5-2019

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

Andree HARTANTO
Singapore Management University, andreeh@smu.edu.sg

Hwajin YANG
Singapore Management University, hjyang@smu.edu.sg

Citation

HARTANTO, Andree, & YANG, Hwajin.(2019). The role of bilingual interactional contexts in predicting interindividual variability in executive functions: A latent variable analysis. *Journal of Experimental Psychology: General,* , 1-25.

Available at: https://ink.library.smu.edu.sg/soss_research/3034

Published in Journal of Experimental Psychology: General, 2019 September, Pages 1-26
https://doi.org/10.1037%2Fxge0000672

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

Andree Hartanto and Hwajin Yang
Singapore Management University

Despite a growing number of studies on bilingual advantages in executive functions (EF), their findings have been inconsistent. To shed light on this issue, we aimed to address both the conceptual and methodological limitations that have prevailed in the literature: failure to consider diverse bilingual experiences when assessing bilingual advantages or to address the task impurity problems that can arise with EF tasks. Drawing on the adaptive control hypothesis and control process model of code-switching, we adopted theory-driven and latent variable approaches to examine the relations between bilingual interactional contexts and EF. By administering 9 EF tasks to 175 bilingual participants over multiple sessions, we found that bilinguals' dual-language context significantly predicted the latent variable of task-switching, while a dense code-switching context significantly predicted 2 latent variables of inhibitory control and goal maintenance. These findings remained robust after controlling for potential confounds of demographics, socioeconomic status, nonverbal intelligence, and unintended language-switching tendency. Our study suggests that bilingual interactional context is a key language experience that modulates bilingual advantages in EF.

Keywords: bilingual interactional context, executive functions, goal maintenance, adaptive control hypothesis, control process model of code-switching

Supplemental materials: http://dx.doi.org/10.1037/xge0000672.supp

Research on executive functions (EF)—a multifaceted construct of higher-order cognitive processes responsible for controlling and regulating thoughts and actions to achieve a goal (Miyake et al., 2000)—has established that EF is crucial for many aspects of our lives across the life span (Diamond, 2013). For example, higher EF has been shown to be associated with better outcomes in physical health (e.g., Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010; Will Crescioni et al., 2011), mental health (Lawson et al., 2015; Paelecke-Habermann, Pohl, & Leplow, 2005), preacademic skills among preschoolers (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 social relationships (e.g., Eakin et al., 2004; Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006).

Due to the vital importance of EF, there has been growing interest among researchers to identify modifiable experiential factors that enhance one's EF—for instance, 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, 2013), and physical exercise (e.g., Best, 2010; Hillman, Erickson, & Kramer, 2008). In addition, given that speaking two or more languages is regarded as one of the most enduring and cognitively challenging experiences humans can engage in (Bialystok, 2017; Kroll & Bialystok, 2013; Marian & Shook, 2012), bilingualism has received the most notable empirical attention as a promising factor that modifies executive functioning (e.g., Bak, Long, Vega-Mendoza, & Sorace, 2016; Bialystok, Craik, & Luk, 2009; Carlson & Meltzoff, 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Hartanto, Toh, & Yang, 2019; Paap & Greenberg, 2013; Prior & Gollan, 2011; Yang & Yang, 2016).

Despite rapidly growing interest in the role of bilingualism in promoting EF, the literature on the relation between bilingualism and EF has largely been inconsistent. Earlier studies have shown that bilinguals outperform monolinguals on a number of tasks that tap into EF, such as the 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, 2009; Yang, Hartanto, & Yang, 2018). An increasing number of recent studies, however, have failed to find any significant differences between bilinguals and monolinguals on

---

Andree Hartanto and Hwajin Yang, School of Social Sciences, Singapore Management University.

This research was supported by a grant awarded to Hwajin Yang by Singapore Management University through a research grant (16-C242-SMU-005) from the Ministry of Education Academic Research Fund Tier 1.

Correspondence concerning this article should be addressed to Andree Hartanto, School of Social Sciences, Singapore Management University, 90 Stamford Road, Level 4, Singapore 178903. E-mail: andreeh@smu.edu.sg

tasks similar to those used in previous studies (de Bruin, Bak, & Della Sala, 2015; Paap & Greenberg, 2013). To shed light on these inconsistencies, we aimed to address both the conceptual and methodological limitations prevalent in the literature: (a) the failure to consider bilinguals' disparate experiences in assessing bilingual advantages (Yang, Hartanto, & Yang, 2016b); and (b) the task impurity problems caused by the influence of the non-EF processes inherent in most EF tasks (Friedman, 2016). To elucidate these issues, we used a theory-driven conceptual framework based on the adaptive control hypothesis (Green & Abutalebi, 2013) and control process model of code-switching (Green & Wei, 2014) to examine both the theoretical and empirical importance of bilinguals' interactional contexts of conversational exchanges as key bilingual experiences that modulate bilingual advantages in EF. We also employed a latent variable approach to address the task impurity issues that have plagued most EF measures (Bollen, 2002).

EF and Bilingualism

EF involves an array of higher-order cognitive abilities that are responsible for achieving goal-directed behaviors. As a multidimensional construct, EF consists of at least three core cognitive processes: inhibitory control, task-switching, and updating working memory representations (Bull & Scerif, 2001; Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000; van der Ven, Kroesbergen, Boom, & Leseman, 2013). Inhibitory control is the ability to override a strong internal predisposition or external distraction (Friedman & Miyake, 2004); task-switching is the ability to switch back and forth between multiple tasks, mental sets, or operations (Monsell, 2003); and updating working memory representations is the ability to hold information in mind while concurrently manipulating it (Smith & Jonides, 1999). Of these three core components of EF, bilingual advantages have often been found for inhibitory control and task-switching, although their underlying mechanisms differ.

It has been assumed that bilingual advantages in inhibitory control are driven by the active engagement of inhibitory control during bilingual language processing (Abutalebi & Green, 2008). The hypothesis is rooted in well-established findings in psycholinguistic research, by which bilinguals' two languages are consistently coactivated, even when only one is in use (Hartanto & Suárez, 2016; Kroll, Dussias, Bogulski, & Valdes-Kroff, 2012; Marian & Spivey, 2003; Van Heuven, Dijkstra, & Grainger, 1998; Von Studnitz & Green, 2002). Given that bilinguals' fluent language processing requires the persistent practice of inhibitory control to resist intrusions from an irrelevant language (Abutalebi & Green, 2008; Green, 1998), bilingualism likely shapes inhibitory control, which in turn results in bilingual advantages over monolinguals on tasks that demand resistance to interference from distractors (Green & Abutalebi, 2013).

On the other hand, bilingual advantages in task-switching are thought to be driven by bilinguals' everyday practice of language switching (Prior & Gollan, 2011; Prior & MacWhinney, 2009). Bilingual advantages in task-switching have received support from recent findings that language-switching and task-switching share partially overlapping neurocognitive mechanisms (De Baene, Duyck, Brass, & Carreiras, 2015; Weissberger, Wierenga, Bondi, & Gollan, 2012). Specifically, De Baene, Duyck, Brass, and Carreiras (2015) observed that highly proficient bilinguals recruited similar brain circuits when performing language-switching and task-switching tasks. Similarly, Weissberger, Wierenga, Bondi, and Gollan (2012) found that language-switching and task-switching exhibit similar patterns of age-related cognitive decline in older adults. In view of evidence suggesting potential shared mechanisms that underlie language-switching and task-switching, the bilingual practice of language-switching likely translates into task-switching efficiency.

Despite favorable predictions for bilingual advantages in inhibitory control and task-switching, studies that compared bilinguals with monolinguals on tasks of inhibitory control and task-switching have reported mixed results (for a review see Paap, Johnson, & Sawi, 2015). For example, in contrast to the bilingual advantages reported on tasks that measure inhibitory control—such as the 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)—some have failed to find any significant differences between bilinguals and monolinguals in the above-mentioned inhibitory-control tasks (e.g., Antón, Fernández García, Carreiras, & Duñabeitia, 2016; Kirk, Fiala, Scott-Brown, & Kempe, 2014; Paap & Greenberg, 2013). Similarly, despite earlier studies that reported bilinguals' greater efficiencies in task-switching (e.g., Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Prior & Gollan, 2011; Prior & MacWhinney, 2009), recent studies have failed to find bilingual advantages in task-switching performance (e.g., Hernández, Martin, Barceló, & Costa, 2013; Paap & Greenberg, 2013; Mor, Yitzhaki-Amsalem, & Prior, 2015). These findings are in line with recent meta-analyses that have shown that bilingual advantages in EF, compared with monolinguals, were significant but highly heterogeneous (Adesope, Lavin, Thompson, & Ungerleider, 2010; de Bruin, Treccani, & Della Sala, 2015; Donnelly, Brooks, & Homer, 2015; Von Bastian, De Simoni, Kane, Carruth, & Miyake, 2017). Given this heterogeneity, therefore, more empirical studies are warranted to address both the conceptual and methodological problems that have proliferated in the literature on bilingualism.

Importance of the Bilingual Interactional Context

One critical challenge that has contributed to the mixed findings concerns the failure to consider largely disparate bilingual experiences when assessing bilingual advantages in EF (Bak, 2015; Woumans & Duyck, 2015; Yang et al., 2016a, 2016b). Most bilingualism studies tend to compare heterogeneous bilingual samples with their monolingual counterparts on EF tasks (Yang, Hartanto, & Yang, 2016a). However, this comparison ignores the crucial fact that bilingualism is a multidimensional construct that consists of a variety of dual-language experiences (Luk & Bialystok, 2013; Surrain & Luk, 2017). Given that active engagement in cognitively demanding bilingual experience is a key factor that leads to bilingual advantages in EF (Green & Abutalebi, 2013), not all bilinguals would necessarily experience benefits to EF due to variations in the extent to which their dual-language experiences impose demands on cognitive control. In light of this, recent studies have started to investigate whether diverse bilingual experiences would moderate bilingual advantages in EF (e.g., Beatty-

Martínez & Dussias, 2017; Gullifer & Titone, 2019; Gullifer et al., 2018; Hartanto & Yang, 2016, 2019).

Notably, bilingual interactional contexts, as one of the defining qualities of diverse bilingual experiences, have recently received substantial theoretical attention (Green & Abutalebi, 2013; Green & Wei, 2014; Yang et al., 2016b). According to the adaptive control hypothesis (Green & Abutalebi, 2013) and control process model of code-switching (Green & Wei, 2014), different interactional contexts of bilinguals' conversational exchanges place different demands on their language control, which in turn adaptively modulates their EF. The theoretical framework identifies bilinguals' three distinct interactional contexts: (a) single-language, (b) dual-language, and (c) dense code-switching. A single-language context occurs when bilinguals use one language in one situation (e.g., at home) and the other language in a separate context, such as a school. Thus, in a single-language context, language-switching is rare, because bilinguals are expected to speak only one language within each context.

In contrast, both dual-language and dense code-switching contexts implicate the use of two languages in the same context (e.g., using both English and Mandarin at home and school), and thereby require that bilinguals switch between languages in their daily conversations. These two interactional contexts, however, can be distinguished further in terms of bilinguals' language-switching practices. Bilinguals in a dense code-switching context routinely mix their languages within a single utterance, whereas dual-language-context bilinguals switch languages between sentences—but not within an utterance—or in conversation with interlocutors of different languages. Because each interactional context implicates different types of language switching and cognitive demands, the adaptive control hypothesis (Green & Abutalebi, 2013) and control process model of code-switching (Green & Wei, 2014) postulate that each interactional context entails different consequences for executive control processes.

Specifically, the adaptive control hypothesis proposes that cognitive demands on opportunistic planning—the ability to make use of whatever comes most readily to mind in order to achieve a goal (Green & Abutalebi, 2013, p. 519)—are deemed highest among bilinguals in a dense code-switching context, because they usually plan their speech opportunistically by mixing languages within an utterance. In contrast, cognitive demands on goal maintenance, interference suppression, salient cue detection, selective response inhibition, task engagement, and task disengagement processes are deemed higher among bilinguals in a dual-language context than those in either a single-language or dense code-switching context (see Table 1 for a summary of the control processes recruited in each interactional context). This is because language-control processing in a dual-language context requires not only constant monitoring of the appropriate language and inhibiting interference from the coactivated nontarget language, but also timely preparation and actual language switching whenever necessary. Because the control processes described above are implicated in most of the core components of EF, the higher control demands placed on bilinguals' language processing in a dual-language context could adaptively enhance some aspects of their EF, compared with bilinguals in either a single-language or dense code-switching context.

