of EFs, there are growing interests among researchers to identify modifiable experiential factors that could enhance one’s EFs, such as video gaming (e.g., Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green, Sugarman, Medford, Klobusicky, & Bavelier, 2012; Hartanto, Toh, & Yang, 2016) musical training (e.g., Moreno et al., 2011; Peretz & Zatorre, 2005), meditation (e.g., Gallant, 2016; Teper & Inzlicht, 2012) and physical exercise (e.g., Best, 2010; Hillman, Erikson, & Kramer, 2008). Among these experiential factors that have been linked with EFs, the relationship between the practices of using two or more languages (i.e., bilingualism) and EFs has received the most notable empirical attention (e.g., Bak, Long, Vega-Mendoza, & Sorace, 2016; Bialystok, Craik, & Luk, 2008; Carlson & Meltzoff, 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Hartanto, Toh, & Yang, 2018; Paap & Greenberg, 2013; Prior & Gollan, 2011; Yang & Yang, 2016). If EFs could be influenced by experiential factors, bilingualism is argued to be the prime candidate for such effects because speaking two languages is considered one of the most sustained cognitively intensive experience which humans can engage (Bialystok, 2017; Kroll & Bialystok, 2013; Marian & Shook, 2012),

Despite the huge interest in bilingual advantages in EFs, the research findings with regards to the relations between bilingualism and EFs are mostly inconsistent. Earlier studies have shown that bilinguals outperformed monolinguals in a number of tasks that tap into EFs such as Attention Network Test (e.g., Costa et al., 2009; Pelham & Abrams, 2014; Yang & Yang, 2016), Simon task (Bialystok, Martin, & Viswanathan, 2005; Poarch & van Hell, 2012), and color-shape switching task (Prior & Gollan, 2011; Prior & MacWhinney, 2010; Yang, Hartanto, Yang, 2017). In contrast, a number of recent studies failed to find any differences between bilinguals and monolinguals in similar EFs tasks with previous studies (de Bruin, Bak, & Della Sala, 2015; Paap & Greenberg, 2013). In order to shed light on these inconsistent findings, the current study aimed to tackle on both conceptual and methodological limitations that are prevalent in the previous studies, namely: (a) failure to consider bilingual experiences in assessing bilingual advantages (Yang, Hartanto, Yang, 2016a), and (b) task impurity due to substantial influence of non-EFs processes on EFs task performance (Friedman, 2016). Here, I employed a theory-driven approach based on Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process

Model of Code-switching (Green & Wei, 2014) to examine theoretical importance bilingual experiences that could influence EFs, coupled with a latent variable approach to address task impurity issue (Bollen, 2002).

EFs and Bilingualism

EFs involve an array of distinct higher-order cognitive abilities that are responsible for achieving goal directed behaviours. As a multidimensional construct, there are consensus among researchers that EFs consist of at least three core cognitive processes (Bull & Scerif, 2001; Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000; van der Ven, Kroesbergen, Boom, & Leseman, 2013). The first component is called inhibitory control, which involves the ability to override a strong internal predisposition or external distraction (Friedman & Miyake, 2004). The second component is task-switching, which refers to the ability to switch back and forth between multiple tasks, mental sets, and operations (Monsel, 2003). The third component is updating working memory representations, which is the ability to hold information in mind while mentally manipulating them (Smith & Jonides, 1999). Among these three core components of EFs, inhibitory control and task-switching have been often linked with bilingualism advantages, each with different mechanisms involves.

For inhibitory control, the mechanisms underlying the bilingual advantages is hypothesized due to active engagement of inhibitory control during bilingual language processing (Abutalebi & Green, 2008). The hypothesis is rooted from a well-established finding in psycholinguistic research that bilinguals constantly activated both of their languages when using only one of them (Hartanto & Suárez, 2016; Kroll, Dussias, Bogulski, & Valdes-Kroff, 2012;

Marian & Spivey, 2003; Van Heuven, Dijkstra, & Grainger, 1998; Von Studnitz & Green, 2002). Therefore, in order to ensure fluent language processing, bilinguals rely on inhibitory control to resist the intrusions from the unwanted language (Abutalebi & Green, 2008; Green, 1998). The constant practice of resisting language intrusion is argued to tune bilinguals' inhibitory control mechanisms over time, resulting bilingual advantages over monolingual when performing tasks that require resisting to distractor interference (Green & Abutalebi, 2013).

Different from inhibitory control, the mechanisms underlying the bilingual advantages in task-switching is hypothesized to be driven by the practices of language-switching (Prior & MacWhinney, 2010; Prior & Gollan, 2011). The bilingual task-switching advantages hypothesis is based on the recent findings that language-switching and task-switching have at least partially overlapped neurocognitive mechanisms (De Baene, Duyck, Brass, & Carreiras, 2015; Weissberger, Wierenga, Bondi, & Gollan, 2012). For instance, Weissberger and colleagues (2012) found that language-switching and task-switching exhibit similar patterns of age-related cognitive decline in old adults. Similarly, De Baene and colleagues observed that highly proficient bilinguals recruited similar brain circuits when performing a language-switching task and a task-switching task. Due to the shared mechanisms underlying language-switching and task-switching, the practices of language-switching in bilinguals are expected to tune their efficiency in engaging task-switching.

Despite the theoretical predictions in favor of bilingual advantages in inhibitory control and task-switching, research findings from the comparison between bilinguals and monolinguals in tasks measuring inhibitory control and task-switching abilities were mostly inconsistent and mixed (for a review see Paap, Johnson, & Sawi, 2015). For example, although previous studies have found that bilinguals outperformed monolinguals in tasks measuring inhibitory control, such as Simon task (e.g., Bialystok, 2006; Bialystok, Craik, Klein, & Viswanathan, 2004; Martin-Rhee & Bialystok, 2008), antisaccade task (e.g., Bialystok, Craik, & Ryan, 2006; Bialystok & Viswanathan, 2009), and Attention Network Test (e.g., Costa et al., 2009; Pelham & Abrams, 2014; Yang & Yang, 2016), there were also studies that failed to find any differences between bilinguals and monolinguals in those inhibitory control tasks (e.g., Antón, García, Carreiras, & Duñabeitia, 2016; Kirk, Fiala, Scott-Brown, & Kempe, 2014; Paap & Greenberg, 2013). Similarly, a number of recent studies failed to find any differences in task-switching performances between bilinguals and monolinguals (e.g., Hernández, Martin, Barceló, & Costa, 2013; Paap & Greenberg, 2013; Mor et al., 2015), despite earlier studies reported more efficient task-switching performances in bilinguals than monolinguals (e.g., Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Prior & Gollan, 2011; Prior & MacWhinney, 2010). These findings are in line with recent meta-analyses that showed the advantages of bilinguals over monolinguals in EFs were significant yet highly heterogenous (Adesope, Lavin, Thompson, & Ungerleider, 2010; de Bruin, Treccani, & Della Sala, 2015; Donnelly, Brooks, & Homer, 2015; Von Bastian, Simoni, Kane, Carruth, & Miyake, 2017). The heterogeneity in the previous studies suggests a need to conduct more empirical studies to address existing limitations that contribute to the mixed findings.

The Importance of Bilingual Interactional Context

One critical limitation that is often argued to contribute to the mixed findings is the failure to consider bilingual experiences in assessing bilingual advantages in EFs (Bak, 2015; Woumans & Duyck, 2015; Yang, Hartanto, Yang, 2016a, 2016b). Most studies that examined bilingual advantages in executive functions tend to rely on the comparison between a heterogenous bilingual group and a monolingual control group (Yang, Hartanto, & Yang, 2016b). However, the reliance of using a heterogenous bilingual group ignores the fact that bilingualism is a multidimensional construct that consists of various dual-language experiences (Luk & Bialystok, 2013; Surrain & Luk, 2017). As the practice of demanding dual-language experience is the key factor responsible for tuning bilinguals' executive functions (Green & Abutalebi, 2013), not all bilinguals are expected to gain executive functions advantages due to their variations in engaging demanding dual-language experiences. In light of the importance of demanding dual-language experience, recent studies have started to investigate various bilingual experiences that might moderate the manifestation of bilingual advantages in executive functions (e.g., Hartanto & Yang, 2016b, 2018). One of the most promising dual-language experience that has been theoretically predicted to influence individual differences in executive functions is bilingual interactional context (Green & Abutalebi, 2013; Green & Wei, 2014; Yang, Hartanto, & Yang, 2016).

According to Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model of Code-switching (Green & Wei, 2014), bilinguals' interactional contexts of conversational exchange place different demands on their language control, which in turns adaptively modulate their executive functions system. The model identifies three distinct interactional contexts – single-language context, dual-language context, and dense code-switching context. The single-language context occurs when bilinguals use one language in one situation (e.g., home) and the other language in a second distinct situation (e.g., school). In the single-language context, language-switching is rare because bilinguals are expected to speak only one language. In contrast, both dual-language context and dense code-switching contexts involve the use of two languages in the same context (e.g., using both English and Mandarin at home and school), which require the speakers to switch between languages during their daily conversation. However, both of the contexts differ in their language-switching practices. In the dense code-switching context, the speakers routinely mix their languages in the course of single utterance. On the other hand, language-switching in dual-language context occurs mostly when switching between speakers and sentences but not within an utterance.

Due to the different degree and type of language-switching associated with each interactional context, the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and the Control Process Model of Code-switching (Green & Wei, 2014) postulate that each interaction context exerts different demands and consequences on executive functions. For instance, the adaptive control hypothesis proposes that the demands on opportunistic planning – “the ability to making use of whatever comes most readily to hand in order to achieve a goal (Green & Abutalebi, p. 519)” – are highest in dense code-switching context because speakers in dense code-switching context are able to plan their speech opportunistically by mixing language within utterances. In contrast, the demands on goal maintenance, interference suppression, salient cue detection, selective response inhibition, task engagement and task disengagement processes are highest in dual-language context than single-language context and dense code-switching context (see Table

1 for the summary control processes that are required in different interactional contexts). This is because language processing in dual-language context requires not only constantly monitoring the appropriateness of their language usage and inhibiting the interference from the activation of nontarget language, speakers in dual-language context are also required to prepare and switch their languages interchangeably when necessary. As these processes implicate most of the core components of EFs, the higher cognitive demands in dual-language context bilinguals could adaptively enhance their EFs system in comparison to single-language context and dense code-switching context bilinguals. Indeed, a recent seminal study by Hartanto and Yang (2016b) found that dual-language context bilinguals who reported to use two languages interchangeably in one situation had more efficient task-switching performance in color-shape switching task than bilinguals who reported to speak only one language in one situation. The advantages of dual-language context bilinguals over single-language context bilinguals in task-switching were still significant after controlling for the frequency of intra-sentential code-switching.

Table 1. *Language Control Demands in Different Types of Interactional Contexts as Postulated by Adaptive Control Hypothesis*

	Interactional Contexts		
Control Processes	Single language	Dual language	Dense code-switching
Goal maintenance	+	+	=

Interference control (conflict monitoring and interference suppression)	+	**+**	=
Salient cue detection	=	+	=
Selective response inhibition	=	+	=
Task disengagement	=	+	=
Task engagement	=	+	=
Opportunistic planning	=	=	+

Note. + indicates higher demands on the language control process in that particular bilingual interactional context relative to demands on the language control process in a monolingual context. The bolded symbol indicates more demands on the language control process than the nonbolded symbol. = indicates similar demands on the language control process in that particular bilingual interactional context relative to demands on the language control process in a monolingual context. Adapted from Green and Abutalebi (2013).

Although the recent finding by Hartanto and Yang (2016b) demonstrates the importance of considering bilingual interactional context in its relation to EFs, the conclusion is still premature due a number of research gaps that have not been addressed yet. First, the relationship between dense code-switching context and EFs have not been well examined since the study by Hartanto and Yang only focused on dual-language context and single-language context. As identified by the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and the Control Process Model of Code-switching (Green & Wei, 2014), dense code-switching context should be considered as another important interactional context that may influence EFs. Second, the operationalization of dual-language context in the study by Hartanto and Yang (2016b) could be confounded by dense code-switching context. In the study by Hartanto and Yang, dual-language context was operationalized by the frequency of the bilinguals speak two or more languages interchangeably within the same situation in general. As a result, this operationalization may not be able to fully distinguish between dual-language context and dense code-switching context because both contexts involve using two languages in the same situation. Even when intrasentential code-switching was controlled in the Hartanto and Yang's analyses, the complexity of dense code-switching may not be fully captured by the mere frequency of intrasentential code-switching (see Green & Li, 2014 for a review). Lastly, it is still unclear whether bilingual interactional context could influence other component of EFs, such as inhibitory control and working memory, since Hartanto and Yang's study only measured task-switching. Taken together, it is critical for future study to take into account the whole dimensionality of bilingual interaction contexts and EFs in examining their relationships.

Task Impurity in EFs

Another critical limitation of the previous studies that has not been addressed is the failure to address task impurity issues when examining the relations between bilingualism and EFs. Research in EFs has consistently observed low inter-correlations among EFs tasks even when the tasks are designed to tap into the same core component of EFs (Miyake et al., 2000). The low inter-correlations are well-expected because every EFs tasks involve non-EFs processes (Burgess, 1997; Hughes & Graham, 2002; Jurado & Rosselli, 2007). For instance, Stroop task involves the ability to inhibit the tendency to read the incongruent color word name and a number of non-EFs processes such as reading ability and color discrimination ability. Similarly, variation in flanker task performance is influenced not only by the ability to inhibit distractions from surrounding flankers but also the ability to discriminate arrow direction. As a result, each EFs task involve domain-general EFs processes and task-specific non-EFs processes – an issue that is commonly referred to as task-impurity in EFs research (Miyake et al., 2000).

The task impurity is often considered as one important factor that contributes to the inconsistent findings in the bilingualism literature (Friedman, 2016; Paap, Johnson, & Sawi, 2015; Paap, 2014; Valian, 2015). It is problematic in bilingual advantages research because any relations between bilingualism and performance in EFs task could be confounded by task-specific non-EFs processes. As a result, the task impurity may not only produce spurious effect that is driven by task-specific non-EFs processes but also suppress any genuine effects, because a specific EFs task may not capture much variance related to the EFs of interest. The issue is further exacerbated by the fact that most of the previous studies employed a single measure of EFs when examining their relations to bilingualism (e.g., Bialystok et al., 2004; Costa et al., 2009; Prior & Gollan, 2011; Yang, & Yang, 2016; see Paap et al., 2015 for a review). Taken together, in order to reconcile the mixed findings in the bilingualism literature, it is critical for studies to use more extensive EFs batteries and advanced methodologies that can maximize the variance of the EFs of interest and rule out the concern that any obtained bilingual advantages in EFs is task specific.

