Bilingualism: Language and Cognition

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Research Article

Cite this article: Yang, H., Tng, G.Y.Q., Ng, W.Q., & Yang, S. (2024). Bilingual profiles differentially predict executive functions during early childhood: A latent profile analysis. *Bilingualism: Language and Cognition*, **27**, 164–177. https://doi.org/10.1017/S1366728923000263

Received: 17 January 2022
Revised: 3 March 2023
Accepted: 6 March 2023
First published online: 31 May 2023

Keywords:
Bilingual profiles; executive functions; latent profile analysis; switching; working memory; inhibitory control; prepotent response inhibition

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Bilingual profiles differentially predict executive functions during early childhood: A latent profile analysis

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Abstract

Recent studies suggest that heterogeneous bilingual experiences implicate different executive functions (EF) in children. Using a latent profile analysis, we conducted a more nuanced investigation of multifaceted bilingual experiences. By concurrently considering numerous bilingual indicators – age of L1 and L2 acquisition, interactional contexts of verbal exchanges, L1 and L2 proficiency, balance of language use at home and school, and receptive vocabulary – we identified three latent profiles (subgroups): balanced dual-language, dominant single-language, and mixed-interaction. We found that the balanced dual-language and dominant single-language profiles predicted significantly better switching than the mixed-interaction profile. However, no profile differences were found in working memory, prepotent response inhibition, or inhibitory control. These results held true when multiple covariates (age, sex, household income, and non-verbal intelligence) were controlled for. Using a person-centered approach, our study underscores that disparate bilingual experiences asymmetrically predict the shifting facet of EF during early childhood.

Introduction

The relation between bilingualism and executive functions (EF) – an array of cognitive processes crucial for goal-oriented behaviors (Miyake et al. 2000) – in young children has received considerable attention. However, the subject is open to debate due to inconsistent findings in the literature. On one hand, a number of studies have demonstrated enhanced EF performance in bilingual, compared with monolingual, preschoolers (e.g., Bialystok, 2010; Carlson & Meltzoff, 2008; Yang et al., 2011). Others, however, have found no differences between the two groups (Gathercole et al. 2014; Hilchey & Klein, 2011; Jaekel et al. 2019). In view of these conflicting findings, previous studies focused on specific bilingual characteristics such as age of second language acquisition or active bilingualism (i.e., early versus late), language proficiency, interactional contexts, and balanced language use, among others, which could modulate bilingual advantages (e.g., Kalia et al., 2014; Pelham & Abrams, 2014; Struys et al. 2015). However, most of these studies focused on adult participants (e.g., Luk et al. 2011b; Yow & Li, 2015); relatively little is known about young children.

Further, despite recent conceptual (e.g., adaptive control hypothesis) and methodological progress in resolving prevailing inconsistencies in the literature (Beatty-Martínez et al. 2020; Hartanto & Yang, 2016, 2019; Kałamała et al. 2020), prior studies are limited, since they classify bilingual children based on a single dimension or limited linguistic dimensions such as the number of languages a child speaks (e.g., Bialystok, 2010; Blom et al. 2014; Yang et al., 2011); the degree of exposure to the first and second language (e.g., Carlson & Meltzoff, 2008; Poulin-Dubois et al. 2011); and relative proficiency in both languages (e.g., Bosma et al. 2017; White & Greenfield, 2017). This approach has drawn criticism, because it disregards the multifaceted and disparate bilingual experiences that may differently shape EF (e.g., Yang et al., 2016). To address these issues, other studies have focused on several bilingual characteristics in combination. For instance, Verhagen, de Bree, and Unsworth (2020) examined bilingual language use at home (degree of balanced language use) and parent-rated language proficiency in relation to young children's cognitive control, and Yow and Li (2015) focused on the balanced use of two languages and their proficiencies in young adults. Although these studies have considered relatively more bilingual characteristics, it is vital that we account for the wider spectrum of bilingual experiences by identifying qualitatively discrete bilingual profiles based on a more diverse range of bilingual characteristics.