Table 1

Language Control Demands in Different Types of Interactional Contexts as Postulated by the Adaptive Control Hypothesis

Control processes	Interactional contexts 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 that the bilingual interactional context imposes greater demands on the corresponding control process than a monolingual context does. The "**+**" symbol in bold face indicates far greater demands on the specific control process than those indicated by the "+" symbol. The "=" symbol indicates similar demands on the control process between bilinguals' interactional context and a monolingual context. From "Language Control in Bilinguals: The Adaptive Control Hypothesis," by D. W. Green and J. Abutalebi, 2013, *Journal of Cognitive Psychology, 25*, p. 519. Copyright 2013 by © 2013 The Author(s). Published by Taylor & Francis. Adapted with permission.

In line with this theoretical perspective, recent studies have provided some promising evidence to support the modulating role of bilingual interaction contexts on EF. For instance, a recent study by Gullifer et al. (2018) examined this issue by assessing the extent to which bilinguals engage in single-language and dual-language contexts, using a novel measure of language entropy. Consistent with their expectation, greater diversity in language usage was found to predict enhanced proactive control measured by the AX-Continuous Performance Task and greater functional connectivity between brain regions involved in language and EF. Similarly, a recent study by Hartanto and Yang (2016) found that dual-language-context bilinguals who reported using two languages interchangeably in the same situation had more efficient task-switching performance on the color-shape switching task than bilinguals who reported speaking only one language in a given context. Notably, given the concomitance between a dual-language context and dense code-switching, dual-language-context bilinguals' advantages in task-switching over single-language-context bilinguals were still significant after controlling for the frequency of intrasentential code-switching—the mixture of linguistic elements (e.g., words) from two languages within a single utterance—which served as a proxy measure of dense code-switching.

Although Gullifer et al. (2018) and Hartanto and Yang (2016) demonstrate the importance of the bilingual interactional context in assessing bilinguals' cognitive advantages in EF, unresolved issues remain that, if resolved, would provide a more comprehensive and coherent account of the phenomenon. First, given that previous studies focused only on dual-language and single-language contexts, but not on the dense code-switching context, the relation between a dense code-switching context and EF should be examined further. As proposed by the adaptive control hypothesis (Green & Abutalebi, 2013) and the control process model of code-switching (Green & Wei, 2014), a dense code-switching context has theoretical and empirical importance, because it is regarded as a commonly observed interactional context that may influence aspects of EF. Despite potential similarities between dual-language and dense code-switching contexts in terms of the use of two languages in the same situation, their operationalization should be clearly distinguished from each other, because there is a qualitative difference in language-switching between a dual-language context and a dense code-switching context. As postulated by the adaptive control hypothesis, language-switching in a dual-language context is mainly between speakers and within a conversation, but not within an utterance. In contrast, language-switching in a dense code-switching context is mostly within an utterance. Although Hartanto and Yang (2016) controlled for intrasentential code-switching when they operationalized the dual-language context, based on the frequency of speaking two or more languages interchangeably within the same situation, the mere frequency of intrasentential code-switching cannot completely capture the complexity of dense code-switching (see Green & Wei, 2014, for a review). Lastly, although new understanding has emerged regarding the relation between bilinguals' interactional context and some limited aspects of EF, there is still much to be discovered about other core components of EF, such as inhibitory control and working memory, which have not received much focus in previous studies. Given these limitations, it is essential to investigate the specific relation of each of the three bilingual interactional contexts to EF.

Task Impurity Issues in EF Measures

Another major issue regarding previous bilingualism studies that has not been explored is the task impurity problem. Studies on EF have consistently reported low intercorrelations among EF tasks, even when they are designed to tap into the same core component of EF (Miyake et al., 2000). These low intercorrelations are expected, because most EF tasks involve non-EF processes (Burgess, 1997; Hughes & Graham, 2002; Jurado & Rosselli, 2007). For instance, the Stroop task, which requires an ability to inhibit one's tendency to read a color that is incongruent with the word name, involves non-EF processes such as reading and color-discrimination abilities. Similarly, variations in performance on flanker tasks can be attributed not only to an inhibitory-control ability (i.e., to inhibit distractions from surrounding flankers), but also to an ability to discriminate the direction of an arrow. Considering that each EF task involves both domain-general EF and task-specific non-EF processes, task impurity has been a long-standing issue in the literature on EF (Miyake et al., 2000).

Given that the task impurity problem is inherent in EF tasks, it has also been argued to be a critical factor that contributes to inconsistent findings in the bilingualism literature (Friedman, 2016; Paap et al., 2015; Paap & Sawi, 2014; Valian, 2015), because the relation between bilingualism and performance on EF tasks could be confounded by task-specific non-EF processes. Namely, task impurity may not only produce spurious effects driven by task-specific non-EF processes, but also suppress any genuine effects of bilingualism on EF. This, in turn, would hinder the specific task's ability to capture as much variance as possible related to the core EF of interest. The issue is further exacerbated because the majority of previous studies have employed a single measure of EF when examining the effects of bilingualism on EF (e.g., Bialystok et al., 2004; Costa et al., 2009; Prior & Gollan, 2011; Yang & Yang, 2016; see Paap et al., 2015, for a review). Therefore, in order to reconcile these mixed findings in the bilingualism literature, it is vital that we employ extensive batteries of EF and advanced methodologies that can maximize the variance of EF while ruling out the possibility that any observation of bilingual advantages in EF is task-dependent.

The Current Study

In view of the aforementioned conceptual and methodological issues, our objectives are threefold. First, in order to identify bilinguals' key language experience that confers benefits on EF (Yang et al., 2016b), we examined various bilingual interactional contexts and their relations to EF by adopting a theoretically driven approach based on the adaptive control hypothesis (Green & Abutalebi, 2013) and the control process model of code-switching (Green & Wei, 2014). We aimed to examine all three distinct interactional contexts postulated by the adaptive control hypothesis by conceptually distinguishing the dual-language context from the dense code-switching context. To this end, we refined the existing measure of bilingual interactional context (Hartanto & Yang, 2016) by taking into account two possible sources of intraindividual variations in bilingual interactional contexts: (a) intersituation variations (e.g., a bilingual whose home environment resembles a dual-language context and school environment resembles a single-language context); and (b) intrasituation variations (e.g., a bilingual whose home environment engages in either dual-language or single-language contexts at different times).

Second, to test different predictions of the adaptive control hypothesis regarding the influence of bilingual interactional contexts on various control processes, we aimed to assess all core aspects of EF—inhibitory control, task-switching, and working memory—in line with the three-factor unity and diversity model of EF, as proposed by Miyake et al. (2000). Testing all aspects of EF would allow us to extend our understanding of the relation of bilingual interactional contexts to other aspects of EF beyond task-switching.

Third, we employed a latent variable approach to address task impurity and reliability issues in measures of EF. In the latent variable approach, common variance among multiple EF tasks that measure the same underlying construct (e.g., task-switching) is extracted statistically (Bollen, 2002). In doing so, the latent variable approach can exclude idiosyncratic non-EF processes that are specific to individual EF tasks, and thereby provide a purer measure of the construct of EF. Moreover, the latent variable approach increases the reliability of EF tasks, because measurement errors can be excluded after common variance is extracted. In view of these notable strengths of a latent variable approach, we generated three latent variables—inhibitory control, task-switching, and working memory—separately by using three different sets of tasks that tap each of the same core EF processes (Miyake et al., 2000). To this end, we employed three variants of modified flanker tasks (modified arrow flanker task, modified color flanker task, modified Eriksen flanker task), task-switching paradigms (color-shape switching task, magnitude-parity switching task, animacy-locomotion switching task), and complex span tasks (operation span task, symmetry span task, rotation span task) to measure inhibitory control, task-switching, and working memory, respectively.

Moreover, given a notable overlap between Miyake et al.'s (2000) construct of EF and more fine-grained control processes proposed by the adaptive control hypothesis, we also aim to shed light on some aspects of those controlled processes that are conceptually similar to Miyake et al.'s (2000) construct of EF. For example, inhibitory control of Miyake et al.'s (2000) framework is conceptually similar to interference control in the adaptive control hypothesis. Similarly, task-switching in Miyake et al.'s (2000) construct of EF are conceptually comparable with task engagement and task disengagement, as described in the adaptive control hypothesis. Furthermore, we aim to examine the relation between bilingual interactional contexts and goal maintenance, another crucial control process related to EF, which refers to a proactive control process that helps to actively maintain task goals throughout the task and is essential to optimize cognitive performance (Braver, 2012). We assessed goal maintenance by using a well-established task-switching paradigm that consists of two types of blocks: a single-task block and mixed-task block. In the single-task block, all of the trials were refereed as single-task trials because the block consisted of only one type of trial. Thus, task-switching was not required in the single-task block. In the mixed-task block, half of the trials were switch trials, in which participants were required to switch between tasks, and the other half were repeat trials, which required that participants repeat the same task as in the immediately preceding trial. From this configuration, goal maintenance was indexed by mixing costs, which were calculated by subtracting the mean reaction time (RT) of single-task trials in single-task blocks from that of repeat trials in mixed-task blocks; note that task-switching was indexed by switch costs. Even though neither type of trial involves switching between tasks, research has shown a robustly slower response in single-task trials of single-task blocks than repeat trials of mixed-task blocks (Rubin & Meiran, 2005), which has been shown to arise from the failure of proactive goal maintenance processes (Braver, Reynolds, & Donaldson, 2003; Bugg & Braver, 2016; Jong, 2001). Given that the adaptive control hypothesis yields different predictions of the influence of bilingual interactional context on goal maintenance processes, the investigation of goal maintenance is theoretically important.

Based on the adaptive control hypothesis (Green & Abutalebi, 2013) and the control process model of code-switching (Green & Wei, 2014), we formulated four hypotheses. First, we expected that bilinguals with more frequent exposure to a dual-language context would perform better on all aspects of EF—inhibitory control, task-switching, working memory, and goal maintenance—than those with more frequent exposure to either a single-language or dense code-switching context. This hypothesis is based on evidence from neurolinguistics that bilinguals in a 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, however, although the theoretical model does not specifically postulate the relation between bilingual interactional contexts and working memory, we expected that greater exposure to a dual-language context would improve working memory, because not only goal maintenance but also inhibitory control processes are implicated in working memory (Engle, 2002; Kane & Engle, 2003; Meier, Smeekens, Silvia, Kwapil, & Kane, 2018).

Second, we hypothesized that bilinguals with greater exposure to a single-language context would exhibit better inhibitory control and goal maintenance than those with greater exposure to a dense code-switching context. This hypothesis is consistent with the theoretical prediction that bilinguals' single-language context would impose greater demands on inhibitory control and goal maintenance than a dense code-switching context, because only the single-language context would require inhibitory control and goal maintenance to minimize inappropriate switching between languages.

Third, we hypothesized that bilinguals in single-language and dense code-switching contexts would not differ in task-switching or working memory, because both interactional contexts make fewer demands on the control processes implicated in task-switching and working memory. And lastly, we hypothesized that the predicted relation between bilingual interactional contexts and EF would be evident even after controlling for potential confounds, such as socioeconomic status (SES) and intelligence (Hartanto & Yang, 2019; Paap et al., 2015; Valian, 2015).

Method

Participants

Young adult bilinguals ($N = 175$) from a local university in Singapore were recruited for either extra course credit or $30. Our sample size met the minimum requirement of 150 to ensure the robustness of our latent variable analyses for latent factors with three or more indicators (Gerbing & Anderson, 1985; Holbert & Stephenson, 2002). All participants were active bilinguals and spoke at least two of the four official languages of Singapore—Chinese, English, Malay, and Tamil. In addition to English, which is the language of instruction in schools, the majority of bilingual participants spoke Chinese ($n = 165$), followed by Malay ($n = 7$) and Tamil ($n = 3$). We limited our participants to bilinguals who spoke one of Singapore's official languages, as this constraint would allow their daily dense code-switching practices to be comparable in terms of the use of "Singlish," which is a unique English-based creole language that has been substantially influenced by loan words from Mandarin, Malay, and Tamil (Wong, 2004; refer to Appendix B & C). Passive bilinguals who reported that they had never actively used their two languages in their daily lives or had 0% second-language exposure (i.e., usage) were excluded, because they did not fit the criteria for bilingual interactional contexts. Participants' demographic and language characteristics, along with their correlations with bilingual interactional contexts, are presented in Tables 2 and 3.

All procedures were approved by the local Institutional Review Board and participants gave written consent before the study.