Current Study

With these conceptual and methodological issues in mind, the current study aimed to reconcile the mixed findings in the bilingualism literature by employing the following. First, to identify key bilingual language experience that could moderate the manifestation of bilingual advantages in EFs (Yang, Hartanto, & Yang, 2016b), I examined various bilingual interactional contexts and their relations to EFs with a theoretically driven approach based on the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and the Control Process Model of Code-switching (Green & Wei, 2014). Aiming to address the limitations of Hartanto and Yang (2016b), the current study simultaneously examined all three distinct interactional contexts as postulated by the Adaptive Control Hypothesis and distinguished clearly the conceptual differences between dual-language context and dense code-switching context. The current study also refined the existing measure of bilingual interactional context (Hartanto & Yang, 2016b) by taking into account two possible source of intra-individual variations in bilingual interactional context, including inter-situation variations of the bilingual interaction context (e.g., an individual who has a home environment that resemble dual-language context and a school environment that resemble single-language context) and intra-environment variations of the bilingual interaction context (e.g., an individual who has a home environment that engage in either dual-language context and single-language context at different times).

Second, in order to test different prediction of adaptive control hypothesis as a function of EFs' core components, the current study was designed to holistically assess all core aspects of EFs based three-factors unity and diversity model of EFs proposed by Miyake et al. (2000). The three-factors model consists of inhibitory control, task-switching, and working memory. The holistic approach allows the current study to examine whether the relations between bilingual interactional contexts and EFs could be expanded beyond task-switching to inhibitory control and working memory. In addition to the three-factors model, the current study also aimed to examine the predictability of bilingual interactional contexts on goal maintenance, which is a form of proactive control process that involves sustained active maintenance of task goals necessary for optimizing cognitive performance (Braver, 2013), as another component of EFs. Here, goal maintenance was measured by well-established mixing costs in task-switching paradigm that has been shown to arise from failure in proactive goal maintenance processes (Braver, Reynolds, & Donaldson, 2003; Bugg & Braver, 2015; De Jong, 2001). The investigation on goal maintenance is important because the Adaptive Control Hypothesis has predicted differential engagement in goal maintenance processes in each type of bilingual interactional context.

Third, the current study employed a latent variable approach to address the issue of task impurity and increase reliability in EFs tasks. In the latent variable approach, common variance among multiple EFs tasks that measure the same underlying construct (e.g., task-switching) is extracted statistically (Bollen, 2002). By extracting the common variance, the latent variable approach excludes idiosyncratic non-EFs processes in each EFs task and provide a purer measure of EFs construct. Moreover, the latent variable approach increases the reliability of EFs tasks because measurement error can be excluded after the extraction of common variance. Following the approach by Miyake et al. (2000), each core components of EFs (inhibitory control, task-switching, working memory) was measured separately in three different tasks.

Based on Adaptive Control Hypothesis (Green & Abutalebi, 2013) and the Control Process Model of Code-switching (Green & Wei, 2014), four hypotheses were proposed. First, I hypothesized that bilinguals with higher exposure to dual-language context would perform better in all aspect of EFs – including inhibitory control, task-switching, working memory, and goal maintenance – than bilinguals with higher exposure to single-language context and dense code-switching context. The first hypothesis was based on the neurolinguistics evidence that bilinguals in dual-language context are required to engage in heightened control processes in inhibitory control, task-switching, and goal maintenance (Green & Abutalebi, 2013; Green & Wei, 2014). For working memory, while the models did not specifically discuss the role of working memory in bilingual interactional contexts, higher working memory in dual-language contexts bilinguals were expected because working memory has been found to implicate goal maintenance and inhibitory control processes (Engle, 2002; Kane & Engle, 2003; Meier, Smeekens, Silvia, Kwapil, & Kane, 2018). Second, I hypothesized that bilinguals with higher exposure to single-language context would exhibit better inhibitory control and goal maintenance than bilinguals with higher exposure to dense code-switching context. The hypothesis is consistent with the theoretical prediction that language usage in single-language context bilinguals require higher demands of inhibitory control and goal maintenance than dense code-switching context, because the former context requires inhibitory control and goal maintenance to minimize inappropriate switching between languages. Third, I hypothesized that bilinguals in single-language context and dense code-switching context would not differ in task-switching and working memory because both contexts require less demands in task-switching and working memory. Lastly, I hypothesized that the predicted relations between bilingual interactional contexts and EFs would be evident even after controlling for potential confounds, such as socioeconomic status (SES) and immigrant status (Hartanto & Yang, 2018; Paap et al., 2015; Valian, 2015)

CHAPTER 2: METHOD

Participants

Young adult bilinguals (*N* = 175) from a local university in Singapore were recruited for either extra course credit or $30. All of the bilinguals were active bilinguals and speak at least two of the four official languages in Singapore (i.e., Chinese, English, Malay, and Tamil). In addition to English, majority of bilingual participants spoke Chinese (*n* = 165), followed by Malay (*n* = 7), and Tamil (*n* = 3). The constraint on Singapore official languages was done to ensure that dense code-switchers in the current study are comparable in terms of the type of dense code-switching in which the bilinguals practice in their daily life. This is because Singapore bilinguals speak a unique English-based creole language that resemble dense code-switching context, “Singlish,” which has been substantially influenced by loan words from Mandarin, Malay and Tamil (Wong, 2004). Passive bilinguals, who reported that they never actively used both languages in their daily lives or has 0% of second language exposure or usage, were also not considered in the current study because they did not fit to any of the bilingual interactional contexts characteristics. The demographic and language characteristics of the bilinguals, along with their associations with each type of the bilingual interactional context, are presented in the Table 1 and Table 2.

Table 2. *Descriptive and Correlation Matrix for Bilingual Interactional Context, Demographic and Intelligence*

	M	SD	1	2	3	4	5	6	7	8	9
1. Single-language context (%)	52.2%	-									
2. Dual-language context (%)	22.7%	-	**-.63**								
3. Dense-code switching context (%)	25.1%	-	**-.76**	-.03							
4. Age	21.59	1.83	-.12	.15	.03						
5. Gender (% of male)	34%	-	.05	-.02	-.04	**.58**					
6. Household income[1]	3.94	2.29	.11	**-.19**	.01	**-.31**	-.14				
7. Subjective socioeconomic status[2]	5.96	1.50	-.07	.06	.03	.04	.07	.14			
8. KBIT-2 (IQ)	106.39	16.04	-.04	.01	.04	.08	.11	.05	-.02		
9. PPVT-III	100.05	7.79	**.19**	**-.20**	-.08	**-.15**	.07	**.24**	-.03	**.32**	

Note. Bolded values are significant ($p < .05$). KBIT-2 = Kaufman Brief Intelligence Test 2nd Edition.

PPVT-III = Peabody Picture Vocabulary Task 3rd Edition.

[1] Household income was rated on a scale of 1 (less than S$2500) to 9 (more than S$20,000), with intervals of S$2500.

[2] Subjective social status was measured by using a ladder scale (1st rung = lowest, 10th rung = highest; Adler et al., 2000)

Table 3. *Descriptive and Correlation Matrix for Bilingual Interactional Context and Language Characteristics*

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Single-language context (%)	52.2%	-													
2. Dual-language context (%)	22.7%	-	**-.63**												
3. Dense-code switching context (%)	25.1%	-	**-.76**	-.03											
4. Age of L2 acquisition	1.08	2.09	-.05	-.03	.00										
5. Age of L2 fluency	9.70	4.52	-.03	.07	.04	**.30**									
6. L1 Exposure (%)	65.10	21.65	**.34**	**-.36**	-.13	-.05	.04								
7. L2 Exposure (%)	31.95	21.10	**-.28**	**.33**	.08	.06	-.04	**-.95**							
8. L1 Usage (%)	67.60	23.99	**.36**	**-.37**	**-.18**	-.06	.02	**.92**	**-.88**						
9. L2 Usage (%)	30.59	23.64	**-.32**	**.33**	.13	.06	-.02	**-.89**	**.92**	**-.97**					
10. L1 speaking proficiency	8.29	1.43	.08	-.06	-.05	.08	.06	**.42**	**-.45**	**.41**	**-.43**				
11. L2 speaking proficiency	6.86	1.75	**-.26**	**.42**	.13	-.05	**-.23**	**-.54**	**.51**	**-.54**	**.53**	.07			
12. L1 comprehension proficiency	8.47	1.39	.13	-.10	-.03	.03	.06	**.40**	**-.43**	**.40**	**-.41**	**.89**	.04		
13. L2 comprehension proficiency	7.29	1.85	**-.26**	**.28**	.10	-.05	**-.21**	**-.42**	**.40**	**-.42**	**.43**	.09	**.82**	.14	

Note. Bolded values are significant ($p < .05$). Value of two participants in age of L2 fluency was missing

Materials

Language background questionnaire. Language background questionnaire –adapted from the Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) and the Language History Questionnaire (Li, Zhang, Tsai, & Puls, 2014) – were administered to assess participants' language background, including age of acquisition, language proficiency, language usage, and language exposure.

Revised Bilingual interactional context questionnaire. Bilingual interactional context questionnaire – revised from Hartanto and Yang (2016b) – were administered to measure variations of interactional contexts in each bilingual. The questionnaire requires participants to report the prevalence of each type of bilingual interactional context, as identified by Green and Abutalebi (2013), across four different situations including home, school, work, and others (refer to Appendix A). Participants indicated in percentage whether their daily conversation exchange in each situation (home, school, work, and others) resemble more single-language context (e.g., *I speak only one language and rarely switch to other language* at home), dual-language context (e.g., *I speak two (or more languages) when I converse with different speakers at home. I often switch languages but I rarely mixing languages within an utterance*), or dense code-switching context (*I routinely mix two (or more) languages within an utterance to most speakers at home*). The total percentage of all bilingual interactional contexts in each situation must be 100%. Participants also reported the percentage of time they spent at home, school, work, and in other situations. Indexes of single-language context, dual-language context, and dense conde are calculated to estimate the prevalence of each type of bilingual interactional context in each participant by using the following formula:

single-language context index = $\sum_{i=4}^{4} \frac{p_i \times sl_i}{100}$

dual-language context index = $\sum_{i=4}^{4} \frac{p_i \times dl_i}{100}$

dense code-switching context = $\sum_{i=4}^{4} \frac{p_i \times dc_i}{100}$

where p_i is the amount of time spent in each situation, sl_i is the percentage of single-language context within a particular situation, dl_i is the percentage of dual-language context within a particular situation, and dc_i is the percentage of dense code-switching context within a particular situation.

Modified arrow flanker task. The modified arrow flanker task was administered as one of the three measures of inhibitory control. In the modified arrow flanker task, a row of five arrows was presented on the middle of the screen, either pointing toward left or right. The central target arrow was flanked by four surrounding arrows pointing toward either the same direction (congruent condition) or the opposite direction (incongruent condition). Participants were instructed to identify the direction in which the central target arrow is pointed as quickly and accurately as possibly by pressing either “f” or “j” on the keyboard for left and right, respectively.

In each trial, a fixation point was presented first for 350 ms in the middle of the screen, followed by the presentation of the central arrow and the surrounding arrows. Participants were required to respond within a 2,000 ms response window. After participant respond to the stimulus, a blank screen appeared for 250 ms before the start of the next trial. In half of the trials, the central target arrow pointed in the same direction along with the surrounding arrows (congruent condition), while the central target arrow pointed in the opposite direction of the surrounding arrows in another half of the trials (incongruent condition). In order to increase the task demand, the central target arrow was significantly displaced toward either the left or right side of the screen in the 15% of the trials (vigilance condition). When the central target arrow was displaced, participants were instructed to press “spacebar” to respond accurately regardless the direction of the central target arrow. In total, there were 85 congruent trials, 85 incongruent trials, and 30 vigilance trials.

Modified Eriksen flanker task. The modified Eriksen flanker task was administered as one of the three measures of inhibitory control. In the modified Eriksen flanker task, a row of alphabets – of either G or H – was presented in the middle of the screen. The central target alphabet was surrounded by four similar alphabets (congruent condition) or four different alphabets (incongruent condition). Participants were instructed to identify the central target alphabet as quickly and accurately as possibly by pressing either “g” or “h” on the keyboard for G and H, respectively.

Similar to the modified arrow flanker task, a fixation point was presented first for 350 ms on the middle of the screen in each trial. The fixation point was followed by the presentation of the central target alphabet and the surrounding alphabets. Participants were required to respond within a 2,000 ms response window, followed by a blank screen for 250. In half of the trials, the central target alphabet was the same as the surrounding alphabets (congruent condition), while the central target alphabet was different from the surrounding alphabets in another half of the trials (incongruent condition). Moreover, the central target alphabet was significantly displaced toward either the left of right side of the screen in the 15% of the trials (vigilance condition). Participants were required to press "spacebar" to respond accurately regardless whether the central target alphabet was a "G" or "H" in the vigilance condition. In total, there were 85 congruent trials, 85 incongruent trials, and 30 vigilance trials.

Modified color flanker task. The modified color flanker task was administered as one of the three measures of inhibitory control. In the modified color flanker task, a row of colored square box – in either red color or green color – was presented in the middle of the screen. The central target box was surrounded by four boxes with similar color (congruent condition) or four boxes with distinct color (incongruent condition). Participants were instructed to identify the color of the central target box as quickly and accurately as possibly by pressing either "g" or "r" on the keyboard for green and red colors, respectively.

In each trial, a fixation point was presented first for 350 ms on the middle of the screen. The fixation point was followed by the presentation of the central target colored box and the surrounding colored boxes and participants were required to respond within a 2,000 ms response window. Subsequently, a blank screen appeared for 250 ms before the transition to the next trial. In half of the trials, the central target box had the same color as the surrounding boxes (congruent condition), while the central target box had distinct color from the surrounding boxes in another half of the trials (incongruent condition). Moreover, the central target box was significantly displaced toward either the left of right side of the screen in the 15% of the trials (vigilance condition). When the central target box was displaced, participants were required to press “spacebar” regardless whether the central target box was in red or green colors. In total, there were 85 congruent trials, 85 incongruent trials, and 30 vigilance trials.

Color-shape switching task. The color-shape switching task – adapted from an established task-switching paradigm (Hartanto & Yang, 2016b; Rubin & Meiran, 2005) – was administered as one of the three measures of task-switching and goal maintenance. In the color-shape switching task, participants were required to respond as fast and accurately as possible to either the color (red or green) or shape (circle or triangle) of the bivalent target stimulus according color or shape cues. The color cue was represented by a color gradient and the shape cue was represented by a row of small black shapes. The bivalent target stimulus in the color-shape switching task was either red triangle or a green circle. Participants were required to identify the target stimulus based on the color when a color cue was presented and identify the target stimulus based on the shape when a shape cue was presented. Participants were instructed to use their left index finger to press “d” to indicate red or a circle and use their right index finger to press “k” to indicate green or a triangle.