Materials

Language background questionnaire. The language background questionnaire, which was adapted from the Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) and the Language History Questionnaire (Li, Zhang, Tsai, & Puls, 2014), was administered to assess bilingual participants' language background, including their age of acquisi-

Table 2

Descriptive Statistics and Correlation Matrix for Bilingual Interactional Contexts and Demographic and Intelligence Variables

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
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 (% male)	34%	—	.05	−.02	−.04	**.58**				
6. Household income[a]	3.94	2.29	.11	**−.19**	.01	**−.31**	−.14			
7. Subjective socioeconomic status[b]	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-IV	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-IV = Peabody Picture Vocabulary Task, 4th edition.

[a] Household income was rated on a scale of 1 (*less than S$2,500*) to 9 (*more than S$20,000*), with intervals of S$2,500. [b] Subjective socioeconomic status was measured by using a ladder scale (first rung = lowest, 10th rung = highest; Adler, Epel, Castellazzo, & Ickovics, 2000).

tion, language proficiency, language usage, and language exposure.

Revised Bilingual Interactional Context Questionnaire. A revised version of the Bilingual Interactional Context Questionnaire (Hartanto & Yang, 2016) was administered to assess bilinguals' interactional contexts. Participants were asked to report the prevalence of each type of bilingual interactional context, as identified by Green and Abutalebi (2013), across four different situations: home, school, work, and others (see Appendix A). Participants used percentages to report whether their daily conversational exchanges in each place (home, school, work, and others) resembled a single-language context (e.g., "I speak only one language and rarely switch to the 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 mix languages within an utterance"), or dense code-switching context (e.g., "I routinely mix two or more languages within an utterance to most speakers at home"). The percentages of all the interactional contexts in each place had to total 100%. Participants also reported the percentage of time they spent at home, school, work, and in other situations. Indices of single-language, dual-language, and dense code-switching contexts were calculated to estimate each participant's prevalence of each type of bilingual interactional context using the following formula:

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

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

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

where p_i denotes the amount of time spent in each situation (home, school, work, or others); sl_i denotes the percentage of a single-language context within a given situation; dl_i denotes the percentage of a dual-language context within a given situation; and dc_i denotes the percentage of a dense code-switching context within a given situation.

The revised version of the Bilingual Interactional Context Questionnaire, which was used in our study, includes a notable change from the previous version (Hartanto & Yang, 2016). In the revised questionnaire, we did not assume that a single-language context is the bipolar opposite of a dual-language context, and thus we

Table 3

Descriptive Statistics and Correlation Matrix for Bilingual Interactional Contexts and Language Characteristics

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
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 (years)	1.08	2.09	−.05	−.03	.00									
5. Age of L2 fluency (years)	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 ($p < .05$). Language proficiency was rated on a 10-point Likert scale (1 = *very low*, 10 = *perfect*; Marian et al., 2007). Data on two participants' age of L2 fluency were missing.

treated each interactional context distinctively. This was done to fully capture all variations in a dense code-switching context as it exists in real life. Specifically, although the previous measure of a bilingual interactional context (Hartanto & Yang, 2016) can accurately assess bilinguals who never encounter a dense code-switching context (0%), it is limited to assessing bilinguals who encounter 100% of dense code-switching context and 0% of both single-language and dual-language contexts. This is because it is not possible to indicate 0% in both single-language and dual-language contexts when they are assumed to exist on a continuum in which 0% experience of a single-language context should always result in 100% experience of a dual-language context, and vice versa. In the case of bilinguals who are purely (100%) dense code-switchers, although unlikely, the previous questionnaire artificially inflates participants' report of their dual-language context because the assumption of bipolar opposites forces them to choose between single-language and dual-language contexts. Given this potential issue, the revised questionnaire allows for better precision and flexibility by taking into account intraindividual variations in bilingual interactional contexts.

Modified arrow flanker task. The modified arrow flanker task served as one of the three measures of inhibitory control. In the task, participants were presented with a row of five arrows in the center of the screen, pointing either left or right, and instructed to identify the direction of the central target arrow as quickly and accurately as possible by pressing either "f" or "j" on the keyboard, labeled "left" and "right," respectively. On each trial, a fixation point appeared first for 350 ms in the center of the screen and was followed by presentation of the target stimulus, which required a participant's response within a 2,000-ms response window. After this, a blank screen appeared for 250 ms before the start of the next trial. In half of the trials, the central target arrow and surrounding arrows pointed in the same direction (i.e., congruent condition), while in the other half (i.e., incongruent condition), the central target arrow and its surrounding arrows pointed in opposite directions. To increase task demand, the central target arrow was displaced toward either the left or right side of the screen in 15% of the trials (i.e., vigilance condition). When the central target arrow was displaced, participants were instructed to press the spacebar, regardless of 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 employed as another measure of inhibitory control. This task is similar to the modified arrow flanker task, except that a row of letters—either G or H—was presented, instead of arrows, in the center of the screen. In the congruent condition, which comprised half of the trials, the central target letter was surrounded by four of the same letter, while in the incongruent condition, the central target appeared in the middle of four different letters. Participants were instructed to identify the central target letter as quickly and accurately as possible by pressing either "g" or "h" on the keyboard, which were labeled "G" and "H," respectively. In the vigilance condition, which comprised 15% of the trials, the target letter appeared displaced toward either the left or right side of the screen, and participants were directed to press the spacebar regardless of the target letter (G or H). Duration of the fixation (350 ms), response window (2,000 ms), and intertrial interval (250 ms), as well as the number of congruent (85), incongruent (85), and vigilance (30) trials, were identical to those in the arrow flanker task.

Modified color flanker task. The modified color flanker task also served as a measure of inhibitory control, in which a row of either red or green square boxes was presented in the center of the screen. Participants were instructed to identify the color of the central target box as quickly and accurately as possible by pressing either "g" or "r" on the keyboard for green and red, respectively. In half of the trials (the congruent condition), the central target box was the same color as the surrounding boxes, and in the other half (incongruent condition) the central target box was a different color from that of the surrounding boxes. In 15% of the trials in the vigilance condition, the central target box appeared displaced either to the left or right, and participants were directed to press the spacebar regardless of the color of the central target box. In total, there were 85 congruent trials, 85 incongruent trials, and 30 vigilance trials, and the duration of the fixation, response window, and intertrial interval were the same as in the flanker tasks described above.

Color-shape switching task. The color-shape switching task adapted from the well-established task-switching paradigm (Hartanto & Yang, 2016; Rubin & Meiran, 2005) was administered as one of three measures of task-switching and goal maintenance. 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 targets (i.e., red triangle or green circle) according to the prescribed color or shape cues. The color cue was represented by a color gradient and the shape cue by a row of small black shapes. Participants used their index fingers to press "d" to indicate red or circle attributes of the target and "k" to indicate green or a triangle attributes. On each trial, a fixation cross appeared for 350 ms and was followed by a blank screen for 150 ms, after which a task cue appeared above the fixation cross and remained until the start of the next trial. After an interval of 250 ms from the onset of the cue, the target stimulus appeared in the center of the screen and remained until the participant responded, after which a blank screen appeared for 850 ms before the next trial.

Participants completed four single-task blocks of either a color or shape task and four mixed-task blocks that included both color and shape tasks. These blocks were arranged in a sandwich-like design, with the first two single-task blocks, four mixed blocks, and the last two single-task blocks presented in this order; the order of the tasks (color vs. shape) in the first two single-task blocks was reversed in the last two single-task blocks. Single-task blocks consisted of 20 main trials per block, and mixed-task blocks consisted of 41 main trials per block. Practice trials were included only in the first two single-task blocks (color vs. shape; eight trials per block) and the first mixed-task block (16 trials). In the mixed-task block, half of the trials were switch trials, on which participants were required to switch between color and shape tasks (or vice versa), and the other half were repeat trials, which required participants to repeat the same task as in the immediately preceding trial. Task cues in the mixed-task blocks were randomly presented, with a maximum of four consecutive trials with the same task cue. The first trial of each of the mixed-task blocks was excluded, as it did not fit with either a switch or repeat trial. There were 80 switch trials, 80 repeat trials, and 80 single-task trials (40 color trials and 40 shape trials).

Magnitude-parity switching task. The magnitude-parity switching task adapted from Von Bastian, Souza, and Gade (2016) assesses task-switching and goal maintenance. The task requires participants to classify a bivalent target digit according to either its parity (odd or even) or magnitude (greater or smaller than 5) based on the given cues. The parity cue was an image depicting an upper row of odd-numbered blue squares and a bottom row of even-numbered yellow squares. The magnitude cue was an image depicting one row of both big blue circles and small yellow circles. The bivalent target digits in the switching task were "2" (an even number less than five) and "7" (an odd number more than five). Depending on the cue presented, participants indicated either the parity (odd or even number) or magnitude (smaller or greater than five) of the bivalent target. Participants used their left index finger to press a key ("d") marked "3" to indicate either an odd number or magnitude smaller than five and right index finger to press another key ("k") marked "6" to indicate an even number or magnitude greater than five. On each trial, a fixation point appeared for 350 ms followed by a blank screen for 150 ms and a subsequent cue that appeared above the fixation and remained on the screen until the end of each trial. After fixating for 250 ms, the target stimulus appeared in the center of the screen and remained until the participant's response was entered, after which an intertrial interval of 850 ms preceded the onset of the next trial. There were a total of 80 switch trials, 80 repeat trials, and 80 single-task trials (40 pure parity trials and 40 pure magnitude trials).

Animacy-locomotion switching task. Similarly, the animacy-locomotion task assessed task-switching and goal maintenance. The task directed participants to classify a bivalent target stimulus according to its animacy (animate or inanimate) or locomotion (flying or nonflying). Animacy was cued by an image of dog paws and bones, while locomotion was cued by an image of road and blue sky. The bivalent target stimuli were a plane (a flying inanimate entity) and rabbit (a nonflying animate entity). In response to the animacy cue, participants indicated whether the target stimulus was animate or inanimate. In response to the locomotion cue, they indicated whether the target stimulus was flying or nonflying. Participants responded by using their left index finger to press a key ("d") that was labeled "bird" to indicate an animate or flying entity, and their right index finger to press a key ("k") labeled "car" to indicate an inanimate or nonflying entity. Similar to the other task-switching tasks, the same numbers of single-task and mixed-task blocks were arranged in a sandwich-like design, and the same kind and number of trials were incorporated. The duration of the fixation (350 ms), fixation-to-cue interval (blank screen, 150 ms), cue-to-stimulus interval (250 ms), and intertrial interval (850 ms) were the same as in the previous task-switching tasks.

Rotation span task. The rotation span task adapted from Foster et al. (2015) was administered as one of the three working memory tasks. Participants judged whether a rotated letter correctly mirrored the target letter. After this, they were presented with either a short or long arrow, pointing in one of eight directions, and asked to remember both the length and direction of the arrow. The number of rotated letters and arrows to recall (i.e., set size) varied from two to five per trial and was randomized across trials. Working memory performance was assessed by the partial-credit unit (PCU) score, which was calculated by dividing the number of arrows correctly recalled by the total number of arrows presented to remember (Conway et al., 2005).

Operation span task. Similarly, the operation span task, adapted from Foster et al. (2015), was used to assess working memory capacity. Participants were first asked to solve a simple mathematical problem, after which they were presented with a to-be-remembered letter. The total number of to-be-remembered letters (i.e., set size) varied from two to five per trial and was randomized across the entire study. Working memory performance was calculated by the same PCU method—that is, the number of correctly recalled letters divided by the total number of letters presented to remember.

Symmetry span task. The symmetry span task (Foster et al., 2015) was also administered as a measure of working memory performance. Participants judged whether a displayed shape was symmetrical along its vertical axis, after which they were asked to remember the location of a red square that appeared in a 4 × 4 grid. The set size—that is, the total number of to-be-remembered locations of a series of red squares—varied from two to five per trial. Working memory performance was calculated using the PCU method described above, by dividing the number of correctly recalled locations of red squares by the total number of red squares presented to remember.

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 of either concrete objects or abstract figures and 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–4th edition (PPVT-4). The PPVT-4 (Dunn & Dunn, 2007) was used to assess participants' verbal intelligence. In this task, participants were shown four pictures and asked to choose the correct picture based on the question. The PPVT-4 also provides age-normed standardized scores, with a mean of 100 and a standard deviation of 15.

Bilingual switching questionnaire. We administered the bilingual switching questionnaire (Rodriguez-Fornells, Krämer, Lorenzo-Seva, Festman, & Münte, 2012) to assess unintended language-switching tendency that is not explained by sociolinguistic or linguistic factors. Participants rated the degree to which each of three described behaviors (three items) characterized their language-switching habits—for example, "I do not realize when I switch the language during a conversation," "It is difficult for me to control the language switches I introduce during a conversation"—on a 5-point Likert scale (1 = *never*, 5 = *always*; $\alpha = .69$).

Procedure

The study was conducted in a quiet computer lab across three separate sessions on three different days to minimize any fatigue effect. In the first session, participants were seated individually in an open cubicle and given the informed consent form to sign. Participants then completed questionnaires about demographics, language background, and bilingual interactional context. After this, in the first session they completed the KBIT-2 and PPVT-4 in a fixed order. In the second session, participants completed the operation span, color-shape, task-switching, modified Eriksen flanker, and rotation span tasks. In the third session, participants completed the modified arrow flanker, animacy-locomotion, task-switching, symmetry span, modified color flanker, and parity-magnitude task-switching tasks. All of the tasks were administered in a fixed order, as listed above, to minimize potential practice effects that could be caused by completing multiple construct-related tasks consecutively. Each session took approximately 60 min to complete.

Results

Data Preprocessing

To improve the construct validity and reliability of inhibitory control and task-switching tasks, we employed a rank-ordered binning procedure, which yields a single comprehensive score for task performance by combining speed and accuracy, as recommended by Draheim, Hicks, and Engle (2016) and Hughes, Linck, Bowles, Koeth, and Bunting (2014). These studies demonstrate that indices calculated from a rank-ordered binning procedure have better construct validity and reliability than pure latency, accuracy, or inverse efficiency scores.

Bin scores were calculated following the recommendation of Draheim et al. (2016; see also Hughes et al., 2014, for details). First, consistent with previous studies (e.g., Hartanto & Yang, 2016; Hernández et al., 2013), we excluded responses that were correct but their RTs fell below 200 ms or were 2.5 *SD* above or below an individual's mean RT for task-switching tasks. For inhibitory control tasks, however, we trimmed outlier RTs based on 3 *SD* cutoff values, because past research has shown that shorter trimming criteria may eliminate potential bilingual advantages in inhibitory control (Zhou & Krott, 2016). After that, we calculated the mean RT of correct repeat trials (in task switching)/congruent trials (in inhibitory control task) for each participant, and subtracted that from the RT of each correct switch/incongruent trial. Because this RT difference was calculated per each correct switch/incongruent trial for each participant, we referred to these as trial-based switch costs in switching tasks and trial-based flanker effects in inhibitory control tasks. Next, all participants' trial-based switch costs/flanker effects were combined, ranked ordered into deciles, and assigned a bin value ranging from 1 to 10. Greater bin values were assigned to trials with relatively larger switch costs (i.e., poorer switching efficiency) or larger flanker effects (i.e., poorer inhibitory-control efficiency), whereas smaller bin values were assigned to trials with relatively smaller switch costs (i.e., better switch efficiency) or smaller flanker effects (better inhibitory control efficiency). Importantly, a penalty was imposed by assigning a higher bin value of 20 to all incorrect responses (Hughes et al., 2014). Lastly, we averaged all of the bin values each participant received for each trial to create a single index of switch costs and flanker effects in terms of bin scores, which ranged from 1 to 20. Overall, lower bin scores for both task-switching and inhibitory control reflect better task-switching and inhibitory-control performance, respectively.

Descriptive statistics and zero-order correlations for all EF tasks are provided in Tables 4 and 5, respectively. Use of the binning procedure allowed relatively higher reliability estimates for most of the tasks employed in the study, even for inhibitory control tasks, which have typically shown lower reliability (Friedman, 2016; Miyake et al., 2000; Paap & Sawi, 2016). Moreover, inspection of the correlation matrix revealed that zero-order correlations among EF tasks were consistent with or even higher than those reported in previous studies (Friedman & Miyake, 2004; Miyake et al., 2000; Paap & Sawi, 2014; Unsworth, Fukuda, Awh, & Vogel, 2014).

Table 4
Descriptive Statistics and Reliability Estimates for EF Tasks

Task	*M*	*SD*	Range	Skewness	Kurtosis	Reliability
Inhibitory control[a]						
Arrow flanker	6.41	2.14	3.69–14.78	1.866	5.757	.925
Color flanker	6.31	.96	3.52–9.24	.166	.726	.709
Eriksen flanker	6.19	.87	4.20–9.66	.940	1.526	.703
Task-switching (switch cost)[a]						
Color-shape switching	6.65	1.48	3.55–12.93	.959	1.908	.866
Magnitude-parity switching	7.09	1.56	4.01–12.36	.842	.939	.874
Animacy-locomotion switching	6.96	1.44	4.52–12.51	.963	1.065	.886
Task-switching (mixing costs)[a]						
Color-shape switching	5.98	1.31	2.44–10.01	−.114	−.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	.773	2.505	.933
Working memory[b]						
Operation span	.87	.13	.36–1.00	−1.516	2.136	.639
Rotation span	.73	.18	.08–1.00	−1.029	1.465	.733
Symmetry span	.80	.16	.26–1.00	−1.054	.574	.735

Note. Lower values for flanker (inhibitory control) and task-switching tasks indicate better performance, while lower values on working memory span tasks indicate poorer performance. Due to technical failures or various errors associated with the experimenter or participants, we had missing data as follows for four tasks: two data points on the arrow flanker, one on the Eriksen flanker, two on the rotation span, and two on the symmetry span. Reliability estimates were computed by the split-half procedure, which was corrected by using the Spearman-Brown prophecy formula.

[a] Calculated by a rank-ordered binning procedure (Hughes, Linck, Bowles, Koeth, & Bunting, 2014). The bin score for mixing costs was calculated by subtracting the mean RT on pure trials in single-task blocks from the RT of each correct repeat trial in mixed-task blocks.

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

Table 5

Correlation Matrix for All EF Tasks

Task	1	2	3	4	5	6	7	8	9	10	11
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 for the flanker and task-switching tasks indicate better performance, while lower values for the working memory span tasks indicate poorer performance.

Latent Variable Approach With a Three-Factor Model

Latent variable analyses were conducted using Mplus 7.4 (Muthén & Muthén, 2012) to estimate the latent variables of inhibitory control, task-switching, and working memory. These latent variables were later regressed on the indices derived from the Revised Bilingual Interactional Context Questionnaire. For latent variable analyses, several fit indices were used to determine model fit. Lower values of Akaike's information criterion (AIC), Bayesian information criterion (BIC), standardized root mean-squared residual (SRMR), and root mean square error of approximation (RMSEA) indicate better fit. In contrast, higher values of Bentler's comparative fit index (CFI) and Tucker-Lewis index (TLI) indicate better fit. For the indices, we followed an established criterion by which an excellent model fit was identified when RMSEA was below .06 (Browne & Cudeck, 1992), CFI and TLI values were close to .95, and SRMR was close to .08 (Hu & Bentler, 1999). Due to technical failures or various errors associated with the experimenter or participants, we had missing data for four tasks: two data points on the arrow flanker, one on the Eriksen flanker, two on the rotation span, and two on the symmetry span. These missing data were imputed by using a maximum likelihood parameter estimation algorithm. Simulation studies have shown that maximum likelihood algorithms are superior to traditional ad hoc missing-data techniques (Arbuckle, 1996; Enders & Bandalos, 2001).

For latent variable analyses, a three-factor model was specified with inhibitory control, task-switching, and working memory as latent variables. The inhibitory control latent variable consisted of flanker effects in terms of bin scores for the arrow flanker, color flanker, and Eriksen flanker tasks. The task-switching latent variable consisted of switch costs in bin scores for the color-shape switching, magnitude-parity switching, and animacy-locomotion switching tasks. The working memory latent variable consisted of PCU scores for the operation span, rotation span, and symmetry span tasks. All measures were specified to load only on the factor of interest, with each factor correlated freely among the latent variables. The fit of the three-factor 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 (i.e., a manifest variable) loaded significantly on its factor of interest, and the factors were significantly intercorrelated (see Figure 1).

Next, a series of structural equation models was estimated, each with additional covariates to ensure robust estimates of the relations between bilingual interactional contexts and EF. In the first model, latent variables of inhibitory control, task-switching, and working memory were regressed on the indices of dual-language and dense code-switching contexts, with the index of a single-language context as the reference (i.e., the control group). Note that to avoid perfect multicollinearity and allow meaningful interpretation of our effect estimates, one interactional context had to be omitted and used as a reference

Table 6

Fit Indices for the Three-Factor Model and Reduced Models

Model	*df*	χ^2	AIC	BIC	SRMR	RMSEA	CFI	TLI
Three-factor model	24	30.01	2773.02	2867.96	.047	.038	.980	.971
Two-factor 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, and higher values of CFI and TLI indicate better fit.

* $p < .05$.

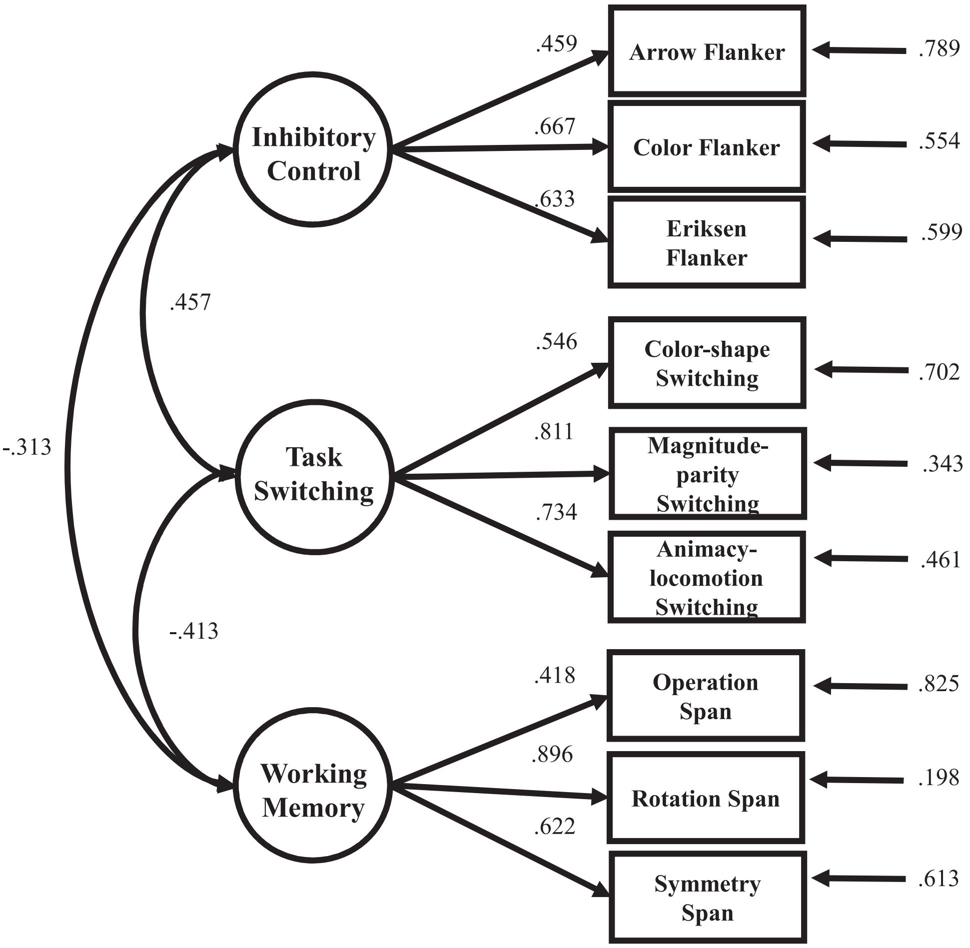

Figure 1. Confirmatory factor analysis of the estimated three-factor model of inhibitory control, task-switching, and working memory. Circles represent the three latent variables and boxes represent individual tasks (manifest variables) that were chosen to tap the specific core component of EF. Curved double-headed arrows connecting latent variables indicate correlations between the constructs. Numbers next to single-headed arrows connecting latent variables to manifest variables represent standardized factor loadings (regression coefficients). Correlations and factor loadings were all significant at the .05 level. Numbers at the ends of the shorter single-headed arrows pointing to manifest variables are error terms.

in the structural equation modeling (see online supplemental material for analyses with either the dual-language context or dense code-switching context as the reference). The first model provides an unadjusted conditional model of the relation between bilingual interactional contexts and EF without taking into account potential covariates. In the second model, demographic covariates, including age, gender, objective SES (household income), and subjective SES were controlled for (Hartanto & Yang, 2019). In the third model, standardized scores of KBIT-2 and PPVT-4 were included as covariates to control for preexisting 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 for to distinguish dense code-switching from unintended code-switching practices, which have been associated with EF deficits (Festman & Münte, 2012; Festman, Rodriguez-Fornells, & Münte, 2010). All of the models had excellent fits, with nonsignificant chi-square values ($ps > .349$), RMSEA lower than .02, CFI higher than 0.98, and TLI higher than 0.98 (see Table 7).