In each trial, participants were presented with a fixation point for 350 ms, followed by a blank screen for 150ms. Subsequently, the cue appeared on above the fixation point and remained on the screen for the whole trial. After 250 ms, the target stimulus appeared on the centre of the screen until the participants responded. Following the response, a blank screen appeared for 850 ms before the onset of the next trial.

Participants completed four single-task blocks (block that only incorporates one type of cue, either color or shape) and four mixed-tasks block (block that incorporate both color and shape cues) that were arranged in a sandwich-like design. In the sandwich-like design, participants first completed two single-task blocks (one with pure color trials and another with pure shape trials) with 8 practice trials and 20 main trials in each block. Subsequently, participants completed 16 mixed-tasks practice trials, followed by 4 mixed-task blocks that consisted of 41 trials in each block. In the mixed-task block, half of the trials were switch trials, where participants were required to switch between task because the previous trial and the current trial had different type of cue. Another half of the trials were repeat trials, where participants were not required to switch between task because the previous trial and the current trial had the same type of cue. Each type of trials was randomly ordered in the mixed-task block with a maximum of 4 consecutive trials. The first trial in each of the mixed-task block will be excluded since the trial will not fit with either switch or repeat trial. Lastly, participants completed the remaining two single-task blocks that will be presented in an opposite order from their first and second single-task block. In total, there were 80 switch trials, 80 repeat trials, and 80 single-task trials (40 pure color trials and 40 pure shape trials).

Magnitude-parity switching task. The magnitude-parity switch task – adapted from von Bastian, Souza, and Gade (2016) – were administered as one of the three measures of task-switching and goal maintenance. In the magnitude-parity switching task, participants were required to classify a bivalent target digit to either the parity (odd or even) or magnitude (greater or smaller than 5) according to parity or magnitude cues. The parity cue was represented by an image that consisted of one row of odd-numbered blue squares and one row of even-numbered yellow squares. The magnitude cue was represented by an image that consisted of one row of big blue circles and small yellow circles. The bivalent target digit in the parity-magnitude switching task was either 2 (an even number digit that is less than 5) or 7 (an odd number digit that is more than 5). Participants were required to indicate whether the bivalent target digit is either odd or even when they were presented with the parity cue. When they were presented with the magnitude cue, they were required to indicate whether the target digit number is either smaller than 5 or greater than 5. Participants were instructed to use their left index finger to choose 3 (by pressing “d” on the keyboard) to indicate odd or smaller than 5 and use their right index finger to choose 8 (by pressing “k” on the keyboard) to indicate even or greater than 5.

In each trial, participants were presented with a fixation point for 350 ms, followed by a blank screen for 150ms. Subsequently, the cue appeared on above the fixation point and remained on the screen for the whole trial. After 250 ms, the target stimulus appeared on the centre of the screen until the participants responded. Following the response, a blank screen appeared for 850 ms before the onset of the next trial.

Participants completed four single-task blocks and four mixed-tasks block that were arranged in the sandwich-like design similar to the color-shape switching task. In total, there were 80 switch trials, 80 repeat trials, and 80 single-task trials (40 pure parity trials and 40 pure magnitude trials).

Animacy-locomotion switching task. The animacy-locomotion task was administered as one of the three measures of task-switching and goal maintenance.

In the animacy-locomotion switching task, participants were required to classify a bivalent target stimulus based on their animacy (living or non-living) or locomotion (flying or non-flying) according to animacy or locomotion cues. The animacy cue was represented by an image consists of dog paws and bones while the locomotion cue was represented by an image of a scenery with roads and blue sky. The target stimulus in the animacy-locomotion switching task was either a plane (a flying non-living entity) or rabbit (a non-flying living entity). Participants were required to indicate whether the target stimulus is either living or non-living entity when they were presented with the animacy cue. When they were presented with the locomotion cue, they are required to indicate whether the target stimulus is either flying or non-flying entity. Participants were instructed to use their left index finger to choose a bird response key (by pressing "d" on the keyboard) to indicate living or flying and use their right index finger to choose a car response key (by pressing "k" on the keyboard) to indicate non-living or non-flying.

In each trial, participants were presented with a fixation point for 350 ms, followed by a blank screen for 150ms. Subsequently, the cue appeared on above the fixation point and remained on the screen for the whole trial. After 250 ms, the target stimulus appeared on the centre of the screen until the participants responded. Following the response, a blank screen appeared for 850 ms before the onset of the next trial.

Participants completed four single-task blocks and four mixed-tasks block that were be arranged in the sandwich-like design similar to color-shape switching task and magnitude-parity switching task. In total, there were 80 switch trials, 80 repeat trials, and 80 single-task trials (40 pure animacy trials and 40 pure locomotion trials).

Rotation span task. The rotation span task – adapted from Foster et al. (2014) – was administered as one of the three working memory measures. In the rotation span task, participants first judged whether a rotated letter is presented correctly. After the response, participants were presented with an arrow of either short or long pointed toward one of eight different directions appeared. Participants were instructed to remember both the length and the direction of the arrow. The rotated letter problem and arrow sequence were repeated from two to five times for each trial with unpredictable length. Working memory performance were measured by partial-credit unit (PCU) score, which was calculated by the proportion of the total number of correct arrow recall divided by the total number of arrows to remember (Conway et al., 2005).

Operation span task. The operation span task – adapted from Foster et al. (2014) – was administered as one of the three working memory measures. In the operation span task, participants first solved a simple mathematical problem. After the response, participants were presented with a to-be-remembered letter. The sequence of the mathematical problem and the to-be-remembered letter were repeated from two to five times for each trial with unpredictable length. Working memory performance was calculated by the proportion of the total number of correct letters recall divided by the total number of letters to remember (PCU method).

Symmetry span task. The symmetry span task – adapted from Foster et al. (2014) – was administered as one of the three working memory measures. In the symmetry span task, participants first judged whether a displayed shape is symmetrical along its vertical axis. Subsequently, a red square appeared in a 4x4 grid and participants were instructed to remember the location of the red square.

The sequence of the symmetry shape problem and the to-be-remembered red square location were repeated from two to five times for each trial with unpredictable length. Working memory performance was calculated by the proportion of the total number of correct red square location recall divided by the total number of the red square location to remember (PCU method).

Kaufman Brief Intelligence Test 2nd Edition (KBIT-2). The KBIT-2 matrices subtest (Kaufman & Kaufman, 2004) was administered to assess participants' nonverbal fluid intelligence. In this task, participants were presented with a series of images representing either the drawing of concrete objects or abstract figures and were asked to complete visual analogies of the target stimulus. The KBIT-2 provides age-normed standardized scores with a mean of 100 and a standard deviation of 15.

Peabody Picture Vocabulary Task 3rd Edition (PPVT-III). The PPVT-III (Dunn & Dunn, 1997) was administered to assess participants' English receptive vocabulary. In this task, participants were presented with four pictures and asked to choose the correct the correct picture based on the question. The PPVT-III provides age-normed standardized scores with a mean of 100 and a standard deviation of 15.

Bilingual switching questionnaire. Bilingual switching questionnaire (Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman, & Münte, 2012) was administered to assess unintended language switching tendency that is not explained by sociolinguistic or linguistic factors. Participants rated the degree to which a behavior characterized their language switching habits (e.g., "I do not realize when I switch the language during a conversation," "It is difficult for me to control the languages switches I introduce during a conversation") on a five-point Likert scale (1=never, 5=always; α=.69) in three items.

Procedure

The experiment was conducted in a computer lab across three separate sessions in three different days to minimize fatigue effect. In the first session, participants were seated individually in an open cubicle after which they were asked to sign an informed consent form. Then, participants completed questionnaires related to demographics, language background, and bilingual interactional context. Subsequently they completed KBIT-2 and PPVT in a fixed order. In the second session, participants returned completed operation span task, color-shape switching task, modified Eriksen flanker task, and rotation span task. In the third session, participants completed modified arrow flanker task, animacy-locomotion switching task, symmetry span task, modified color flanker task, and parity-magnitude switching task. All of the tasks were administered in the order listed above to minimize practice effect from completing construct-related task consecutively. Each of the session took approximately 60 minutes to complete.

CHAPTER 3: RESULTS

Data pre-processing

In order to improve construct validity and reliability of inhibitory control and task-switching tasks, rank-ordered binning procedure was employed as recommended by Hughes, Linck, Bowles, Koeth, and Bunting (2014) and Draheim, Hick, and Engle (2016). These studies have demonstrated that indexes calculated from rank-ordered binning procedure have better reliability and construct validity than pure latency score, pure accuracy score and inverse efficiency procedure. In the binning procedure, performance in terms of speed and accuracy was combined to form a single comprehensive score of task performance. Binning procedure was calculated by the following steps (see Draheim et al., 2016; Hughes et al., 2014 for more details): First, accurate responses that were below 200 ms as well as either 2.5 *SD* (for task-switching tasks) or 3 *SD* (for inhibitory control tasks) above or below an individual’s mean reaction time (RT) were excluded. Three *SD* criteria for inhibitory control was chosen because past research has shown that shorter trimming criteria may eliminate possible bilingual cognitive advantage in inhibitory control (Zhou & Krott, 2016). Subsequently, average reaction time (RT) of the repeat trials (for task-switching tasks) or congruent trials (for inhibitory control tasks) were computed for each participant. Next, the average RT of the repeat trials or congruent trials for each participant were subtracted from the RT of each switch trial (for task-switching tasks) or incongruent trial (for inhibitory control tasks). The subtraction was only carried out only for switch or incongruent trials that had correct responses. Then, the RT of each subtracted switch trial or incongruent trials for all participants combined were rank ordered into deciles and assigned a bin value from 1 to 10, with higher bin value indicate slower responses. Subsequently, switch trials or incongruent trials with inaccurate responses were assigned a bin value of 20, regardless their RT. Lastly, all of the bin scores from the switch trials or incongruent trials of each participants were averaged to compute a single bin score, resulting lower bin score in inhibitory control or task-switching task reflects better inhibitory control or task-switching performances.

Descriptive statistics and zero-order correlations for all EFs tasks are provided in the Table 4 and Table 5, respectively. Due to the binning procedure, reliability estimates were generally high for most dependent variables, even for inhibitory control tasks that typically were reported to suffer from low reliability (Friedman, 2016; Miyake et al., 2000; Paap & Sawi, 2016). Moreover, inspection of the correlation matrix indicates zero-order correlations among EFs tasks were consistent or even higher than most previous studies (Friedman & Miyake, 2004; Miyake et al., 2000; Paap & Sawi, 2014; Unsworth, Fukuda, Awh, & Vogel, 2014), ranging from low to high.

Table 4. *Descriptive Statistics and Reliability Estimates for EFs Tasks*

	M	SD	Range	Skewness	Kurtosis	Reliability
Inhibitory control [1]						
Arrow flanker	6.41	2.14	3.69-14.78	1.866	5.757	.925
Color flanker	6.31	0.96	3.52-9.24	0.166	0.726	.709
Eriksen flanker	6.19	0.87	4.20-9.66	0.940	1.526	.703
Task-switching (Switch Cost) [1]						
Color-shape switching	6.65	1.48	3.55-12.93	0.959	1.908	.866
Magnitude-parity switching	7.09	1.56	4.01-12.36	0.842	0.939	.874
Animacy-locomotion switching	6.96	1.44	4.52-12.51	0.963	1.065	.886
Task-switching (Mixing Costs) [1]						
Color-shape switching	5.98	1.31	2.44-10.01	-0.114	-0.128	.937
Magnitude-parity switching	6.45	1.60	3.35-14.79	1.491	5.113	.915
Animacy-locomotion switching	6.21	1.60	2.66-13.06	0.773	2.505	.933
Working Memory[2]						

Operation span	0.87	0.13	0.36-1.00	-1.516	2.136	.639
Rotation span	0.73	0.18	0.08-1.00	-1.029	1.465	.733
Symmetry span	0.80	0.16	0.26-1.00	-1.054	0.574	.735

Note. Lower values indicate better performance in flanker and task-switching while lower values indicate better performance in working memory span. Due to experimenter, computer, or participant errors, seven participants had missing data in one of their EF tasks: 2 in arrow flanker, 1 in Eriksen flanker, 2 in rotation span, and 2 in symmetry span. Reliability estimates were computed by split-half procedure that were corrected using the Spearman-Brown prophecy formula

[1] Calculated by rank-ordered binning procedure (Hughes et al., 2014)

[2] Calculated by partial-credit unit method (Conway et al., 2005)

Table 5. *Descriptive and Correlation Matrix for Bilingual Interactional Context, Demographic and Intelligence*

	1	2	3	4	5	6	7	8	9	10	11	12
1. Arrow flanker												
2. Color flanker	**.30**											
3. Eriksen flanker	**.25**	**.45**										
4. Color-shape (switch costs)	**.21**	**.09**	**.25**									
5. Magnitude-parity (switch costs)	**.27**	**.24**	**.23**	**.43**								
6. Animacy-locomotion (switch costs)	**.27**	**.17**	.14	**.39**	**.60**							
7. Color-shape (mixing costs)	.14	.06	**.02**	.02	.10	.09						
8. Magnitude-parity (mixing costs)	**.26**	**.26**	**.35**	**.24**	**.50**	**.40**	**.34**					
9. Animacy-locomotion (mixing costs)	**.36**	**.15**	.11	**.25**	**.40**	**.51**	**.25**	**.53**				
10. Operation span	-.06	-.02	**-.18**	**-.22**	**-.17**	**-.17**	-.12	**.19**	-.14			
11. Rotation span	**-.17**	**-.09**	**-.18**	**-.26**	**-.28**	**-.29**	**-.24**	**-.36**	**-.25**	**.36**		
12. Symmetry span	-.13	-.02	**-.18**	**-.19**	**-.16**	-.12	**-.17**	**-.30**	**-.25**	**.29**	**.56**	

Note. Bolded values are significant ($p < .05$). Lower values indicate better performance in flanker and task-switching while lower values indicate worse performance in working memory span

Latent Variable Approach with Three Factor Model

To examine the relations between bilingual interactional contexts and EFs, latent variable analyses were conducted using MPLUS 7.4 (Muthén & Muthén, 2012) to estimate latent variables of inhibitory control, task-switching, and working memory. These latent variables were later regressed on the indexes calculated from the bilingual interactional context questionnaire. For the latent variable analyses, several fit indices were used to determine the model fit. For the comparative indices, a good model fit was determined when RMSEA has value below .06, (Browne & Cudeck, 1992) while CFI and TLI have values close to .095 (Hu & Bentler, 1999). Missing data was imputed using a maximum likelihood parameter estimation algorithm.