Inhibitory control. Coefficient estimates of bilingual interactional contexts for the latent variable of inhibitory control are summarized in Table 8. A dual-language context, compared with a single-language context, did not significantly predict the latent variable of inhibitory control in any of the models: the unadjusted conditional Model 1 ($\beta = -.136$, $SE = .093$, $t = -1.466$, $p = .143$); Model 2, in which demographics and SES were controlled for ($\beta = -.166$, $SE = .095$, $t = -1.758$, $p = .079$); Model 3, in which nonverbal and verbal intelligence were additionally controlled for ($\beta = -.160$, $SE = .092$, $t = -1.733$, $p = .083$); and Model 4, in which unintended switching was added as a covariate ($\beta = -.157$, $SE = .092$, $t = -1.698$, $p = .090$). However, a dense code-switching, compared with a single-language, context signif-

Table 7

Fit Indices for 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 the dual-language and dense code-switching contexts; Model 2 includes covariates of age, gender, household income, and subjective SES; Model 3 includes additional covariates of nonverbal and verbal intelligence; Model 4 includes an additional covariate of unintended switching.

icantly predicted the latent variable of inhibitory control across the four models: Model 1 ($\beta = -.222$, $SE = .091$, $t = -2.432$, $p = .015$); Model 2 ($\beta = -.234$, $SE = .091$, $t = -2.574$, $p = .010$); Model 3 ($\beta = -.220$, $SE = .088$, $t = -2.492$, $p = .013$); and Model 4 ($\beta = -.220$, $SE = .088$, $t = -2.496$, $p = .013$). The negative coefficient estimates for all four models suggest that higher exposure to a dense code-switching, relative to a single-language, context is associated with better inhibitory control. Nonetheless, it is noteworthy that a dense code-switching, relative to a dual-language, context did not significantly predict the latent variable of inhibitory control in any of the models: Model 1 ($\beta = -.060$, $SE = .143$, $t = -0.423$, $p = .673$); Model 2 ($\beta = -.036$, $SE = .144$, $t = -0.246$, $p = .805$); Model 3 ($\beta = -.029$, $SE = .139$, $t = -0.211$, $p = .833$); and Model 4 ($\beta = -.033$, $SE = .139$, $t = -0.237$, $p = .812$) (see online supplemental material for comparisons based on a different reference group).

Task-switching. Coefficient estimates of bilingual interactional contexts for the latent variable of task-switching are summarized in Table 9. Different from results for the latent variable of inhibitory control (see Table 8), we observed that bilinguals' dual-language context, compared with the single-language context, significantly predicted the latent variable of task-switching in all models: the unadjusted conditional Model 1 ($\beta = -.183$, $SE = .083$, $t = -2.205$, $p = .027$); Model 2, with demographics and SES controlled for ($\beta = -.217$, $SE = .084$, $t = -2.585$, $p = .010$); Model 3, with nonverbal and verbal intelligence controlled for ($\beta = -.201$, $SE = .080$, $t = -2.518$, $p = .012$); and Model 4, with unintended switching controlled for ($\beta = -.214$, $SE = .079$, $t = -2.710$, $p = .007$). The robust negative coefficient estimates suggest that dual-language-context bilinguals' task-switching abilities are superior to single-language-context bilinguals, even after controlling for multiple confounds such as demographics, SES, intelligence, and unintended switching tendency. However, the dense code-switching, compared with the single-language, context did not significantly predict the latent variable of task-switching in any of the models: Model 1 ($\beta = -.135$, $SE = .083$, $t = -1.614$, $p = .106$); Model 2 ($\beta = -.144$, $SE = .084$, $t = -1.751$, $p = .080$); Model 3 ($\beta = -.121$, $SE = .078$, $t = -1.554$, $p = .120$); and Model 4 ($\beta = -.119$, $SE = .077$, $t = -1.549$, $p = .121$). Similarly, the dense code-switching, compared with the dual-language, context did not significantly predict the latent variable of task-switching in any of the models: Model 1 ($\beta = .084$, $SE = .130$, $t = 0.647$, $p = .517$); Model 2 ($\beta = .115$, $SE = .129$, $t = 0.889$, $p = .374$); Model 3 ($\beta = .1191$, $SE = .121$, $t = 0.985$, $p = .325$); and Model 4 ($\beta = .136$, $SE = .119$, $t = 1.140$, $p = .254$). Notably, however, we found that unintended switching significantly predicted the latent variable of task-switching (i.e., poorer task-switching; $\beta = .193$, $SE = .084$, $t = 2.307$, $p = .021$).

Working memory. Coefficient estimates of bilingual interactional contexts for the latent variable of working memory are shown in Table 10. None of the bilingual interactional contexts significantly predicted the latent variable of working memory. Bilinguals' dual-language context, compared with the single-language context, failed to predict the latent variable of working memory in all models: Model 1 ($\beta = .092$, $SE = .083$, $t = 1.097$, $p = .273$); Model 2 ($\beta = .115$, $SE = .086$, $t = 1.339$, $p = .181$); Model 3 ($\beta = .101$, $SE = .078$, $t = 1.296$, $p = .195$); and Model 4 ($\beta = .097$, $SE = .078$, $t = 1.243$, $p = .214$). Likewise, bilinguals' dense code-switching, compared with the single-language, context did not significantly predict the latent variable of

Table 8

Standardized Coefficient Estimates for the Latent Variable of Inhibitory Control

	Model 1		Model 2		Model 3		Model 4	
Variable	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. The single-language context served as the reference for the dual-language and dense code-switching contexts. Gender was dummy coded, with male as the reference category.

$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .001$.

Table 9

Standardized Coefficient Estimates for the Latent Variable of Task-Switching

	Model 1		Model 2		Model 3		Model 4	
Variable	Estimates	*SE*	Estimates	*SE*	Estimates	*SE*	Estimates	*SE*
Predictors								
Dual-language context	$-.183^{*}$	.083	$-.217^{*}$	.084	$-.201^{*}$	.080	$-.214^{*}$	.079
Dense code-switching context	−.135	.083	$-.144^{\dagger}$	.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			$.126^{\dagger}$	.086	.107	.081	.091	.081
Nonverbal intelligence					$-.416^{**}$	.079	$-.369^{**}$	.081
Verbal intelligence					.054	.087	.091	.087
Unintended switching							$.193^{*}$	.084

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

working memory in any of the models: Model 1 ($\beta = -.006$, *SE* = .084, $t = -0.072$, $p = .943$); Model 2 ($\beta = .006$, *SE* = .083, $t = 0.078$, $p = .938$); Model 3 ($\beta = -.022$, *SE* = .076, $t = -0.288$, $p = .773$); and Model 4 ($\beta = -.021$, *SE* = .075, $t = -0.275$, $p = .784$). Moreover, the dense code-switching, compared with the dual-language, context did not significantly predict the latent variable of working memory in any of the models: Model 1 ($\beta = -.141$, *SE* = .128, $t = -1.097$, $p = .273$); Model 2 ($\beta = -.130$, *SE* = .129, $t = -1.006$, $p = .314$); Model 3 ($\beta = -.143$, *SE* = .117, $t = -1.221$, $p = .222$); and Model 4 ($\beta = -.137$, *SE* = .117, $t = -1.171$, $p = .242$).

Latent Variable Approach With a Four-Factor Model

Another primary goal of our research was to examine the relations between bilingual interactional contexts and goal maintenance, an important control process proposed by the adaptive control hypothesis. To this end, we conducted additional structural equation modeling with a four-factor model that consisted of goal maintenance and the three core components of EF—inhibitory control, task-switching, and working memory. The latent variables of inhibitory control, task-switching, and working memory were similar to those of the three-factor model described earlier. For goal maintenance, which involves a proactive control process to facilitate the active maintenance of task goals, the latent variable consisted of mixing costs calculated in bin scores from the color-shape switching, magnitude-parity switching, and animacy-locomotion switching tasks. The bin score was calculated in a similar manner, by subtracting the mean RT on pure trials in single-task blocks from the RT of each correct repeat trial in mixed-task blocks (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 compared with alternative models (see Table 11). More importantly, each measure (indicator) was loaded significantly on its factor of interest, and the factors were significantly intercorrelated (see Figure 2).

Subsequently, as was done for the three-factor structural equation model, four separate models were estimated by including

Table 10

Standardized Coefficient Estimates for the Latent Variable of Working Memory

	Model 1		Model 2		Model 3		Model 4	
Variable	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	$.182^{\dagger}$	.094	$.174^{\dagger}$	.094
Household income			.020	.089	−.027	.082	−.023	.082
Subjective SES			$-.148^{\dagger}$	.086	$-.134^{\dagger}$	.076	$-.136^{\dagger}$	.076
Nonverbal intelligence					$.523^{**}$	.073	$.535^{**}$	.075
Verbal intelligence					.018	.084	.027	.085
Unintended switching							.052	.082

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

Table 11

Fit Indices for the Four-Factor 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								
Inhibitory 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.

$^* p < .05$.

additional covariates: indices of the dual-language and dense code-switching contexts, with the index of the single-language context as the reference (Model 1); age, gender, household income, and subjective SES (Model 2); nonverbal and verbal intelligence (Model 3); and unintended switching (Model 4). As shown in Table 12, all of the models had acceptable to excellent fit, according to the recommended threshold (Browne & Cudeck, 1992; Hu & Bentler, 1999).

Coefficient estimates of bilingual interactional contexts for the latent variable of goal maintenance are displayed in Table 13. Analyses showed that the dual-language, compared with the single-language, context did not significantly predict the latent variable of goal maintenance in any of the models: Model 1 ($\beta = -.042$, $SE = .086$, $t = -0.491$, $p = .623$); Model 2 ($\beta = -.059$, $SE = .088$, $t = -0.677$, $p = .499$); Model 3 ($\beta = -.038$, $SE = .079$, $t = -0.473$, $p = .636$); and Model 4 ($\beta = -.046$, $SE = .079$, $t = -0.576$, $p = .564$). However, the dense code-switching, compared with the single-language, context significantly predicted the latent variable of goal maintenance in the unadjusted conditional Model 1 ($\beta = -.225$, $SE = .083$, $t = -3.059$, $p = .002$); Model 2 ($\beta = -.260$, $SE = .083$, $t = -3.141$, $p = .002$); Model 3 ($\beta = -.231$, $SE = .076$, $t = -3.050$, $p = .002$); and Model 4 ($\beta = -.230$, $SE = .075$, $t = -3.055$, $p = .002$). These results indicate a robust positive association between exposure to a dense code-switching context (relative to a single-language context) and goal maintenance abilities. However, when compared with the dual-language context, the dense code-switching context did not significantly predict the latent variable of goal maintenance in any of the models: Model 1 ($\beta = .065$, $SE = .132$, $t = -0.491$, $p = .623$); Model 2 ($\beta = .091$, $SE = .135$, $t = 0.677$, $p = .499$); Model 3 ($\beta = .058$, $SE = .122$, $t = 0.473$, $p = .636$); and Model 4 ($\beta = .070$, $SE = .122$, $t = 0.576$, $p = .564$).

Furthermore, results from the four-factor model for the latent variables of inhibitory control, task-switching, and working memory were similar to those from the three-factor model. Specifically, the dense code-switching, compared with the single-language, context was positively associated with better latent abilities of inhibitory control, even after controlling for the confounds of demographics, SES, intelligence, and unintended switching. On the other hand, only the dual-language, compared with the single-language, context was positively associated with better latent abilities of task-switching after controlling for multiple confounds (see online supplemental material for the standardized coefficient estimates for the latent variables of inhibitory control, task-switching, and working memory in the four-factor model). Notably, all of our results remained similar and robust when immigrant status—which has confounded previous bilingualism studies (e.g., Valian, 2015)—was included as an additional covariate (see also online supplemental material for more detailed results when immigrant status was controlled for and different references for the bilingual interactional context were used). Our results also remained similar when the age of second language acquisition was controlled for and different RT trimming criteria (2.5 *SD* vs. 3 *SD*) were employed.

Regression Analyses on Individual EF Tasks

Lastly, a series of multiple regressions were conducted to examine the predictability of bilingual interactional contexts on performance on each of the EF tasks. Results are summarized in Table 14. Although we found partly consistent results with those from structural equation modeling, none of the bilingual interactional contexts significantly predicted all of the three tasks that were used to estimate a specific latent variable. For example, although bilinguals' dense code-switching context significantly predicted the latent variable of inhibitory control in all four structural equation models, the dense code-switching context only significantly predicted the bin score of the Eriksen flanker, and not those of the arrow flanker or color flanker. Moreover, significant associations between the dense code-switching context and Eriksen flanker disappeared in Models 3 and 4. These findings demonstrate issues with unreliability and idiosyncratic task-specific effects of EF measures, which in turn underscore the crucial importance of a latent variable approach in examining the relations between bilingualism and EF.

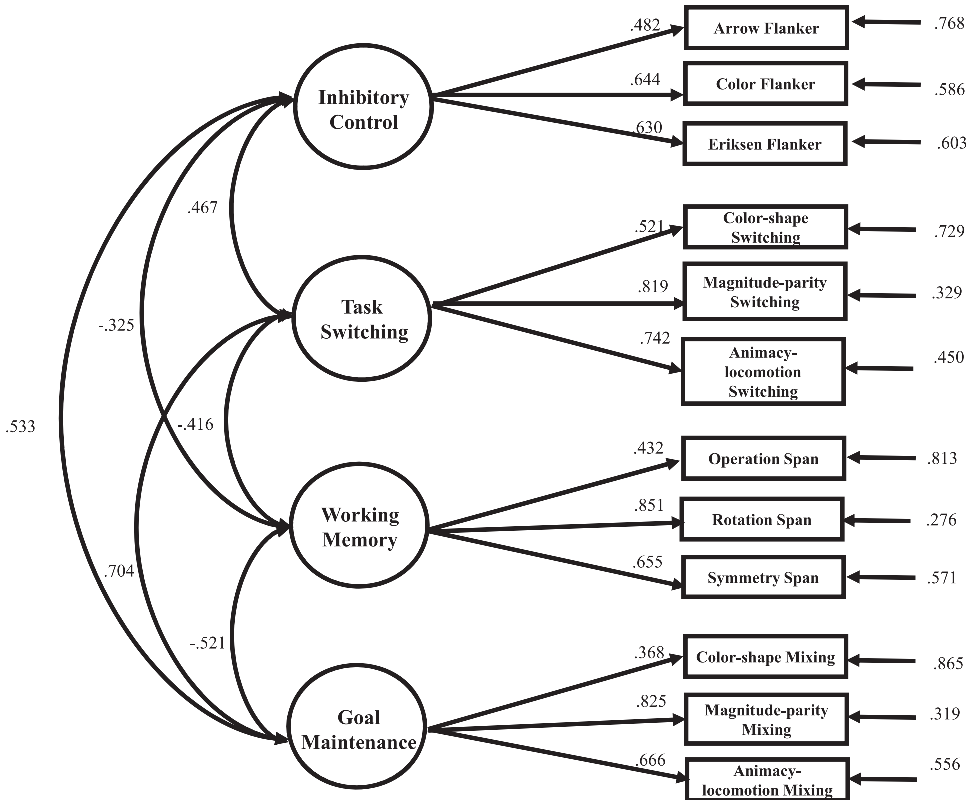

Figure 2. Confirmatory factor analysis of the estimated four-factor model of inhibitory control, task-switching, working memory, and goal maintenance. Circles represent the four latent variables and rectangles represent individual tasks (manifest variables) that were chosen to tap the specific core component of EF. Curved double-headed arrows connecting the latent variables to each other denote correlations between the constructs. Numbers next to single-headed arrows connecting latent variables to manifest variables represent the standardized factor loading. Correlations and factor loadings are all significant at the .05 level. Numbers shown at the end of the shorter single-headed arrows pointing to the manifest variables are error terms.

Discussion

We sought to shed light on inconsistent findings in the bilingualism literature by investigating bilingual interactional contexts of conversational exchanges as key bilingual experiences that moderate bilingual advantages in EF. By employing a finely grained theoretical approach—based on the adaptive control hypothesis (Green & Abutalebi, 2013) and control process model of code-switching (Green & Wei, 2014)—and a sophisticated statistical methodology, latent variable analysis, to address the low reliability of EF tasks and task impurity issues, we systematically examined the relations between various types of bilingual interactional contexts and EF measured by nine separate tasks administered over multiple sessions. Our major findings are discussed below in three sections.

Task-Switching

First, consistent with our hypothesis, we found that bilinguals with greater exposure to a dual-language context than a single-language context displayed better task-switching. More importantly, the finding remained robust even after controlling for well-established confounds such as demographics, SES, and intelligence. This finding is also consistent with the prediction of the adaptive control hypothesis and control process model of code-switching, which postulate that a dual-language context would adaptively enhance bilinguals' task-switching abilities, because the context imposes stronger demands on task-switching than the single-language and dense code-switching contexts do. Our results replicated and extended previous findings of Hartanto and Yang (2016) by showing that dual-language-context bilinguals' better task-switching performance than single-language-context bilinguals can be generalized to other tasks with various task-switching rules, such as magnitude-parity or animacy-locomotion.

Moreover, we found that the frequency of unintended switching—characterized by involuntary and inappropriate language switching that reflects accidental speech errors and is not explained by sociolinguistic or linguistic factors (Rodriguez-Fornells et al., 2012)—was associated with deficits in task-switching. In contrast, as we hypothesized, dense code-switching, which is characterized by more conscious, opportunistic, and voluntary language switching, did not predict task-switching performance. Given that both dense code-switching and unintended switching involve intrasentential code-switching, our findings reveal that intrasentential code-switching is not always associated with deficits in task-switching. Supporting Festman, Rodriguez-Fornells, and Münte's (2010) claim that unin-

Table 12

Fit Indices for the Four-Factor 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 varied with additional covariates. Model 1 consisted of the dual-language and dense code-switching contexts as covariates; Model 2 included additional covariates of age, gender, household income, and subjective SES; Model 3 had additional covariates of nonverbal and verbal intelligence; and Model 4 included an additional covariate of unintended switching.

* $p < .05$.

tended switching is a form of language control failure driven by task-switching deficits, our findings further suggest that the frequency of intrasentential code-switching is not an ideal proxy for a dense code-switching context, as the former could be confounded by task-switching failures in unintended switching.

Our findings on the dual-language context and switch costs can explain, in part, the inconsistency of previous studies. For instance, Paap et al. (2017) failed to find any significant relation between language switching frequency and switch costs when language switching was assessed by general frequency—"I usually switch from one language to the other"—on a 5-point Likert scale (1 = *a couple of times a month*, 5 = *dozens of times a day*). Given that a general language-switching frequency likely captures language-switching within an utterance—which we found not to predict switch costs—Paap et al.'s (2017) null finding can be attributed to a lack of sophistication in assessing qualitative differences in bilinguals' language switching. Moreover, given our finding that unintended language switching is associated with greater switch costs, Paap et al.'s (2017) use of general frequency of language switching does not adequately distinguish language switching from unintended language switching, which in turn could have attenuated the association between language switching and switch costs. Therefore, unless language switching is precisely classified, it is tenuous to argue that language switching does not affect switch costs.

Inhibitory Control and Goal Maintenance

The second notable finding is that, in contrast to our hypothesis and the predictions of the adaptive control hypothesis and control process model of code-switching, bilinguals in dual-language and single-language contexts did not demonstrate better inhibitory control and goal maintenance abilities than those in a dense code-switching context. We found, however, that bilinguals in a dense code-switching context demonstrated significantly better inhibitory control and goal maintenance than those in a single-language context, even after controlling for a set of notable confounding variables. The robust findings suggest that engaging in dense code-switching may involve, and adaptively enhance, inhibitory control and goal maintenance abilities over time.

Although this finding is contrary to our hypothesis, we reason that it may be ascribed to our operationalization of dense code-switching. Importantly, a dense code-switching context was operationalized to implicate, inevitably, both insertion and dense code-switching, which are regarded as different patterns

Table 13

Standardized Coefficient Estimates for the Latent Variable of Goal Maintenance

Variable	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. The single-language context served as the reference for the dual-language and dense code-switching contexts. Gender was dummy coded, with male as the reference category.

† $p < .10$. * $p < .05$. ** $p < .001$.

Table 14

Summary of Standardized Coefficient Estimates From Multiple Regression Analyses Predicting Performance on Individual EF Tasks

	Inhibitory control			Task-switching			Working memory			Goal maintenance		
Predictor	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. 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. The index of the single-language context served as the reference for indices of dual-language and dense code-switching contexts. Arrow flanker, color flanker, Eriksen flanker, color-shape switch costs, magnitude-parity switch costs, and animacy-locomotion switch costs were calculated using the rank-ordered binning procedure (Hughes et al., 2014). Model 1 consisted of the dual-language and dense code-switching contexts; Model 2 included covariates of age, gender, household income, and subjective SES; Model 3 included additional covariates of nonverbal and verbal intelligence measures; Model 4 included an additional covariate of unintended switching. Standardized coefficient estimates for covariates were not displayed for simplicity.

* $p < .05$.

of code-switching; note that according to the adaptive control hypothesis, dense code-switching refers to a context in which bilinguals routinely interleave languages in the course of a single utterance (i.e., dense code-switching) and adapt words from one of the languages into other (i.e., insertion). The distinction between these two types of code-switching is important, because they have different effects on cognitive control. According to the control process model of code-switching (Green & Wei, 2014), insertion should predict better cognitive control than dense code-switching, because insertion relies on a coupled control mode in which two language task schemas take turns passing control from one schema to the other, while dense code-switching operates in an open control mode in which language task schemas do not exert top-down control on language choice (see Green & Wei, 2014, for more details).

Considering this theoretical prediction, our finding of the positive impact of dense code-switching on inhibitory control and goal maintenance can be attributed to our bilinguals' more frequent use of an insertion type of code-switching, which is quite common among Singapore bilinguals. However, because our measure of a dense code-switching context does not differentiate insertion and dense code-switching, which is a limitation of the study, it is important that future studies devise a measure that distinguishes different types of code-switching (i.e., insertion, alternation, and dense code-switching) and take into account the distribution of code-switched utterances within a given conversational interaction. For instance, we suggest employing a more ecologically valid method, such as an ecological momentary assessment (e.g., Jylkkä, Soveri, Laine, & Lehtonen, 2019), which obtains repeated sampling of participants' linguistic experiences in real time.

Alternatively, it is plausible that a dense code-switching context may actually facilitate inhibitory control. Given Green's (2018) recent theoretical account, which has extended his previous control process model of code-switching, an open control mode of dense code-switching is arguably associated with a specific type of inhibitory control because of between-language competition in binding to the functional roles in the utterance plan. This is consistent with Hofweber, Marinis, and Treffers-Daller's (2016) recent findings of better inhibitory control and goal maintenance abilities (as assessed by a flanker task) among highly frequent dense code-switchers. Hofweber et al.'s (2016) reason that this could be because the management of coactivated language structures in a dense code-switching context still implicates inhibitory control. Although it is premature to draw a clear conclusion about the causal mechanism, our findings suggest that bilinguals' dense code-switching context, as compared with either single-language or dual-language contexts, does not necessarily result in poorer EF functioning, especially in inhibitory control and goal maintenance. These findings have important practical implications, given that code-switching is often negatively perceived by bilinguals and monolinguals alike (Chana & Romaine, 1984; Dewaele & Wei, 2014; Lawson & Sachdev, 2000), especially in Singapore's sociolinguistic context (Fong, Lim, & Wee, 2002; Hoon, 2003; Tan & Tan, 2008), in which bilinguals' frequent use of Singlish—characterized by routine code mixing or switching in an utterance and lexical loans of words from one of the languages in the context of other—likely enhances inhibitory control and goal maintenance.

Working Memory

Our last notable finding is that although we predicted that bilinguals in a dual-language context would perform better on working memory tasks than those in the other two interactional contexts, we failed to find any association between interaction context and the latent variable of working memory. These findings suggest that the impact of bilinguals' interactional contexts on EF may be specific to certain aspects of EF—such as inhibitory control, task-switching, and goal maintenance, but not to working memory—although working memory is closely related to inhibitory control and goal maintenance processes (Engle, 2002; Kane & Engle, 2003; Meier et al., 2018). Notably, these results are not entirely inconsistent with the adaptive control hypothesis and control process model of code-switching, both of which are silent regarding the relation between bilinguals' different interactional contexts and the updating of working memory representations. Given that working memory is a multicomponent system that implicates numerous control processes (Conway et al., 2005; Engle, 2002), it is plausible that the various control processes that underlie working memory are not necessarily implicated to the same degree in bilinguals' diverse interactional contexts. Alternatively, cognitive demands on working memory during bilinguals' language production could be similar regardless of bilingual interactional contexts. Therefore, our findings suggest that the influence of bilinguals' interactional contexts on working memory may be more difficult to manifest than its influence on other core components of EF, such as inhibitory control and task-switching. It is noteworthy, however, that the lack of group differences in working memory may not necessarily suggest a null relation between bilingualism and working memory (Yang & Yang, 2017). For instance, Grundy and Timmer's (2016) recent meta-analysis found a small to medium population effect size of .20 in favor of bilingual advantages in working memory over monolinguals. Moreover, Linck, Osthus, Koeth, and Bunting's (2014) meta-analysis of 79 samples, with 3,707 participants, found a robust positive relation between second-language proficiency and working memory, regardless of either verbal or nonverbal working memory tasks. Therefore, it is plausible that other aspects of bilinguals' language experiences can be conducive to modulating bilingual advantages in working memory.