For the latent variable analyses, a three-factors model was specified with inhibitory control, task-switching, and working memory as the latent variables. The inhibitory control latent variable consisted of flanker effect in bin score of arrow flanker, color flanker, and Eriksen flanker. The task-switching latent variable consisted of switch costs in bin score of color-shape switching task, magnitude-parity switching task, and animacy-locomotion switching task. The working memory latent variable consisted of PCU score of operation span task, rotation span task, and symmetry span task. All measures were specified to load only on the factor of interest with each factor and correlate freely among the latent variables. The fit of the three-factors model was excellent, $\chi^2(24) = 30.01$, $p = .184$, RMSEA = .038, SRMR = .047, CFI = .980, TLI = .971 (see Table 6). Consistent with prior research (Miyake et al., 2000), each measure loaded significantly on its factor of interest, and the factors were significantly intercorrelated (see Figure 1).

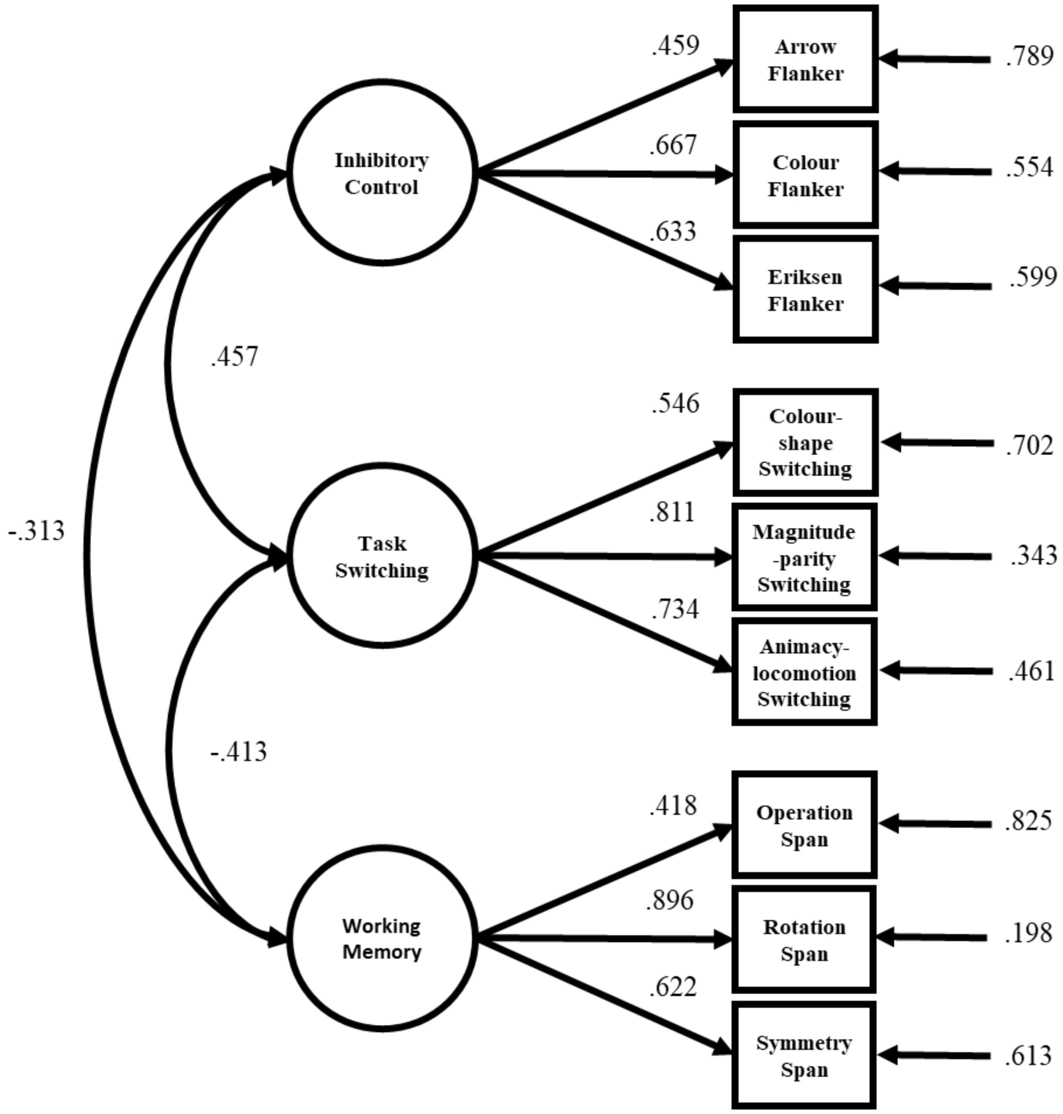

Figure 1. Confirmatory factor analysis model of three-factor model of inhibitory control, task-switching, and working memory. The circles represent the three latent variables, and the rectangles represent the individual tasks (manifest variables) that were chosen to tap the specific core component of EFs. The curved double-headed arrows connecting the latent variables to each other represent the correlations between the constructs and the numbers beside the single-headed arrows connecting the latent variable to the manifest variables represent the standardized factor loading. The correlations and factor loadings are all significant at the .05 level. The numbers at the ends of the shorter single-headed arrows pointing toward the manifest variables are error terms.

Table 6. *Fit Indices for the Three-factors Models and the Reduced Models*

Model	*df*	χ^2	AIC	BIC	SRMR	RMSEA	CFI	TLI
Three-factors model	24	30.01	2773.02	2867.96	.047	.038	.980	.971
Two-factors model								
Task-switching = working memory	26	97.95	2836.96	2925.58	.082	.126	.765	.674
Task-switching = inhibitory control	26	63.36	2802.37	2890.99	.068	.091	.878	.831
Working memory = inhibitory control	26	84.25	2823.26	2911.88	.087	.113	.810	.736
One-factor model	27	128.05	2865.06	2950.51	.094	.146	.670	.559

Note. AIC = Akaike’s Information Criterion; BIC = Bayesian information criterion; SRMR = standardized root mean-squared residual; RMSEA = root mean square Error of approximation; CFI = Bentler’s Comparative Fit Index; TLI = Tucker-Lewis Index. Lower values of AIC, BIC, SRMR, and RMSEA indicate better fit. Higher values of CFI and TLI indicate better fit.

Next, a series of structural equation modeling were estimated, each with additional covariates, to ensure robust estimates of the relations between bilingual interactional contexts and EFs. In the first model, latent variables of inhibitory control, task-switching, and working memory were regressed on the index of dual-language context and the index of dense code-switching context with the single-language context index as the reference (i.e., the control group). The first model provides an unadjusted conditional model of the relation between bilingual interactional contexts and EFs, without taking into account potential covariates. In the second model, demographic and socioeconomic status (SES) covariates, including age, gender, objective SES (household income), and subjective SES, were included in the model to control for demographic and SES confounds (Hartanto & Yang, 2018). In the third model, standardized scores in KBIT-2 and PPVT was included in the model to control for pre-existing differences in general nonverbal and verbal intelligence (Bak, Nissan, Allerhand, & Deary, 2014; Cox et al., 2016). In the fourth model, unintended switching frequency (Rodriguez-Fornells et al., 2012) was controlled to distinguish dense code-switching from unconscious code-switching practices that have been associated with EFs deficits (Festman, Rodriguez-Fornells, & Münte, 2010; Festman & Münte, 2012). All of the models have excellent fits, with non-significance chi-square values (ps > .349), RMSEA lower than .02, CFI higher than 0.98, and TLI higher than 0.98 (see Table 7).

Table 7. *Fit Indices for the Three-factors Models Structural Equation Models*

Model	*df*	χ^2	AIC	BIC	SRMR	RMSEA	CFI	TLI

Model 1	36	34.14	2772.65	2886.58	.041	.000	1.000	1.009
Model 2	60	63.65	2780.27	2932.18	.042	.019	.988	.983
Model 3	72	69.39	2733.15	2904.05	.039	.000	1.000	1.011
Model 4	78	73.04	2731.95	2912.34	.038	.000	1.000	1.020

Note. AIC = Akaike's Information Criterion; BIC = Bayesian information criterion; SRMR = standardized root mean-squared residual; RMSEA = root mean square Error of approximation; CFI = Bentler's Comparative Fit Index; TLI = Tucker-Lewis Index. Lower values of AIC, BIC, SRMR, and RMSEA indicate better fit. Higher values of CFI and TLI indicate better fit. Each model consists of additional covariates. Model 1 consists of dual-language context and dense code-switching context; Model 2 additionally consists age, gender, household income, and subjective SES; Model 3 additionally consists nonverbal intelligence and verbal intelligence; Model 4 additionally consists unintended switching.

The coefficient estimates of bilingual interactional contexts on latent variable of inhibitory control are summarized in Table 8. Dual-language context, in comparison to single-language context, did not significantly predict latent variable of inhibitory control in the unadjusted conditional model in the Model 1 (β = -.136, SE = .093, *t* = -1.466, *p* = .143), after demographics and SES were controlled in the Model 2 (β = -.166, SE = .095, *t* = -1.758, *p* = .079), nonverbal and verbal intelligence in the Model 3 (β = -.160, SE = .092, *t* = -1.733, *p* = .083), and unintended switching in the Model 4 (β = -.157, SE = .092, *t* = -1.698, *p* = .090). However, dense code-switching, in comparison to single-language context, significantly predicted latent variable of inhibitory control across the four models; Model 1 (β = -.222, SE = .091, *t* = -2.432, *p* = .015), Model 2 (β = -.234, SE = .091, *t* = -2.574, *p* = .010), Model 3 (β = -.220, SE = .088, *t* = -2.492, *p* = .013), and Model 4 (β = -.220, SE = .088, *t* = -2.496, *p* = .013). The negative coefficient estimates in all of the four models suggest that higher exposure to dense code-switching context relative to single-language context is associated with better inhibitory control. Nonetheless, it is noteworthy that dense code-switching, relative to dual-language, did not significantly predict latent variable of inhibitory control in all of the models; Model 1 (β = -.060, SE = .143, *t* = -0.423, *p* = .673), Model 2 (β = -.036, SE = .144, *t* = -0.246, *p* = .805), Model 3 (β = -.029, SE = .139, *t* = -0.211, *p* = .833), and Model 4 (β = -.033, SE = .139, *t* = -0.237, *p* = .812) (see appendix B and C for the other reference group comparisons).

Table 8. *Standardized Coefficient Estimates on Latent Variable of Inhibitory Control*

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language context	-.136	.093	-.166†	.095	-.160†	.092	-.157†	.092
Dense code-switching context	-.222*	.091	-.234*	.091	-.220*	.088	-.220*	.088
Covariates								
Age			.071	.120	.077	.117	.080	.117
Gender			-.198*	.114	-.159	.113	-.155	.113
Household Income			-.077	.100	-.052	.098	-.055	.098
Subjective SES			.023	.095	.010	.091	.013	.091
Nonverbal Intelligence					-.346**	.094	-.356**	.096
Verbal Intelligence					.001	.100	-.007	.102
Unintended Switching							-.043	.098

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

The coefficient estimates of bilingual interactional contexts on latent variable of task-switching are summarized in Table 9. Different from inhibitory control, I observed that dual-language context, in comparison to single-language context, significantly predicted latent variable of task-switching in the unadjusted conditional model in the Model 1 (β = -.183, SE = .083, *t* = -2.205, *p* = .027), after demographics and SES were controlled in the Model 2 (β = -.217, SE = .084, *t* = -2.585, *p* = .010), nonverbal and verbal intelligence in the Model 3 (β = -.201, SE = .080, *t* = -2.518, *p* = .012), and unintended switching in the Model 4 (β = -.214, SE = .079, *t* = -2.710, *p* = .007). The robust negative coefficient estimates suggest that higher task-switching abilities in bilinguals who had higher exposure in dual-language context relative to single-language context, even after controlling for possible confounds such as demographics, SES, intelligence, and unintended switching tendency. In contrast, dense code-switching context, in comparison to single-language context, did not significantly predict latent variable of task-switching in all of the models; Model 1 (β = -.135, SE = .083, *t* = -1.614, *p* = .106), Model 2 (β = -.144, SE = .084, *t* = -1.751, *p* = .080), Model 3 (β = -.121, SE = .078, *t* = -1.554, *p* = .120), and Model 4 (β = -.119, SE = .077, *t* = -1.549, *p* = .121). Similarly, dense code-switching, in comparison to dual-language context, did not significantly predict latent variable of task-switching across the four models; Model 1 (β = .084, SE = .130, *t* = 0.647, *p* = .517), Model 2 (β = .115, SE = .129, *t* = 0.889, *p* = .374), Model 3 (β = .1191, SE = .121, *t* = 0.985, *p* = .325), and Model 4 (β = .136, SE = .119, *t* = 1.140, *p* = .254). Nevertheless, for task-switching, it is also noteworthy that unintended switching significant predicted lower performances in latent variable of task-switching (β = .193, SE = .084, *t* = 2.307, *p* = .021).

Table 9. *Standardized Coefficient Estimates on Latent Variable of Task-switching*

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language contexts	-.183*	.083	-.217*	.084	-.201*	.080	-.214*	.079
Dense code-switching context	-.135	.083	-.144†	.082	.121	.078	-.119	.077
Covariates								
Age			.098	.108	.119	.103	.104	.102
Gender			-.032	.104	.005	.099	-.013	.098
Household Income			-.076	.089	-.052	.085	-.037	.084
Subjective SES			.126†	.086	.107	.081	.091	.081
Nonverbal Intelligence					-.416**	.079	-.369**	.081
Verbal Intelligence					.054	.087	.091	.087
Unintended Switching							.193*	.084

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

The coefficient estimates of bilingual interactional contexts on latent variable of working memory are summarized in Table 10. None of the bilingual interactional contexts significantly predicted latent variable of working memory. Dual-language context, in comparison to single-language context, did not significantly predict latent variable of working memory in all of the models; Model 1 (β = .092, SE = .083, *t* = 1.097, *p* = .273), Model 2 (β = .115, SE = .086, *t* = 1.339, *p* = .181), Model 3 (β = .101, SE = .078, *t* = 1.296, *p* = .195), and Model 4 (β = .097, SE = .078, *t* = 1.243, *p* = .214). Similarly, dense code-switching context, in comparison to single-language context, did not significantly predict latent variable of working memory across the four models; Model 1 (β = -.006, SE = .084, *t* = -0.072, *p* = .943), Model 2 (β = .006, SE = .083, *t* = 0.078, *p* = .938), Model 3 (β = -.022, SE = .076, *t* = -0.288, *p* = .773), and Model 4 (β = -.021, SE = .075, *t* = -0.275, *p* = .784). Moreover, dense code-switching, in comparison to dual-language context, did not significantly predict latent variable of working memory in all of the models; Model 1 (β = -.141, SE = .128, *t* = -1.097, *p* = .273), Model 2 (β = -.130, SE = .129, *t* = -1.006, *p* = .314), Model 3 (β = -.143, SE = .117, *t* = -1.221, *p* = .222), and Model 4 (β = -.137, SE = .117, *t* = -1.171, *p* = .242).