Taken together, our study demonstrates a robust link between bilingual interactional contexts and EF—specifically, in inhibitory control, goal maintenance, and task-switching. Our findings are consistent with Gullifer et al. (2018), who observed enhanced goal maintenance in bilinguals with greater diversity of language usage measured by language entropy across social spheres, in which two languages are used in relative balance. Our study, along with that of Gullifer et al. (2018), underscores the importance of considering bilingual interactional contexts in assessing bilingual advantages in EF. As noted above, most bilingualism studies in the literature have mainly compared EF between bilinguals and monolinguals, while failing to address the fact that bilingualism is a multidimensional construct that implicates diverse dual-language experiences.

Implications and Limitations

Our study is not without limitations. One potential limitation is the lack of monolingual control; hence, caution should be exercised when generalizing our findings to monolinguals. It is noteworthy, however, that comparing monolinguals with bilinguals with disparate language experiences also warrants caution, because collapsing over a wide range of bilingual variations is not necessarily an ideal approach to study bilingualism and EF. For instance, bilinguals in our study revealed a varying extent of interactional contexts, which suggests that a bilingual interactional context should be considered as a continuous variable (Gullifer & Titone, 2019).

Despite the absence of a monolingual comparison group, our findings, in the context of previous work that compares bilinguals with monolinguals, imply that bilingual advantages over monolinguals in task-switching are more likely to be observed in dual-language-context bilinguals. On the other hand, bilingual advantages in inhibitory control and goal maintenance over monolinguals are more likely to be found in dense code-switching-context bilinguals, especially among those who frequently engage in an insertion type of code-switching, than single-language context bilinguals. This explains in part why previous studies on Catalan-Spanish bilinguals in Catalonia who frequently engage in insertion (Rodriguez-Fornells et al., 2012) tend to report bilingual advantages in 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, 2016; Hernández et al., 2013). Our view is also consistent with that of Woumans, Ceuleers, Van der Linden, Szmalec, and Duyck's (2015) findings of enhanced inhibitory control and goal maintenance in balanced French-Dutch bilinguals who are fluent in language switching. Moreover, given that the majority of bilingualism studies that compare bilinguals with monolinguals on EF tasks have found either null effects or bilingual advantages, but not bilingual disadvantages (Bialystok, Kroll, Green, MacWhinney, & Craik, 2015; de Bruin et al., 2015), it is less likely that single-language-context bilinguals—who were found to perform worse on a number of EF tasks than bilinguals in other interactional contexts— could have lower EF than monolinguals. It is important to note, however, that because most previous studies did not provide comprehensive profiles of their bilingual participants' sociolinguistic environments and interactional contexts (Surrain & Luk, 2017), it is difficult to infer the impact of bilingual interactional contexts on EF in these studies. Therefore, future studies are warranted to assess bilingual interactional contexts in order to more comprehensively understand the relation between bilingualism and EF.

Another potential limitation is the correlational nature of the study, which limits causal interpretation of our findings. One could argue that the relations between bilingual interactional contexts and EF could be driven by the effect of EF on bilingual interactional contexts. For example, it is possible that bilinguals with higher inhibitory control and goal maintenance may prefer dense code-switching contexts more than those in single-language or dual-language contexts. Although our study's design does not completely rule out this alternative interpretation, the reverse relationship is less likely, because bilingual interactional contexts are mostly determined by the linguistic traditions of a bilingual environment. In addition, in view of the prevalent negative perception of dense code-switching in Singapore's sociolinguistic context (Fong et al., 2002; Hoon, 2003; Tan & Tan, 2008), it is less likely that bilinguals with higher EF in our study would voluntarily choose a dense code-switching context.

Lastly, our study is also susceptible to the presence of third variables that may have confounded the relation between bilingual interactional contexts and EF. Although we have controlled for demographics, SES, intelligence, and unintended switching tendency in four separate models, we were not able to rule out a wide array of confounding variables (Hartanto & Yang, 2019). Thus, it is still important that future studies replicate our findings in other sociolinguistic contexts with a larger sample size and more comprehensive list of control variables. In addition, given that the majority of our bilinguals are early bilinguals and English is the language of instruction in all schools, we used the English PPVT-4 as a measure of verbal intelligence. However, the English PPVT-4 may not be the best assessment tool for verbal intelligence, especially for those who are more proficient in the other language.

Contributions and Future Directions

Despite the limitations described above, our study's methodological advance is noteworthy. First, the use of a latent variable approach and rank-ordered binning procedure circumvents task impurity, low construct validity, and reliability issues in EF tasks, all of which have plagued the bilingualism literature for several decades (Friedman, 2016). We believe that our relatively large sample size and the use of latent variables—which account for measurement errors that can cause task impurity issue and lower reliability of EF tasks—have increased the statistical power necessary to detect the true effect of bilingual interactional contexts on EF. As demonstrated in our analyses, when each of the EF tasks was analyzed separately, we found inconsistent relations between bilingual interactional context and EF. Thus, without the use of a latent variable approach, there is a heightened possibility of misinterpreting results or drawing an inaccurate conclusion by which the relation between bilingual interactional context and EF is task-specific.

Second, our use of the Revised Bilingual Interactional Context Questionnaire allowed us to simultaneously examine the three distinct bilingual interactional contexts and take into account both intersituation and intrasituation variations of bilingual interactional contexts. The Revised Interactional Context Questionnaire allows conceptually more advanced assessment of bilingual interactional contexts, and thus should replace the previous version, which measures dual-language-context bilingualism (Hartanto & Yang, 2016).

There are several notable avenues for future research. First, it is important to empirically examine bilingual interactional contexts in line with more fine-grained control processes proposed by the adaptive control hypothesis. In particular, the adaptive control hypothesis postulates that dense code-switching should impose greater cognitive demand on opportunistic planning—one of the control processes that can be influenced by bilingual interactional contexts—because bilinguals in a dense code-switching context usually plan their speech opportunistically by mixing languages within an utterance. Considering this, particular attention should be paid to the relation between bilingual interactional contexts and nonverbal opportunistic planning performance.

Further, future studies should extend their focus on other relevant cognitive abilities (e.g., creativity or cognitive flexibility) beyond major control processes. In particular, the control process model of code-switching proposes the possibility that bilinguals in a dense code-switching context would exert enhanced creativity, because they likely exercise creative code-switching. In line with this notion, a recent study by Kharkhurin and Wei (2015) found enhanced creativity among habitual code-switchers. More studies are needed, therefore, to confirm important theoretical predictions. Moreover, it is important that future studies ensure convergence validity by incorporating other measures of bilingual interactional contexts, such as language entropy, which estimates the social diversity of language use within and across bilingual communicative contexts (Gullifer & Titone, 2019), which in turn would contribute to triangulating the relation between bilingual interactional contexts and EF. Relatedly, it would be worthwhile to investigate potential interactions between bilingual interactional contexts and other bilingual characteristics, such as age of second language acquisition, in influencing EF.

Conclusion

In sum, given that bilingualism is a multidimensional construct (Luk & Bialystok, 2013), more finely grained examination of the various bilingual experiences that contribute to interindividual variations in EF would be highly valuable. Our study contributes to the bilingualism literature by demonstrating that the bilingual interactional context is a key bilingual experience that modulates bilingual advantages in EF. Bilingual interactional contexts are a promising avenue for research that could not only reconcile discrepancies in the literature but also shed light on the mechanisms that drive the interplay between experiential factors and EF and higher-order 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,* 557–582. http://dx.doi.org/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,* 207–245. http://dx.doi.org/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,* 586–592. http://dx.doi.org/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. http://dx.doi.org/10.1016/j.jml.2016.04.007

Arbuckle, J. L. (1996). Full information estimation in the presence of incomplete data. In G. A. Marcoulides & R. E. Schumacker (Eds.), *Advanced structural equation modeling* (pp. 243–277). Mahwah, NJ: Erlbaum.

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,* 122–141. http://dx.doi.org/10.1196/annals.1412.011

Bak, T. H. (2015). Beyond a simple "yes" and "no." *Cortex, 73,* 332–333. http://dx.doi.org/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,* e0153485. http://dx.doi.org/10.1371/journal.pone.0153485

Bak, T. H., Nissan, J. J., Allerhand, M. M., & Deary, I. J. (2014). Does bilingualism influence cognitive aging? *Annals of Neurology, 75,* 959–963. http://dx.doi.org/10.1002/ana.24158

Beatty-Martínez, A. L., & Dussias, P. E. (2017). Bilingual experience shapes language processing: Evidence from codeswitching. *Journal of Memory and Language, 95,* 173–189. http://dx.doi.org/10.1016/j.jml.2017.04.002

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30,* 331–351. http://dx.doi.org/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,* 68–79. http://dx.doi.org/10.1037/cjep2006008

Bialystok, E. (2017). The bilingual adaptation: How minds accommodate experience. *Psychological Bulletin, 143,* 233–262. http://dx.doi.org/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,* 290–303. http://dx.doi.org/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,* 859–873. http://dx.doi.org/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,* 1341–1354. http://dx.doi.org/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,* 944–946. http://dx.doi.org/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,* 325–339. http://dx.doi.org/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. *The International Journal of Bilingualism, 9,* 103–119. http://dx.doi.org/10.1177/13670069050090010701

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

Bollen, K. A. (2002). Latent variables in psychology and the social sciences. *Annual Review of Psychology, 53,* 605–634. http://dx.doi.org/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,* 387–398. http://dx.doi.org/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,* 195–208. http://dx.doi.org/10.1017/S136672891600119X

Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences, 16,* 106–113. http://dx.doi.org/10.1016/j.tics.2011.12.010

Braver, T. S., Reynolds, J. R., & Donaldson, D. I. (2003). Neural mechanisms of transient and sustained cognitive control during task switching. *Neuron, 39,* 713–726. http://dx.doi.org/10.1016/S0896-6273(03)00466-5

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

Bugg, J. M., & Braver, T. S. (2016). Proactive control of irrelevant task rules during cued task switching. *Psychological Research, 80,* 860–876. http://dx.doi.org/10.1007/s00426-015-0686-5

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,* 205–228. http://dx.doi.org/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,* 273–293. http://dx.doi.org/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,* 282–298. http://dx.doi.org/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,* 447–473. http://dx.doi.org/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,* 769–786. http://dx.doi.org/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,* 135–149. http://dx.doi.org/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,* 59–86. http://dx.doi.org/10.1016/j.cognition.2006.12.013

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. http://dx.doi.org/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*. Advance online publication. http://dx.doi.org/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,* 1752–1765. http://dx.doi.org/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. http://dx.doi.org/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,* 99–107. http://dx.doi.org/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,* 235–251. http://dx.doi.org/10.1080/01434632.2013.859687

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135–168. http://dx.doi.org/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 D. C. Noelle, R. Dale, A. S. Warlaumont, J. Yoshimi, T. Matlock, C. D. Jennings, & P. P. Maglio (Eds.), *Proceedings of the 37th annual meeting of the cognitive science society* (pp. 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,* 133–155. http://dx.doi.org/10.1177/1745691615596990

Dunn, L. M., & Dunn, L. M. (2007). *PPVT-III: Peabody picture vocabulary test.* Minneapolis, MN: Pearson.