Table 10. *Standardized Coefficient Estimates on Latent Variable of Working Memory*

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language context	.092	.083	.115	.086	.101	.078	.097	.078
Dense code-switching context	-.006	.084	.006	.083	-.022	.076	-.021	.075
Covariates								
Age			-.028	.107	-.043	.098	-.047	.098
Gender			.237*	.102	.182†	.094	.174†	.094
Household Income			.020	.089	-.027	.082	-.023	.082
Subjective SES			-.148†	.086	-.134†	.076	-.136†	.076
Nonverbal Intelligence					.523**	.073	.535**	.075
Verbal Intelligence					.018	.084	.027	.085
Unintended Switching							.052	.082

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Latent Variable Approach with Four Factor Model

Additional structural equation modeling was conducted with a four-factors model to examine the relations between bilingual interactional contexts and goal maintenance. The four-factor model consisted of inhibitory control, task-switching, working memory, and goal maintenance. The operationalization of the latent variable of inhibitory control, task-switching, and working memory was similar the three-factor model that was conducted earlier. For goal maintenance, the latent variable consisted of mixing costs in bin score of color-shape switching, magnitude-parity switching task, and animacy-locomotion switching task. The calculation of the bin score was similar to switch costs, except that the bin score was computed by subtracting the RT of pure trials from the RT of repeat trials (Hughes et al., 2014). Although the fit of the four-factor model was barely acceptable, $\chi^2(48) = 83.11$, $p = .001$, RMSEA = .065, SRMR = .056, CFI = .929, TLI = .902, the model had the best fit among all of the alternative models (see Table 11). More importantly, each measure loaded significantly on its factor of interest, and the factors were significantly intercorrelated (see Figure 2).

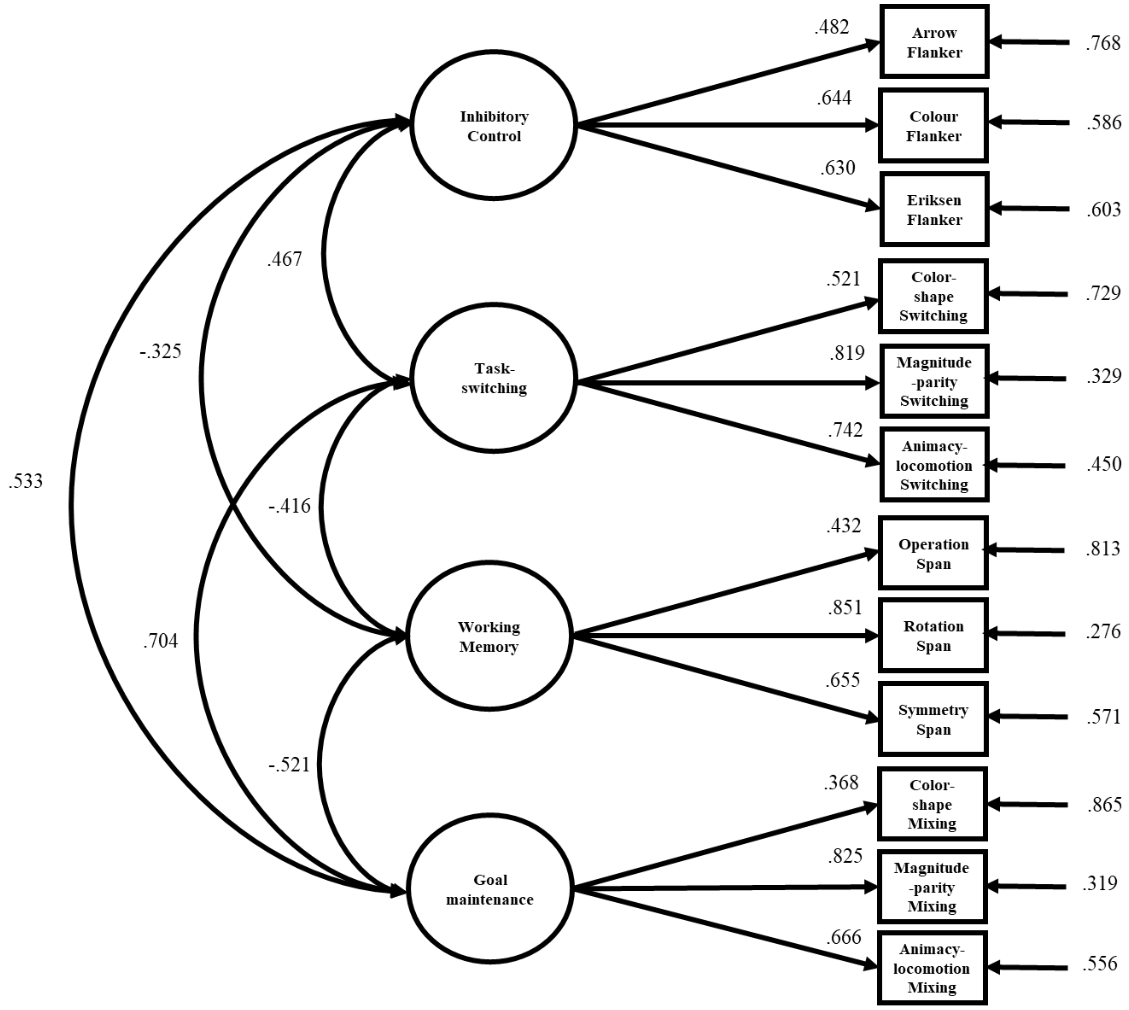

Figure 2. Confirmatory factor analysis model of four-factor model of inhibitory control, task-switching, working memory, and goal maintenance. The circles represent the four latent variables, and the rectangles represent the individual tasks (manifest variables) that were chosen to tap the specific core component of EFs. The curved double-headed arrows connecting the latent variables to each other represent the correlations between the constructs and the numbers beside the single-headed arrows connecting the latent variable to the manifest variables represent the standardized factor loading. The correlations and factor loadings are all significant at the .05 level. The numbers at the ends of the shorter single-headed arrows pointing toward the manifest variables are error terms.

Table 11. *Fit Indices for the Four-factors Model and the Reduced Models*

Model	*df*	χ^2	AIC	BIC	SRMR	RMSEA	CFI	TLI
Four-factor model	48	83.11	4544.126	4677.047	.056	.065	.929	.902
Three-factor model								
Task-switching = working memory	51	153.45	4608.469	4731.90	.077	.107	.792	.731
Task-switching = inhibitory control	51	116.94	4571.96	4695.39	.065	.086	.866	.827
Task-switching = goal maintenance	51	111.87	4566.893	4690.320	.064	.083	.876	.840
Working memory = inhibitory control	51	138.31	4593.33	4716.75	.079	.099	.823	.771
Working memory = goal maintenance	51	136.43	4591.44	4714.87	.072	.098	.827	.776
Inhibitory control = goal maintenance	51	108.59	4563.61	4687.034	.062	.080	.883	.849
Two-factor model								
Interference control as a separate factor	53	170.97	4621.99	4739.08	.079	.113	.761	.702
Goal maintenance as a separate factor	53	182.47	4633.49	4750.59	.083	.118	.737	.673
Task-switching as a separate factor	53	162.79	4613.81	4730.90	.078	.109	.777	.723
Working memory as a separate factor	53	137.72	4588.74	4705.84	.069	.096	.828	.786
One-factor model	54	196.56	4645.58	4759.52	.085	.123	.711	.646

Note. AIC = Akaike's Information Criterion; BIC = Bayesian information criterion; SRMR = standardized root mean-squared residual; RMSEA = root mean square Error of approximation; CFI = Bentler's Comparative Fit Index; TLI = Tucker-Lewis Index. Lower values of AIC, BIC, SRMR, and RMSEA indicate better fit. Higher values of CFI and TLI indicate better fit.

Subsequently, a series of modeling were conducted similar to the structural equation modeling in the three-factors model. In total, four separate models were estimated, each with additional covariates: index of dual-language context and index of dense code-switching context with the single-language context index as the reference (Model 1); age, gender, household income, and subjective SES (Model 2); nonverbal intelligence and verbal intelligence (Model 3); and unintended switching (Model 4). As shown in the Table 12, all of the models have acceptable to excellent fits based on the recommended threshold (Browne & Cudeck, 1992; Hu & Bentler, 1999).

Table 12. *Fit Indices for the Four-factors Models Structural Equation Models*

Model	*df*	χ^2	AIC	BIC	SRMR	RMSEA	CFI	TLI
Model 1	64	92.32	4540.35	4698.59	.052	.050	.943	.920
Model 2	96	130.82	4553.17	4762.05	.049	.046	.931	.901
Model 3	112	139.07	4502.20	4736.40	.046	.037	.952	.930
Model 4	120	143.46	4502.44	4749.29	.044	.033	.958	.939

Note. AIC = Akaike's Information Criterion; BIC = Bayesian information criterion; SRMR = standardized root mean-squared residual; RMSEA = root mean square Error of approximation; CFI = Bentler's Comparative Fit Index; TLI = Tucker-Lewis Index. Lower values of AIC, BIC, SRMR, and RMSEA indicate better fit. Higher values of CFI and TLI indicate better fit. Each model consists of additional covariates. Model 1 consists of dual-language context and dense code-switching context; Model 2 additionally consists age, gender, household income, and subjective SES; Model 3 additionally consists nonverbal intelligence and verbal intelligence; Model 4 additionally consists unintended switching.

The coefficient estimates of bilingual interactional contexts on latent variable of goal maintenance are summarized in Table 13. The analyses showed that dual-language context, in comparison to single-language context, did not significantly predict latent variable of goal maintenance in all of the models; Model 1 (β = -.042, SE = .086, *t* = -0.491, *p* = .623), Model 2 (β = -.059, SE = .088, *t* = -0.677, *p* = .499), Model 3 (β = -.038, SE = .079, *t* = -0.473, *p* = .636), and Model 4 (β = -.046, SE = .079, *t* = -0.576, *p* = .564). However, dense code-switching, in comparison to single-language context, significantly predicted latent variable of goal maintenance in the unadjusted conditional model in the Model 1 (β = -.225, SE = .083, *t* = -3.059, *p* = .002), after controlling for demographics and SES in the Model 2 (β = -.260, SE = .083, *t* = -3.141, *p* = .002), nonverbal and verbal intelligence in the Model 3 (β = -.231, SE = .076, *t* = -3.050, *p* = .002), and unintended switching in the Model 4 (β = -.230, SE = .075, *t* = -3.055, *p* = .002). These results indicate a robust association between higher exposure to dense code-switching context relative to single-language context and better goal maintenance abilities. Nevertheless, when compared to dual-language context, dense code-switching did not significantly predict latent variable of goal maintenance across the four models; Model 1 (β = .065, SE = .132, *t* = -0.491, *p* = .623), Model 2 (β = .091, SE = .135, *t* = 0.677, *p* = .499), Model 3 (β = .058, SE = .122, *t* = 0.473, *p* = .636), and Model 4 (β = .070, SE = .122, *t* = 0.576, *p* = .564).

Table 13. *Standardized Coefficient Estimates on Latent Variable of Goal Maintenance*

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language context	-.042	.086	-.059	.088	-.038	.079	-.046	.079
Dense code-switching context	-.255*	.083	-.260*	.083	-.231*	.076	-.230*	.075
Covariates								
Age			-.042	.110	-.010	.100	-.017	.099
Gender			-.056	.105	-.016	.095	-.029	.095
Household Income			-.068	.093	-.042	.085	-.034	.085
Subjective SES			.158†	.085	.140†	.077	.132†	.077
Nonverbal Intelligence					-.513**	.073	-.484**	.077
Verbal Intelligence					.078	.085	.100	.086
Unintended Switching							.115	.083

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

For latent variables of interference control, task-switching, and working memory, the results in the four-factors model were similar as the analyses in the three-factors model. Specifically, only higher dense code-switching context, as comparison to single-language context, were associated with better abilities in the latent variable of interference control even after controlling for the confounds in demographics, SES, intelligence, and unintended switching. In contrast, only higher dual-language context, as comparison to single-language context, were associated with better abilities in the latent variable of task-switching, even after for confounds (see appendix D and E for the other reference group comparison).

Regressions on Single EFs Tasks

Lastly, a series of multiple regressions were conducted to examine the predictability of bilingual interactional contexts on each of the EFs task. The results were summarized in the Table 14. Although some of the results were consistent with the above structural equation modeling, none of the bilingual interactional contexts significantly predicted all of the three tasks that represent a latent variable. For example, although dense code-switching significantly predicted the latent variable of inhibitory control in the structural equation modeling across all of the four models, dense code-switching context only significantly predicted the bin score of Eriksen flanker but not arrow flanker and color flanker. Moreover, the significant associations between dense code-switching context and Eriksen flanker disappeared in the Model 3 and Model 4. These findings demonstrate issues with unreliability and idiosyncratic task effect of EFs measures, and highlight the superiority of latent variable approach in examining the relations between bilingualism and EFs.

Table 14. *Standardized Coefficient Estimates on Single EFs Tasks*

	Inhibitory Control			Task-switching			Working Memory			Goal Maintenance		
	AF	CF	EF	CSC	MSC	ASC	OS	RS	SS	CMC	MMC	AMC
Model 1												
Dual-language context	-.066	-.072	-.106	-.168*	-.128	-.131	.003	.084	.045	.118	-.056	-.032
Dense code-switching context	-.120	-.128	-.151*	-.082	-.126	-.069	-.066	.007	-.019	-.023	-.198*	-.213*
Model 2												
Dual-language context	-.071	-.096	-.125	-.178*	-.176*	-.132	.022	.105	.054	.127	-.080	-.029
Dense code-switching context	-.128	-.138	-.154*	-.087	-.140	-.064	-.057	.019	-.007	-.015	-.203*	-.220*
Model 3												
Dual-language context	-.056	-.095	-.122	-.162*	-.166*	-.118	.015	.086	.056	.126	-.061	-.012
Dense code-switching context	-.112	-.133	-.144	-.067	-.125	-.046	-.071	.000	-.026	-.011	-.179*	-.199*
Model 4												
Dual-language context	-.058	-.094	-.118	-.166*	-.176*	-.129	.011	.081	.058	.127	-.068	-.017
Dense code-switching context	-.112	-.133	-.144	-.067	-.124	-.045	-.071	.000	-.026	-.011	-.179*	-.199*

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Arrow flanker, color flanker, Eriksen flanker, color-shape switch costs, magnitude-parity switch costs, and animacy-locomotion switch costs were calculated based on rank-ordered binning procedure (Hughes et al., 2014). Model 1 consists of dual-language context and dense code-switching context; Model 2 additionally consists age, gender, household income, and subjective SES; Model 3 additionally consists nonverbal intelligence and verbal intelligence; Model 4 additionally consists unintended switching. Standardized coefficient estimates for Covariates were not displayed for simplicity. AF = arrow flanker, CF = color flanker, EF = Eriksen flanker, CSC = color-shape switch costs, MSC = magnitude-parity switch costs, ASC = animacy-locomotion switch costs, OS = operation span, RS = rotation span, SS = symmetry span, CMC = color-shape mixing costs, MMC = magnitude-parity mixing costs, AMC = animacy-locomotion mixing costs. $^{*}p < .05$

CHAPTER 4: DISCUSSION

In order to shed light on the inconsistent findings in the bilingualism literature, the current study aimed to identify key bilingual experiences that could moderate the manifestation of bilingual advantages in EFs. To do so, the current study employed a theoretically driven approach based on the Adaptive Control Hypothesis (Green & Abutalebi, 2013) and Control Process Model of Code-switching (Green & Wei, 2014), coupled with a latent variable approach to address low reliability and task impurity issues in EFs tasks. As a result, a multisession study was conducted to examine systematically the relations between various type of bilingual interactional contexts and EFs, measured by nine separate EFs tasks. The experiment yielded three major findings.

First, I found that bilinguals with higher exposure to dual-language context relative to single-language context was found to perform better in task-switching. More importantly, the finding was still robust even after controlling for well-established confounds such as demographics, SES, and intelligence. This finding is consistent with the prediction of Adaptive Control Hypothesis and Control Process Model of Code-switching, which argued dual-language context adaptively enhances bilinguals' task-switching as the context imposes stronger task-switching demands than single-language context and dense code-switching context. The finding replicates and extends Hartanto and Yang (2016) by showing that higher task-switching performance in dual-language context relative to single-language context can be generalized to other task-switching rules, such as magnitude-parity and animacy-locomotion.

In addition, the current study found that frequency of unintended switching, characterized by involuntary language switching not explained by sociolinguistic or linguistic factors (Rodriguez-Fornells et al., 2012), were associated with deficits in task-switching. In contrast, engagement in dense code-switching did not predict performance in task-switching. Although both dense code-switching and unintended switching involve intrasentential code-switching, the finding demonstrates that not all types of intrasentential code-switching are associated with deficits in task-switching. Contradict with Hartanto and Yang (2016), the current finding suggests that frequency of intrasentential code-switching should not be used as a proxy of dense code-switching context because it could be confounded by task-switching failure in unintended switching. However, consistent with Festman et al. (2010), the current study supports the contention that unintended switching is a form of language control failure, driven by task-switching deficits.

Second, different from my prediction based on the Adaptive Control Hypothesis and Control Process Model of Code-switching, I did not observe higher inhibitory control and goal maintenance in dual-language context and single-language contexts bilinguals as compared to dense code-switching context. In contrast, I found that dense code-switching, in comparison to single-language context, performed significantly better in inhibitory control and goal maintenance even after controlling for confounding variables. The robust findings may suggest that engaging in dense code-switching involve inhibitory control and goal maintenance and adaptively enhance these EFs processes over time. In fact, the findings are in line with a recent study by Hofweber, Marinis, and Treffers-Daller (2016) that found higher inhibitory control and goal maintenance abilities, as measured by flanker task, in high frequency dense code-switchers. As suggested by the authors, the management of co-activated language structures in dense code-switching may still involve inhibitory control and goal maintenance. Alternatively, it is plausible that inhibitory control and goal maintenance are still necessary to ensure successful opportunistic planning in dense code-switchers' speech. While more research is necessary, it is still safe to conclude that bilinguals in dense code-switching context may not have lower EFs, especially in inhibitory control and goal maintenance, as compared to bilinguals in single-language context and dual-language context. This finding has important practical implication as code-switching was often perceived negatively among both bilinguals and monolinguals (Chana & Romaine, 1984; Dewaele & Wei, 2014; Lawson & Sachdev, 2000), especially in Singapore sociolinguistic context (Hoon, 2003; Fong, Lim, & Wee, 2014; Tan & Tan, 2008).

Third, in terms of working memory, the current study failed to find any differences among single-language context, dual-language context, and dense code-switching contexts in the latent variable of working memory. These findings suggest that EFs variations in bilingual interaction contexts were mostly specific to inhibitory control, goal maintenance, task-switching, but not working memory. While dual-language context was hypothesized to perform better in working memory as compared to the other two contexts, the hypothesis was based on the close relations among working memory, goal maintenance, and inhibitory control processes (Engle, 2002; Kane & Engle, 2003; Meier et al., 2018). It is noteworthy that the Adaptive Control Hypothesis and Control Process Model of Code-switching did not specifically discuss whether updating working memory representations processes or working memory in general were engaged differently in single-language context, dual-language context, and dense code-switching context. As working memory is a multicomponent system that implicate numerous control processes (Conway et al., 2005; Engle, 2002), it is plausible that not all control processes involve in working memory are differently implicated between bilingual interactional contexts. For example, the demands on updating working memory representations during bilingual language production could be similar regardless bilingual interactional contexts. Therefore, the finding of the current study may suggest that differences between bilingual interactional contexts in working memory could be more difficult to manifest than other core component of EFs, such as inhibitory control and task-switching

It is noteworthy, however, that the lack of differences in working memory may not necessarily suggest null relation between bilingualism and working memory. In fact, a recent meta-analysis by Grundy and Timmer (2016) has found a small to medium population effect size of .20 in favor of bilingual advantages in working memory than monolinguals. It is plausible that other aspect of bilingual language experience is more responsible for modulating the manifestation of bilingual advantages in working memory. For example, a meta-analysis of 79 samples involving 3,707 participants by Linck, Osthus, Koeth, and Bunting (2014) found a robust positive relation between second language proficiency and working memory, regardless whether the working memory task was verbal or nonverbal in nature.

Taken together, the significant relations between bilingual interactional contexts and EFs – specifically in inhibitory control, goal maintenance, and task-switching – highlight the importance of considering bilingual interactional contexts in assessing bilingual advantages in EFs (Yang, Hartanto, & Yang, 2016). As previously noted, most studies in bilingualism literature have solely focused on the comparison between bilingual and monolinguals in EFs. These comparison, however, have neglected the fact that bilingualism is a multidimensional construct that consists of various dual-language experiences. By demonstrating a robust link between bilingual interactional contexts and EFs, the finding of the current study suggests that bilingual interactional context could modulate the manifestation of bilingual advantages in EFs, particularly in inhibitory control, goal maintenance, and task-switching. For instance, from the current findings, it is plausible that bilingual advantages over monolingual in task-switching are more likely to be observed in dual-language context bilinguals. In contrast, inhibitory control and goal maintenance advantages in bilinguals over monolinguals are more likely to occur in dense code-switching context bilinguals. This could explain why findings from Catalan-Spanish bilinguals from Catalonia, who were predominantly dense code-switching bilinguals, tend to find bilingual advantages in EFs tasks related to inhibitory control or goal maintenance (Costa et al., 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Hernández, Costa, Fuentes, Vivas, & Sebastián-Gallés, 2010) but not in task-switching (Branzi, Calabria, Gade, Fuentes, & Costa, 2018; Hernández et al., 2013). Nevertheless, due to the fact that most previous studies did not provide a comprehensive sociolinguistic environment of their bilinguals or assess bilingual interactional contexts (Surrain & Luk, 2017), it is may not be possible to reevaluate the role of bilingual interactional contexts in the previous studies. Therefore, it is important for future study to assess bilingual interactional contexts to provide a comprehensive examination of the relations between bilingualism and EFs.

Nevertheless, the current study is not without its limitations. One potential limitation of the current study is the lack of monolingual control. As a result, caution need to be exercised when generalized the current findings to monolinguals. For instance, it is still plausible that bilinguals from dual-language contexts could perform better in inhibitory control and goal maintenance than monolinguals, despite the current study found that dual-language context and single-language context bilinguals were comparable in the latent variable of inhibitory control and goal maintenance. Due to the fact that almost all of the studies comparing bilinguals and monolinguals in EFs found either null effect or bilinguals advantages but not bilingual disadvantages (Bialystok, Kroll, Green, MacWhinney, & Craik, 2015; De Bruin et al., 2015), it is less likely that single-language bilinguals, who were found in the current study to perform the worse in a number of EFs tasks, could have lower EFs than monolinguals. Nevertheless, future study could be benefited by including a monolingual control group to improve the generalizability of the findings.

Another potential limitation is the correlational nature of the current study, which may limit the causal interpretation of the current findings. One could argue that the relations between bilingual interactional contexts and EFs could be driven by the effect of EFs on bilingual interactional contexts. For example, bilinguals with higher inhibitory control and goal maintenance may prefer dense code-switching contexts more than single-language context and dual-language context. While the design of the current study was unable to completely rule out this alternative interpretation, this interpretation is less likely because bilingual interactional contexts are mostly driven by linguistic tradition of the bilingual's environment. In addition, it is less likely that higher EFs bilingual in the current study voluntarily chose to immerse in dense code-switching context due to the prevalent negative attitudes toward dense code-switching in Singapore sociolinguistic context (Hoon, 2003; Fong et al., 2014; Tan & Tan, 2008). In addition, due to the correlational design, the current study could be susceptible to issues with third variables that may confound the relations between bilingual interactional contexts and EFs. While the current study was able to rule out a number of potential confounding variables by controlling for demographics, SES, intelligence, and unintended switching tendency in four separate models, it is still important for future studies to replicate the current findings in other sociolinguistic contexts with a larger sample size and more comprehensive control variables.

Despite the potential limitations, the methodological advances in the current study are also noteworthy. The latent variable approach coupled with rank-ordered binning procedure in the current study circumvents issues with regards to task impurity, low construct validity, and low reliability in EFs tasks, which has been plagued the bilingualism literature for decades (Friedman, 2016). As shown in my analyses, the relations between bilingual interactional contexts and EFs were inconsistent when the EFs tasks were analyzed separately. As a result, without the use of latent variable approach, one could misinterpret the results and inaccurately conclude that the relations between bilingual interactional contexts and EFs are task specifics. In addition, the Revised Interactional Context Questionnaire allows the current study to simultaneously examine all three distinct bilingual interactional contexts and take into account both inter-situation variations and intra-situation variations of bilingual interactional contexts. The Revised Interactional Context Questionnaire is more conceptually advance and should replace the use of composite score of dual-language context bilingualism (Hartanto & Yang, 2016b) to assess bilingual interactional contexts

To conclude, given that bilingualism is a multidimensional construct (Luk & Bialystok, 2013), there is a need for a more fine-grained examination on various bilingual experiences that contribute to interindividual variation in EFs. The current study contributes to the bilingualism literature by demonstrating bilingual interactional contexts as the key bilingual experiences that could moderate the manifestation of bilingual advantages in EFs. Bilingual interactional contexts provide a promising avenue of research that could not only reconcile the discrepancies in the current literature but also shed light on the mechanisms underlying the interplay between experiential factors and cognition in general.

References

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

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

Adler, N. E., Epel, E. S., Castellazzo, G., & Ickovics, J. R. (2000). Relationship of subjective and objective social status with psychological and physiological functioning: Preliminary data in healthy, white women. *Health Psychology*, *19*(6), 586-592. doi:10.1037/0278-6133.19.6.586

Antón, E., Fernández García, Y., Carreiras, M., & Duñabeitia, J. A. (2016). Does bilingualism shape inhibitory control in the elderly? *Journal of Memory and Language, 90*, 147–160. doi:10.1016/j.jml.2016.04.007

Arán Filippetti, A. V., & Richaud, M. C. (2017). A structural equation modeling of executive functions, IQ and mathematical skills in primary students: Differential effects on number production, mental calculus and arithmetical problems. *Child Neuropsychology, 23*(7), 864-888. doi:10.1080/09297049.2016.1199665

Bailey, C. E. (2007). Cognitive accuracy and intelligent executive function in the brain and in business. *Annals of the New York Academy of Sciences, 1118*(1), 122–141. doi:10.1196/annals.1412.011

Bak, T. H. (2015). Beyond a simple “yes” and “no.” *Cortex, 73,* 332–333. doi:10.1016/j.cortex.2015.08.003

Bak, T. H., Long, M. R., Vega-Mendoza, M., & Sorace, A. (2016). Novelty, challenge, and practice: The impact of intensive language learning on attentional functions. *PLOS ONE, 11*(4), e0153485. doi:10.1371/journal.pone.0153485

Best, J. R. (2010). Effects of physical activity on children’s executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30*(4), 331–351. doi:10.1016/j.dr.2010.08.001

Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Canadian Journal of Experimental Psychology, 60*(1), 68–79. doi:10.1037/cjep2006008

Bialystok, E. (2017). The bilingual adaptation: How minds accommodate experience. *Psychological Bulletin, 143*(3), 233–262. doi:10.1037/bul0000099

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19*(2), 290–303. doi:10.1037/0882-7974.19.2.290

Bialystok, E., Craik, F., & Luk, G. (2009). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35*(3), 828–828. doi:10.1037/a0015638

Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 32(6), 1341–1354. doi:10.1037/0278-7393.32.6.1341

Bialystok, E., Kroll, J. F., Green, D. W., MacWhinney, B., & Craik, F. I. M. (2015). Publication bias and the validity of evidence. *Psychological Science, 26*(6), 944–946. doi:10.1177/0956797615573759

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

Bialystok, E., Martin, M. M., & Viswanathan, M. (2005). Bilingualism across the lifespan: The rise and fall of inhibitory control. *International Journal of Bilingualism, 9*(1), 103–119. doi:10.1177/13670069050090010701

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition, 112*(3), 494–500. doi:10.1016/j.cognition.2009.06.014

Bollen, K. A. (2002). Latent variables in psychology and the social sciences. *Annual Review of Psychology, 53*(1), 605–634. doi:10.1146/annurev.psych.53.100901.135239

Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M., & Gratton, G. (2008). The effects of video game playing on attention, memory, and executive control. *Acta Psychologica, 129*(3), 387–398. doi:10.1016/j.actpsy.2008.09.005

Branzi, F. M., Calabria, M., Gade, M., Fuentes, L. J., & Costa, A. (2016). On the bilingualism effect in task switching. *Bilingualism: Language and Cognition, 21*(1), 195–208. doi:10.1017/s136672891600119x

Browne, M. W., & Cudeck, R. (1992). Alternative ways of assessing model fit. *Sociological Methods & Research, 21*(2), 230–258. doi:10.1177/0049124192021002005

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205–228. doi:10.1080/87565640801982312

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, *19*(3), 273-293. doi: 10.1207/s15326942dn1903_3

Burgess, P. W. (1997). Theory and methodology in executive function research. In P. Rabbitt (Ed.), *Methodology of frontal and executive function* (pp. 81-116). Hove, UK: Psychology Press.