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,* 1–10. http://dx.doi.org/10.1177/108705470400800101

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling, 8,* 430–457. http://dx.doi.org/10.1207/S15328007SEM0803_5

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

Festman, J., & Münte, T. F. (2012). Cognitive control in Russian-German bilinguals. *Frontiers in Psychology*. Advance online publication. http://dx.doi.org/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,* 5. http://dx.doi.org/10.1186/1744-9081-6-5

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,* 314–336. http://dx.doi.org/10.1037/ocp0000086

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. http://dx.doi.org/10.1016/j.learninstruc.2013.11.003

Fong, V., Lim, L., & Wee, L. (2002). "Singlish": Used and abused. *Asian Englishes, 5,* 18–39. http://dx.doi.org/10.1080/13488678.2002.10801087

Foster, J. L., Shipstead, Z., Harrison, T. L., Hicks, K. L., Redick, T. S., & Engle, R. W. (2015). Shortened complex span tasks can reliably measure working memory capacity. *Memory & Cognition, 43,* 226–236. http://dx.doi.org/10.3758/s13421-014-0461-7

Friedman, N. P. (2016). Research on individual differences in executive functions. *Linguistic Approaches to Bilingualism, 6,* 535–548. http://dx.doi.org/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,* 101–135. http://dx.doi.org/10.1037/0096-3445.133.1.101

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

Gerbing, D. W., & Anderson, J. C. (1985). The effects of sampling error and model characteristics on parameter estimation for maximum likelihood confirmatory factor analysis. *Multivariate Behavioral Research, 20,* 255–271. http://dx.doi.org/10.1207/s15327906mbr2003_2

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,* 984–994. http://dx.doi.org/10.1016/j.chb.2011.12.020

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1,* 67–81. http://dx.doi.org/10.1017/s1366728998000133

Green, D. W. (2018). Language control and code-switching. *Languages, 3,* 8. http://dx.doi.org/10.3390/languages3020008

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

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

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

Gullifer, J. W., Chai, X. J., Whitford, V., Pivneva, I., Baum, S., Klein, D., & Titone, D. (2018). Bilingual experience and resting-state brain connectivity: Impacts of L2 age of acquisition and social diversity of language use on control networks. *Neuropsychologia, 117,* 123–134. http://dx.doi.org/10.1016/j.neuropsychologia.2018.04.037

Gullifer, J. W., & Titone, D. (2019). Characterizing the social diversity of bilingualism using language entropy. *Bilingualism: Language and Cognition*. Advance online publication. http://dx.doi.org/10.1017/S1366728919000026

Hartanto, A., & Suárez, L. (2016). Conceptual representation changes in Indonesian–English bilinguals. *Journal of Psycholinguistic Research, 45,* 1201–1217. http://dx.doi.org/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,* 1125–1136. http://dx.doi.org/10.3758/s13414-016-1068-9

Hartanto, A., Toh, W. X., & Yang, H. (2019). Bilingualism narrows socioeconomic disparities in executive functions and self-regulatory behaviors during early childhood: Evidence from the early childhood longitudinal study. *Child Development, 90,* 1215–1235. http://dx.doi.org/10.1111/cdev.13032

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

Hartanto, A., & Yang, H. (2019). Does early active bilingualism enhance inhibitory control and monitoring? A propensity-matching analysis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45,* 360–378. http://dx.doi.org/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. http://dx.doi.org/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,* 315–325. http://dx.doi.org/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,* 257–276. http://dx.doi.org/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,* 58–65. http://dx.doi.org/10.1038/nrn2298

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

Holbert, R. L., & Stephenson, M. T. (2002). Structural equation modeling in the communication sciences, 1995–2000. *Human Communication Research, 28,* 531–551. http://dx.doi.org/10.1093/hcr/28.4.531

Hoon, C. H. (2003). "You see me no up": Is Singlish a problem? *Language Problems and Language Planning, 27,* 45–62. http://dx.doi.org/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, 6,* 1–55. http://dx.doi.org/10.1080/10705519909540118

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

Hughes, M. M., Linck, J. A., Bowles, A. R., Koeth, J. T., & Bunting, M. F. (2014). Alternatives to switch-cost scoring in the task-switching paradigm: Their reliability and increased validity. *Behavior Research Methods, 46,* 702–721. http://dx.doi.org/10.3758/s13428-013-0411-5

Jong, R. D. (2001). Adult age differences in goal activation and goal maintenance. *The European Journal of Cognitive Psychology, 13,* 71–89. http://dx.doi.org/10.1080/09541440042000223

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

Jylkkä, J., Soveri, A., Laine, M., & Lehtonen, M. (2019). Assessing bilingual language switching behavior with Ecological Momentary Assessment. *Bilingualism: Language and Cognition*. Advance online publication. http://dx.doi.org/10.1017/S1366728918001190

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,* 47–70. http://dx.doi.org/10.1037/0096-3445.132.1.47

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Brief Intelligence Test* (2nd ed.). Circle Pines, MN: American Guidance Service.

Kharkhurin, A. V., & Wei, L. (2015). The role of code-switching in bilingual creativity. *International Journal of Bilingual Education and Bilingualism, 18,* 153–169. http://dx.doi.org/10.1080/13670050.2014.884211

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,* 640–648. http://dx.doi.org/10.1080/20445911.2014.929580

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

Kroll, J. F., Dussias, P. E., Bogulski, C. A., & Valdes-Kroff, J. R. (2012). Juggling two languages in one mind. *Psychology of Learning and Motivation, 56,* 229–262. http://dx.doi.org/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,* 445–453. http://dx.doi.org/10.1037/neu0000145

Lawson, S., & Sachdev, I. (2000). Codeswitching in Tunisia: Attitudinal and behavioural dimensions. *Journal of Pragmatics, 32,* 1343–1361. http://dx.doi.org/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,* 59–80. http://dx.doi.org/10.1348/026151003321164627

Li, P., Zhang, F., Tsai, E., & Puls, B. (2014). Language History Questionnaire (LHQ 2.0): A new dynamic web-based research tool. *Bilingualism: Language and Cognition, 17,* 673–680. http://dx.doi.org/10.1017/s1366728913000606

Linck, J. A., Osthus, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review, 21,* 861–883. http://dx.doi.org/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,* 605–621. http://dx.doi.org/10.1080/20445911.2013.795574

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research, 50,* 940–967. http://dx.doi.org/10.1044/1092-4388(2007/067)

Marian, V., & Shook, A. (2012). The cognitive benefits of being bilingual. *Cerebrum*. Advance online publication. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3583091/

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6,* 97–115. http://dx.doi.org/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,* 81–93. http://dx.doi.org/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,* 68–84. http://dx.doi.org/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,* 49–100. http://dx.doi.org/10.1006/cogp.1999.0734

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7,* 134–140. http://dx.doi.org/10.1016/S1364-6613(03)00028-7

Mor, B., Yitzhaki-Amsalem, S., & Prior, A. (2015). The joint effect of bilingualism and ADHD on executive functions. *Journal of Attention Disorders, 19,* 527–541. http://dx.doi.org/10.1177/1087054714527790

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,* 1425–1433. http://dx.doi.org/10.1177/0956797611416999

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

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology, 66,* 232–258. http://dx.doi.org/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. http://dx.doi.org/10.1016/j.cortex.2015.04.014

Paap, K. R., Myuz, H. A., Anders, R. T., Bockelman, M. F., Mikulinsky, R., & Sawi, O. M. (2017). No compelling evidence for a bilingual advantage in switching or that frequent language switching reduces switch cost. *Journal of Cognitive Psychology, 29,* 89–112. http://dx.doi.org/10.1080/20445911.2016.1248436

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*. Advance online publication. http://dx.doi.org/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. http://dx.doi.org/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,* 125–135. http://dx.doi.org/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,* 313–325. http://dx.doi.org/10.1037/a0035224

Peretz, I., & Zatorre, R. J. (2005). Brain organization for music processing. *Annual Review of Psychology, 56,* 89–114. http://dx.doi.org/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,* 535–551. http://dx.doi.org/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,* 682–691. http://dx.doi.org/10.1017/S1355617711000580

Prior, A., & MacWhinney, B. (2009). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13,* 253–262. http://dx.doi.org/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,* 300–309. http://dx.doi.org/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,* 398–403. http://dx.doi.org/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*. Advance online publication. http://dx.doi.org/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,* 1477–1491. http://dx.doi.org/10.1037/0278-7393.31.6.1477

Schmidt, K.-H., Neubach, B., & Heuer, H. (2007). Self-control demands, cognitive control deficits, and burnout. *Work and Stress, 21,* 142–154. http://dx.doi.org/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,* 749–768. http://dx.doi.org/10.1007/s11145-013-9470-3

Smith, E. E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science, 283,* 1657–1661. http://dx.doi.org/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: Human Experimental Psychology, 59,* 745–759. http://dx.doi.org/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*. Advance online publication. http://dx.doi.org/10.1017/S1366728917000682

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

Teper, R., & Inzlicht, M. (2013). Meditation, mindfulness and executive control: The importance of emotional acceptance and brain-based performance monitoring. *Social Cognitive and Affective Neuroscience, 8,* 85–92. http://dx.doi.org/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. http://dx.doi.org/10.1016/j.cogpsych.2014.01.003

Valian, V. (2015). Bilingualism and cognition. *Bilingualism: Language and Cognition, 18,* 3–24. http://dx.doi.org/10.1017/S1366728914000522

van der Ven, S. H. G., Kroesbergen, E. H., Boom, J., & Leseman, P. P. M. (2013). The structure of executive functions in children: A closer examination of inhibition, shifting, and updating. *British Journal of Developmental Psychology, 31,* 70–87. http://dx.doi.org/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,* 458–483. http://dx.doi.org/10.1006/jmla.1998.2584

Von Bastian, C. C., De Simoni, C., Kane, M. J., Carruth, N. P., & Miyake, A. (2017, November). *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,* 246–258. http://dx.doi.org/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*. Advance online publication. http://dx.doi.org/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,* 959–974. http://dx.doi.org/10.1037/a0028281

Will 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,* 750–759. http://dx.doi.org/10.1177/1359105310390247

Wong, J. (2004). The particles of Singapore English: A semantic and cultural interpretation. *Journal of Pragmatics, 36,* 739–793. http://dx.doi.org/10.1016/s0378-2166(03)00070-5

Woumans, E., Ceuleers, E., Van der Linden, L., Szmalec, A., & Duyck, W. (2015). Verbal and nonverbal cognitive control in bilinguals and interpreters. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41,* 1579–1586. http://dx.doi.org/10.1037/xlm0000107

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

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

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

Yang, H., Hartanto, A., & Yang, S. (2018). Bilingualism confers advantages in task switching: Evidence from the dimensional change card sort task. *Bilingualism: Language and Cognition, 21,* 1091–1109. http://dx.doi.org/10.1017/S136672891700044X

Yang, H., & Yang, S. (2017). Are all interferences bad? Bilingual advantages in working memory are modulated by varying demands for controlled processing. *Bilingualism: Language and Cognition, 20,* 184–196. http://dx.doi.org/10.1017/S1366728915000632

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. http://dx.doi.org/10.1016/j.jecp.2016.01.011

Zhou, B., & Krott, A. (2016). Data trimming procedure can eliminate bilingual cognitive advantage. *Psychonomic Bulletin & Review, 23,* 1221–1230. http://dx.doi.org/10.3758/s13423-015-0981-6

(*Appendices follow*)

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 answers carefully.**

	List percentage here
I speak only one language and rarely switch to the other language at **home**	
I speak two (or more languages) when I converse with different speakers at **home**. I often switch languages but rarely mix 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 answers carefully.**

	List percentage here
I speak only one language and rarely switch to the other language at **school**	
I speak two (or more languages) when I converse with different speakers at **school**. I often switch languages but rarely mix 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 answers carefully.**

	List percentage here
I speak only one language and rarely switch to the other language at **work**	
I speak two (or more languages) when I converse with different speakers at **work**. I often switch languages but rarely mix 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 answers carefully.**

	List percentage here
I speak only one language and rarely switch to the 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 mix 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**	

(*Appendices continue*)

Appendix B

Distribution of Bilingual Interactional Contexts as a Function of Bilinguals' Language Pair

Bilingual interactional context	English-Chinese Bilingual ($n = 165$)	English-Malay Bilingual ($n = 7$)	English-Tamil Bilingual ($n = 3$)
Single-language context (%)	53%^{a}	33%^{a}	44%^{a}
Dual-language context (%)	23%^{a}	17%^{a}	33%^{a}
Dense code-switching context (%)	24%^{a}	50%^{b}	23%^{a}

Note. Mean percentages bearing different superscript letters differ significantly from each other within the same row ($p < .05$).

Appendix C

Examples of Dense Code-Switching Context in English-Chinese, English-Malay, and English-Tamil Bilinguals in Singapore

Dense code-switching example	English translation
Zhe ge event very *sian leh*. I think we should *zao yi dian* go home *shui jiao la.*	This event is very boring. I think we should go home earlier and rest.
If you are hungry, we can *lepak* for a while *dan makan* some *ayam penyet.*	If you are hungry, we can rest for a while and eat some fried chicken.
Machi, the saapadu I ate was *romba mosam.*	Bro, the food I ate was really bad.