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

Chana, U., & Romaine, S. (1984). Evaluative reactions to Panjabi/English code-switching. *Journal of Multilingual and Multicultural Development, 5*(6), 447–473. doi:10.1080/01434632.1984.9994174

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user’s guide. *Psychonomic Bulletin & Review, 12*(5), 769–786. doi:10.3758/bf03196772

Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don’t. *Cognition, 113*(2), 135–149. doi:10.1016/j.cognition.2009.08.001

Costa, A., Hernández, M., & Sebastián-Gallés, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition, 106*(1), 59–86. doi:10.1016/j.cognition.2006.12.013

Crescioni, A., Ehrlinger, J., Alquist, J. L., Conlon, K. E., Baumeister, R. F., Schatschneider, C., & Dutton, G. R. (2011). High trait self-control predicts positive health behaviors and success in weight loss. *Journal of Health Psychology, 16*(5), 750–759. doi:10.1177/1359105310390247

Cox, S. R., Bak, T. H., Allerhand, M., Redmond, P., Starr, J. M., Deary, I. J., & MacPherson, S. E. (2016). Bilingualism, social cognition and executive functions: A tale of chickens and eggs. *Neuropsychologia, 91*, 299–306. doi:10.1016/j.neuropsychologia.2016.08.029

Davis, J. C., Marra, C. A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC Geriatrics, 10*(1). doi:10.1186/1471-2318-10-16

De Baene, W., Duyck, W., Brass, M., & Carreiras, M. (2015). Brain circuit for cognitive control is shared by task and language switching. *Journal of Cognitive Neuroscience, 27*(9), 1752–1765. doi:10.1162/jocn_a_00817

De Bruin, A., Bak, T. H., & Della Sala, S. (2015). Examining the effects of active versus inactive bilingualism on executive control in a carefully matched non-immigrant sample. *Journal of Memory and Language, 85*, 15–26. doi:10.1016/j.jml.2015.07.001

De Bruin, A., Treccani, B., & Della Sala, S. (2015). Cognitive advantage in bilingualism: An example of publication bias? *Psychological Science, 26*(1), 99–107. doi:10.1177/0956797614557866

Dewaele, J.-M., & Wei, L. (2014). Attitudes towards code-switching among adult mono- and multilingual language users. *Journal of Multilingual and Multicultural Development, 35*(3), 235–251. doi:10.1080/01434632.2013.859687

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. doi:10.1146/annurev-psych-113011-143750

Donnelly, S., Brooks. P.J., & Homer, B.D. (2015). Examining the bilingual advantage on conflict resolution tasks: A meta-analysis. In Noelle, D. C., Dale, R., Warlaumont, A. S., Yoshimi, J., Matlock, T., Jennings, C. D., & Maglio, P. P. (Eds.) (2015). *Proceedings of the 37th Annual Meeting of the Cognitive Science Society,* 596-601. Austin, TX: Cognitive Science Society.

Draheim, C., Hicks, K. L., & Engle, R. W. (2016). Combining reaction time and accuracy. *Perspectives on Psychological Science*, *11*(1), 133–155. doi:10.1177/1745691615596990

Dunn, L. M., & Dunn, L. M. (1997). *PPVT-III: Peabody picture vocabulary test*. Circle Pines, MN: American Guidance Service.

Eakin, L., Minde, K., Hechtman, L., Ochs, E., Krane, E., Bouffard, R., … Looper, K. (2004). The marital and family functioning of adults with ADHD and their spouses. *Journal of Attention Disorders*, *8*(1), 1–10. doi:10.1177/108705470400800101

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*(1), 19–23. doi:10.1111/1467-8721.00160

Festman, J., & Münte, T. F. (2012). Cognitive control in Russian–German bilinguals. *Frontiers in Psychology*, 3. doi:10.3389/fpsyg.2012.00115

Festman, J., Rodriguez-Fornells, A., & Münte, T. F. (2010). Individual differences in control of language interference in late bilinguals are mainly related to general executive abilities. *Behavioral and Brain Functions*, *6*(1), 5. doi:10.1186/1744-9081-6-5

Fitzpatrick, C., McKinnon, R. D., Blair, C. B., & Willoughby, M. T. (2014). Do preschool executive function skills explain the school readiness gap between advantaged and disadvantaged children? *Learning and Instruction*, *30*, 25-31. doi:10.1016/j.learninstruc.2013.11.003

Fisher, G. G., Chaffee, D. S., Tetrick, L. E., Davalos, D. B., & Potter, G. G. (2017). Cognitive functioning, aging, and work: A review and recommendations for research and practice. *Journal of Occupational Health Psychology*, *22*(3), 314-336. doi:10.1037/ocp0000086

Foster, J. L., Shipstead, Z., Harrison, T. L., Hicks, K. L., Redick, T. S., & Engle, R. W. (2014). Shortened complex span tasks can reliably measure working memory capacity. *Memory & Cognition, 43*(2), 226–236. doi:10.3758/s13421-014-0461-7

Friedman, N. P. (2016). Research on individual differences in executive functions. *Linguistic Approaches to Bilingualism*, *6*(5), 535–548. doi:10.1075/lab.15041.fri

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology: General, 133*(1), 101–135. doi:10.1037/0096-3445.133.1.101

Fong, V., Lim, L., & Wee, L. (2002). “Singlish”: Used and abused. *Asian Englishes, 5*(1), 18–39. doi:10.1080/13488678.2002.10801087

Gallant, S. N. (2016). Mindfulness meditation practice and executive functioning: Breaking down the benefit. *Consciousness and Cognition, 40*, 116–130. doi:10.1016/j.concog.2016.01.005

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1*(2), 67. doi: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. doi:10.1080/20445911.2013.796377

Green, D. W., & Wei, L. (2014). A control process model of code-switching. *Language, Cognition and Neuroscience, 29*(4), 499–511. doi:10.1080/23273798.2014.882515

Green, C. S., Sugarman, M. A., Medford, K., Klobusicky, E., & Bavelier, D. (2012). The effect of action video game experience on task-switching. *Computers in Human Behavior, 28*(3), 984–994. doi:10.1016/j.chb.2011.12.020

Grundy, J. G., & Timmer, K. (2016). Bilingualism and working memory capacity: A comprehensive meta-analysis. *Second Language Research, 33*(3), 325–340. doi:10.1177/0267658316678286

Hartanto, A., & Suárez, L. (2016). Conceptual Representation Changes in Indonesian–English Bilinguals. *Journal of Psycholinguistic Research, 45*(5), 1201–1217. doi:10.1007/s10936-015-9399-6

Hartanto, A., Toh, W. X., & Yang, H. (2016). Age matters: The effect of onset age of video game play on task-switching abilities. *Attention, Perception, & Psychophysics, 78*(4), 1125–1136. doi:10.3758/s13414-016-1068-9

Hartanto, A., Toh, W. X., & Yang, H. (2018). Bilingualism narrows socioeconomic disparities in executive functions and self-regulatory behaviors during early childhood: Evidence from the Early Childhood Longitudinal Study. *Child Development*. doi:10.1111/cdev.13032

Hartanto, A., & Yang, H. (2016a). Is the smartphone a smart choice? The effect of smartphone separation on executive functions. *Computers in Human Behavior, 64,* 329–336. doi:10.1016/j.chb.2016.07.002

Hartanto, A., & Yang, H. (2016b). Disparate bilingual experiences modulate task-switching advantages: A diffusion-model analysis of the effects of interactional context on switch costs. *Cognition, 150,* 10–19. doi:10.1016/j.cognition.2016.01.016

Hartanto, A., & Yang, H. (2018). Does early active bilingualism enhance inhibitory control and monitoring? A proponesity-matching analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* doi:10.1037/xlm0000581

Hartanto, A., Yang, H., & Yang, S. (2018). Bilingualism positively predicts mathematical competence: Evidence from two large-scale studies. *Learning and Individual Differences, 61*, 216–227. doi:10.1016/j.lindif.2017.12.007

Hernández, M., Costa, A., Fuentes, L. J., Vivas, A. B., & Sebastián-Gallés, N. (2010). The impact of bilingualism on the executive control and orienting networks of attention. *Bilingualism: Language and Cognition*, *13*(3), 315-325. doi:10.1017/s1366728909990010

Hernández, M., Martin, C. D., Barceló, F., & Costa, A. (2013). Where is the bilingual advantage in task-switching? *Journal of Memory and Language, 69*(3), 257–276. doi:10.1016/j.jml.2013.06.004

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58–65. doi:10.1038/nrn2298

Hofweber, J., Marinis, T., & Treffers-Daller, J. (2016). Effects of dense code-switching on executive control. *Bilingualism and Executive Function, 6*(5), 648–668. doi:10.1075/lab.15052.hof

Hoon, C. H. (2003). “You see me no up”: Is Singlish a problem? *Language Problems and Language Planning, 27*(1), 45–62. doi:10.1075/lplp.27.1.04hoo

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. doi:10.1080/10705519909540118

Hughes, C., & Graham, A. (2002). Measuring executive functions in childhood: Problems and solutions? *Child and Adolescent Mental Health, 7*(3), 131–142. doi:10.1111/1475-3588.00024

Hughes, M. M., Linck, J. A., Bowles, A. R., Koeth, J. T., & Bunting, M. F. (2013). Alternatives to switch-cost scoring in the task-switching paradigm: Their reliability and increased validity. *Behavior Research Methods, 46*(3), 702–721. doi:10.3758/s13428-013-0411-5

Jurado, M. B., & Rosselli, M. (2007). The elusive nature of executive functions: A review of our current understanding. *Neuropsychology Review, 17*(3), 213–233. doi:10.1007/s11065-007-9040-z

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132*(1), 47–70. doi:10.1037/0096-3445.132.1.47

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Brief Intelligence Test, Second Edition.* Circle Pines, MN: American Guidance Service.

Kaushanskaya, M., Park, J. S., Gangopadhyay, I., Davidson, M. M., & Weismer, S. E. (2017). The relationship between executive functions and language abilities in children: A latent variables approach. *Journal of Speech*

Language and Hearing Research, 60(4), 912. doi:10.1044/2016_jslhr-l-15-0310

Kirk, N. W., Fiala, L., Scott-Brown, K. C., & Kempe, V. (2014). No evidence for reduced Simon cost in elderly bilinguals and bidialectals. *Journal of Cognitive Psychology, 26*(6), 640–648. doi:10.1080/20445911.2014.929580

Kline, R. B. (2011). *Principles and practice of structural equation modelling*. New York, NY: Guilford Press.

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

Kroll, J. F., Dussias, P. E., Bogulski, C. A., & Kroff, J. R. V. (2012). Juggling two languages in one mind. *Psychology of Learning and Motivation*, 229–262. doi:10.1016/b978-0-12-394393-4.00007-8

Lawson, R. A., Papadakis, A. A., Higginson, C. I., Barnett, J. E., Wills, M. C., Strang, J. F., … Kenworthy, L. (2015). Everyday executive function impairments predict comorbid psychopathology in autism spectrum and attention deficit hyperactivity disorders. *Neuropsychology, 29*(3), 445–453. doi:10.1037/neu0000145

Lawson, S., & Sachdev, I. (2000). Codeswitching in Tunisia: Attitudinal and behavioural dimensions. *Journal of Pragmatics, 32*(9), 1343–1361. doi:10.1016/s0378-2166(99)00103-4

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*(1), 59–80. doi:10.1348/026151003321164627

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2013). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review, 21*(4), 861–883. doi:10.3758/s13423-013-0565-2

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

Marian, V., & Shook, A. (2012). The cognitive benefits of being bilingual. *Cerebrum: The Dana Forum on Brain Science* (Vol. 2012). Dana Foundation.

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6*(2), 97–115. doi:10.1017/s1366728903001068

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*(1). doi:10.1017/s1366728907003227

Meier, M. E., Smeekens, B. A., Silvia, P. J., Kwapil, T. R., & Kane, M. J. (2018). Working memory capacity and the antisaccade task: A microanalytic–macroanalytic investigation of individual differences in goal activation and maintenance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(1), 68–84. doi:10.1037/xlm0000431

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. doi:10.1006/cogp.1999.0734

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*(3), 134–140. doi:10.1016/s1364-6613(03)00028-7

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological Science, 22*(11), 1425–1433. doi:10.1177/0956797611416999

Muthén, B. O., & Muthén, L. K. (2012). *Mplus version 7: User’s guide*. Los Angeles, CA: Author.

Paap, K. R. (2014). Bilingual advantages in executive functioning: problems in convergent validity, discriminant validity, and the identification of the theoretical constructs. *Frontiers in Psychology, 5*. doi:10.3389/fpsyg.2014.00962

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

Paap, K. R., Johnson, H. A., & Sawi, O. (2015). Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex, 69*, 265–278. doi:10.1016/j.cortex.2015.04.014

Paap, K. R., & Sawi, O. (2014). Bilingual advantages in executive functioning: problems in convergent validity, discriminant validity, and the identification of the theoretical constructs. *Frontiers in Psychology*, 5. doi:10.3389/fpsyg.2014.00962

Paap, K. R., & Sawi, O. (2016). The role of test-retest reliability in measuring individual and group differences in executive functioning. *Journal of Neuroscience Methods, 274,* 81–93. doi:10.1016/j.jneumeth.2016.10.002

Paelecke-Habermann, Y., Pohl, J., & Leplow, B. (2005). Attention and executive functions in remitted major depression patients. *Journal of Affective Disorders, 89*(1-3), 125–135. doi:10.1016/j.jad.2005.09.006

Pelham, S. D., & Abrams, L. (2014). Cognitive advantages and disadvantages in early and late bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*(2), 313–325. doi:10.1037/a0035224

Peretz, I., & Zatorre, R. J. (2005). Brain organization for music processing. *Annual Review of Psychology, 56*(1), 89–114. doi:10.1146/annurev.psych.56.091103.070225

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

Prior, A., & Gollan, T. H. (2011). Good language-switchers are good task-switchers: Evidence from Spanish–English and Mandarin–English bilinguals. *Journal of the International Neuropsychological Society, 17*(04), 682–691. doi:10.1017/s1355617711000580

Prior, A., & Macwhinney, B. (2009). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*(2), 253. doi:10.1017/s1366728909990526

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social–emotional competence. *Journal of Applied Developmental Psychology, 27*(4), 300–309. doi:10.1016/j.appdev.2006.04.002

Riggs, N. R., Spruijt-Metz, D., Sakuma, K.-L., Chou, C.-P., & Pentz, M. A. (2010). Executive cognitive function and food intake in children. *Journal of Nutrition Education and Behavior, 42*(6), 398–403. doi:10.1016/j.jneb.2009.11.003

Rodriguez-Fornells, A., Krämer, U. M., Lorenzo-Seva, U., Festman, J., & Münte, T. F. (2012). Self-Assessment of individual differences in language switching. *Frontiers in Psychology*, 2. doi:10.3389/fpsyg.2011.00388

Rubin, O., & Meiran, N. (2005). On the origins of the task mixing cost in the cuing task-switching paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(6), 1477–1491. doi:10.1037/0278-7393.31.6.1477

Schmidt, K.-H., Neubach, B., & Heuer, H. (2007). Self-control demands, cognitive control deficits, and burnout. *Work & Stress, 21*(2), 142–154. doi:10.1080/02678370701431680

Shaul, S., & Schwartz, M. (2014). The role of the executive functions in school readiness among preschool-age children. *Reading and Writing*, *27*(4), 749-768. doi:10.1007/s11145-013-9470-3

Smith, E. E. (1999). Storage and executive processes in the frontal lobes. *Science, 283*(5408), 1657–1661. doi:10.1126/science.283.5408.1657

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology, 59*(4), 745–759. doi:10.1080/17470210500162854

Surrain, S., & Luk, G. (2017). Describing bilinguals: A systematic review of labels and descriptions used in the literature between 2005–2015. *Bilingualism: Language and Cognition*, 1–15. doi:10.1017/s1366728917000682

Tan, P. K. W., & Tan, D. K. H. (2008). Attitudes towards non-standard English in Singapore1. *World Englishes, 27*(3-4), 465–479. doi:10.1111/j.1467-971x.2008.00578.x

Teper, R., & Inzlicht, M. (2012). Meditation, mindfulness and executive control: the importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience*, *8*(1), 85–92. doi:10.1093/scan/nss045

Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. K. (2014). Working memory and fluid intelligence: Capacity, attention control, and secondary memory retrieval. *Cognitive Psychology, 71*, 1–26. doi:10.1016/j.cogpsych.2014.01.003

Valian, V. (2015). Bilingualism and cognition. *Bilingualism: Language and Cognition, 18*(01), 3–24. doi:10.1017/s1366728914000522

van der Ven, S. H. G., Kroesbergen, E. H., Boom, J., & Leseman, P. P. M. (2012). The structure of executive functions in children: A closer examination of inhibition, shifting, and updating. *British Journal of Developmental Psychology, 31*(1), 70–87. doi:10.1111/j.2044-835x.2012.02079.x

Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language, 39*(3), 458–483. doi:10.1006/jmla.1998.2584

Von Bastian, C. C., De Simoni C., Kane, M. J., Carruth, N. P., & Miyake, A. (2017). *Does being bilingual entail advantages in working memory? A meta-analysis*. Poster presented at the 58th Annual Meeting of Psychonomic Society, Vancouver, BC.

Von Bastian, C. C., Souza, A. S., & Gade, M. (2016). No evidence for bilingual cognitive advantages: A test of four hypotheses. *Journal of Experimental Psychology: General, 145*(2), 246–258. doi:10.1037/xge0000120

Von Studnitz, R. E., & Green, D. W. (2002). Interlingual homograph interference in German–English bilinguals: Its modulation and locus of control. *Bilingualism: Language and Cognition, 5*(1). doi:10.1017/s1366728902000111

Weissberger, G. H., Wierenga, C. E., Bondi, M. W., & Gollan, T. H. (2012). Partially overlapping mechanisms of language and task control in young and older bilinguals. *Psychology and Aging, 27*(4), 959–974. doi:10.1037/a0028281

Wolf, E. J., Harrington, K. M., Clark, S. L., & Miller, M. W. (2013). Sample size requirements for structural equation models. *Educational and Psychological Measurement, 73*(6), 913–934. doi:10.1177/0013164413495237

Woumans, E., & Duyck, W. (2015). The bilingual advantage debate: Moving toward different methods for verifying its existence. *Cortex, 73*, 356–357. doi:10.1016/j.cortex.2015.07.012

Yang, H., Hartanto, A., & Yang, S. (2016a). The importance of bilingual experience in assessing bilingual advantages in executive functions. *Cortex, 75*, 237–240. doi:10.1016/j.cortex.2015.11.018

Yang, H., Hartanto, A., & Yang, S. (2016b). The complex nature of bilinguals' language usage modulates task-switching outcomes. *Frontiers in psychology, 7*, 560. doi:10.3389/fpsyg.2016.00560

Yang, H., Hartanto, A., & Yang, S. (2017). Bilingualism confers advantages in task switching: Evidence from the dimensional change card sort task. *Bilingualism: Language and Cognition*, 1–19. doi:10.1017/s136672891700044x

Yang, S., & Yang, H. (2016). Bilingual effects on deployment of the attention system in linguistically and culturally homogeneous children and adults.

Journal of Experimental Child Psychology, 146, 121–136. doi:10.1016/j.jecp.2016.01.011

Zhou, B., & Krott, A. (2015). Data trimming procedure can eliminate bilingual cognitive advantage. *Psychonomic Bulletin & Review, 23*(4), 1221–1230. doi:10.3758/s13423-015-0981-6

Appendix A

Revised Interactional Contexts Questionnaire

Q1. How much time do you spend in each of the following situations, in general? Note that your answers should add up to 100%.

	Home	School	Work	Other than home, school and work
List percentage here				

Q2. What is the percentage of your language-switching tendency at **home**? (Your percentage should add up to 100%).

Please read the possible answer carefully

	List percentage here
I speak only one language and rarely switch to other language at **home**	
I speak two (or more languages) when I converse with different speakers at **home**. I often switch languages but rarely mixing languages within an utterance	
I routinely mix two (or more) languages within an utterance to most speakers at **home**	

Q3. What is the percentage of your language-switching tendency at **school**? (Your percentage should add up to 100%).

Please read the possible answer carefully.

	List percentage here
I speak only one language and rarely switch to other language at **school**	
I speak two (or more languages) when I converse with different speakers at **school**. I often switch languages but rarely mixing languages within an utterance	
I routinely mix two (or more) languages within an utterance to most speakers at **school**	

Q4. What is the percentage of your language-switching tendency at **work**? (Your percentage should add up to 100%).

Please read the possible answer carefully

	List percentage here
I speak only one language and rarely switch to other language at **work**	
I speak two (or more languages) when I converse with different speakers at **work**. I often switch languages but rarely mixing languages within an utterance	

I routinely mix two (or more) languages within an utterance to most speakers at **work**	

Q5. What is the percentage of your language-switching tendency at **places other than home, school, and work**? (Your percentage should add up to 100%).

Please read the possible answer carefully

	List percentage here
I speak only one language and rarely switch to other language at **places other than home, school, and work**	
I speak two (or more languages) when I converse with different speakers at **places other than home, school, and work**. I often switch languages but rarely mixing languages within an utterance	
I routinely mix two (or more) languages within an utterance to most speakers at **places other than home, school, and work**	

Appendix B

Table B1. Standardized Coefficient Estimates on Latent Variable of Inhibitory Control in the Three-Factors Model with Dual-language Context as the Reference for Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language contexts	.209	.142	.256†	.146	.246†	.142	.241†	.142
Dense code-switching contexts	-.060	.143	-.036	.144	-.029	.139	-.033	.139
Covariates								
Age			.071	.120	.077	.117	.080	.117
Gender			-.198*	.114	-.159	.113	-.155	.113
Household Income			-.077	.100	-.052	.098	-.055	.098
Subjective SES			.023	.095	.010	.091	.013	.091
Nonverbal Intelligence					-.346**	.094	-.356**	.096
Verbal Intelligence					.001	.100	-.007	.102

Unintended Switching	-.043	.098

Note. Dual-language context was served as the reference for single-language context and dense code-switching context. Gender was dummy coded with male as the reference category. $^{\dagger} p < .10$, $^{*} p < .05$, $^{**} p < .001$

Table B2. Standardized Coefficient Estimates on Latent Variable of Task-switching in the Three-factors model with Dual-language Context as the Reference for Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language contexts	$.282^{*}$	.128	$.334^{*}$	.129	$.309^{*}$	.123	$.329^{*}$	.121
Dense code-switching contexts	.084	.130	.115	.129	.119	.121	.136	.119
Covariates								
Age			.098	.108	.119	.103	.104	.102
Gender			-.032	.104	.005	.099	-.013	.098
Household Income			-.076	.089	-.052	.085	-.037	.084

Subjective SES	$.126^{\dagger}$	.086	.107	.081	.091	.081
Nonverbal Intelligence			$-.416^{**}$	.079	$-.369^{**}$	.081
Verbal Intelligence			.054	.087	.091	.087
Unintended Switching					$.193^{*}$	.084

Note. Dual-language context was served as the reference for single-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Table B3. Standardized Coefficient Estimates on Latent Variable of Working Memory in the Three-factors Model with Dual-language Context as the Reference for Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language context	-.141	.128	-.176	.132	-.156	.120	-.150	.120
Dense code-switching context	-.115	.129	-.130	.129	-.143	.117	-.137	.117
Covariates								

Age	-.028	.107	-.043	.098	-.047	.098
Gender	.237*	.102	.182†	.094	.174†	.094
Household Income	.020	.089	-.027	.082	-.023	.082
Subjective SES	-.148†	.086	-.134†	.076	-.136†	.076
Nonverbal Intelligence			.523**	.073	.535**	.075
Verbal Intelligence			.018	.084	.027	.085
Unintended Switching					.052	.082

Note. Dual-language context was served as the reference for single-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Appendix C

Table C1. Standardized Coefficient Estimates on Latent Variable of Inhibitory Control in the Three-factors model with Dense Code-switching Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language contexts	.287*	.118	.302*	.117	.284*	.114	.284*	.114
Dual-language context	.051	.120	.030	.121	.025	.116	.028	.117
Covariates								
Age			.071	.120	.077	.117	.080	.117
Gender			-.198*	.114	-.159	.113	-.155	.113
Household Income			-.077	.100	-.052	.098	-.055	.098
Subjective SES			.023	.095	.010	.091	.013	.091
Nonverbal Intelligence					-.346**	.094	-.356**	.096
Verbal Intelligence					.001	.100	-.007	.102

Unintended Switching							-.043	.098

Note. Dense code-switching context was served as the reference for single-language context and dual-language switching context. Gender was dummy coded with male as the reference category. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .001$

Table C2. Standardized Coefficient Estimates on Latent Variable of Task-switching in the Three-factors Model with Dense Code-switching Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language contexts	.174†	.108	.186†	.106	.156	.100	.154	.099
Dual-language contexts	-.070	.109	-.096	.108	-.100	.101	-.114	.100
Covariates								
Age			.098	.108	.119	.103	.104	.102
Gender			-.032	.104	.005	.099	-.013	.098
Household Income			-.076	.089	-.052	.085	-.037	.084
Subjective SES			.126†	.086	.107	.081	.091	.081

Nonverbal Intelligence					-.416**	.079	-.369**	.081
Verbal Intelligence					.054	.087	.091	.087
Unintended Switching							.193*	.084

Note. Dense code-switching context was served as the reference for single-language context and dual-language switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Table C3. Standardized Coefficient Estimates on Latent Variable of Working Memory in the Three-factors Model with Dense Code-switching Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Single-language contexts	.008	.108	-.008	.107	.028	.097	.027	.097
Dual-language contexts	.097	.108	.109	.129	.120	.098	.115	.098
Covariates								
Age			-.028	.107	-.043	.098	-.047	.098
Gender			.237*	.102	.182†	.094	.174†	.094

Household Income	.020	.089	-.027	.082	-.023	.082
Subjective SES	-.148†	.086	-.134†	.076	-.136†	.076
Nonverbal Intelligence			.523**	.073	.535**	.075
Verbal Intelligence			.018	.084	.027	.085
Unintended Switching					.052	.082

Note. Dense code-switching context was served as the reference for single-language context and dual-language switching context.

Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Appendix D

Table D1. Standardized Coefficient Estimates on Latent Variable of Inhibitory Control in the Four-factors model with Single-language Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language context	-.138	.093	-.169†	.095	-.161†	.093	-.158†	.093
Dense code-switching context	-.225*	.092	-.237*	.091	-.221*	.089	-.221*	.089
Covariates								
Age			.066	.120	.076	.118	.078	.118
Gender			-.202†	.114	-.163	.113	-.158	.113
Household Income			-.077	.100	-.051	.098	-.054	.098
Subjective SES			.026	.095	.012	.092	.015	.092
Nonverbal Intelligence					-.350**	.094	-.360**	.097
Verbal Intelligence					.003	.101	-.005	.103

Unintended Switching							-.041	.099

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. $^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .001$

Table D2. Standardized Coefficient Estimates on Latent Variable of Task-switching in the Four-factors model with Single-language Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language contexts	.181*	.083	-.215*	.084	-.201*	.080	-.212*	.079
Dense code-switching context	-.134	.083	-.143†	.082	.121	.078	-.118	.077
Covariates								
Age			.094	.108	.119	.103	.102	.101
Gender			-.027	.104	.005	.099	-.010	.098
Household Income			-.076	.089	-.052	.085	-.037	.084

Subjective SES			.124†	.086	.107	.081	.093	.080
Nonverbal Intelligence					-.416**	.079	-.365**	.081
Verbal Intelligence					.054	.087	.090	.087
Unintended Switching							.193*	.083

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. † $p < .10$, * $p < .05$, ** $p < .001$

Table D3. Standardized Coefficient Estimates on Latent Variable of Working Memory in the Four-factors model with Single-language Context as the Reference for the Predictors

	Model 1		Model 2		Model 3		Model 4	
	Estimates	SE	Estimates	SE	Estimates	SE	Estimates	SE
Predictors								
Dual-language context	.092	.086	.115	.087	.101	.078	.099	.079
Dense code-switching context	-.013	.086	.001	.085	-.022	.076	-.023	.076

Covariates						
Age	-.030	.109	-.043	.098	-.047	.098
Gender	.246*	.103	.182†	.094	.178†	.094
Household Income	.018	.091	-.027	.082	-.025	.082
Subjective SES	-.157†	.086	-.134†	.076	-.139†	.076
Nonverbal Intelligence			.523**	.073	.537**	.075
Verbal Intelligence			.018	.084	.029	.085
Unintended Switching					.049	.083

Note. Single-language context was served as the reference for dual-language context and dense code-switching context. Gender was dummy coded with male as the reference category. $^{\dagger} p < .10$, $^{*} p < .05$, $^{**} p < .001$