Accordingly, the traditional categorical approach to defining bilinguals can be problematic, since it fails to consider heterogeneous bilingual characteristics that are intricately tied to other

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individual differences (Gunnerud et al. 2020). This, among other issues, could obscure the genuine relation between bilingualism and EF (de Bruin, 2019; Takahesu Tabori et al., 2018), which highlights the need for a more sophisticated approach that accounts for heterogeneity across bilinguals. To this end, we used latent profile analysis – i.e., a person-centered approach – to identify qualitatively distinct bilingual profiles by statistically determining one's profile membership according to the patterns across numerous bilingual characteristics (i.e., indicators). Compared with a traditional variable-centered approach, a person-centered approach allows us to examine how multidimensional bilingualism would operate within individuals according to their qualitatively distinct profiles (Wang & Hanges, 2010). As a result, a person-centered approach provides richer information on bilingual heterogeneity than the traditional variable-centered approach. Using a latent profile method, therefore, we sought to determine whether distinctive bilingual profiles, which signify heterogeneous bilingual experiences, would uniquely predict various aspects of EF assessed by a battery of tasks.

Bilingualism and executive functions

EF have been shown to play a crucial role in cognitive development during early childhood (Diamond, 2002) and to predict academic achievement (Röthlisberger, et al. 2013) and a broad range of outcomes in later life (Diamond, 2013). The construct of EF comprises three different but interrelated facets (Miyake et al., 2000): (a) inhibition, which can be more finely differentiated as prepotent response inhibition (an ability to suppress predominant or automatic responses; Nigg, 2000) and inhibitory control (an ability to suppress irrelevant stimuli that interfere with attention); (b) shifting, which is the ability to switch back and forth between different task sets; and (c) working memory, which is the ability to retain and manipulate information.

Importantly, bilingualism has been identified as an experiential factor that modifies the development of EF (Diamond & Lee, 2011; Tran et al., 2019), since managing two linguistic systems that are concurrently activated, even in contexts that involve only one of them (Martin et al. 2009), imposes cognitive demands on various aspects of EF and thereby improves bilinguals' EF skills (Bialystok, 2009; Green, 1998). Specifically, this joint activation of two languages requires that bilinguals exercise inhibition in order to attend to the target language while suppressing the non-target language (Green, 1998), which in turn likely enhances prepotent response inhibition (White & Greenfield, 2017) and inhibitory control (Poarch & van Hell, 2012). Further, bilinguals' frequent language-switching is thought to rely on cognitive mechanisms similar to set-shifting (Prior & Macwhinney, 2010), and thereby benefits the shifting (switching) aspects of EF (Bialystok, 2010; Moriguchi & Lertladaluck, 2019). Last, given that bilinguals' constant management of competing languages places demands on working memory resources (Thorn & Gathercole, 1999) to suitably retrieve and update representations of contexts and interlocutors, bilingualism likely also strengthens working memory (Blom et al., 2014; Daubert & Ramani, 2019).

Although these notions point to a bilingual advantage in EF, discrepant findings in the literature have cast doubt on this view. For instance, Hilchey and Klein (2011) reviewed the literature and found little evidence for a bilingual advantage in children's prepotent response inhibition, as assessed by the Simon task (see also Gathercole et al., 2014). In the domains of shifting and working memory, several studies have similarly failed to find evidence for a bilingual advantage in preschoolers' shifting or working memory abilities, as assessed by a Dimensional Change Card Sort task (DCCS; Haft et al. 2019; Kaushanskaya et al., 2014) and modified pattern recall task (Namazi & Thordardottir, 2010), respectively.

Given these inconsistencies, an emerging strand of research suggests that multiple aspects of bilingual experiences may differentially contribute to cognitive outcomes (Takahesu Tabori et al., 2018) and highlights the importance of considering disparate bilingual experiences in relation to EF outcomes. For instance, some studies further differentiated bilinguals based on age of second language acquisition (Haft et al., 2019); age of active bilingualism (Hartanto & Yang, 2019); home language environment (i.e., usage of and exposure to both languages at home; Guerrero et al., 2016; Haft et al. 2021); degree of balance in language proficiencies across speaking, comprehension, reading, and writing (Yow & Li, 2015); interactional contexts of conversational exchanges (Beatty-Martínez et al., 2020; Hartanto & Yang, 2016, 2020); language switching (e.g., Ooi et al. 2018); and literacy skills (Yang et al., 2019).

Of the many bilingual characteristics, we focused on the following, which are theoretically important and relevant to preschoolers: age of L1 (first language) and L2 (second language) acquisition, parent-reported L1 and L2 proficiency for speaking, objective receptive vocabulary size of English, interactional contexts of conversational exchanges, and parent- and teacher-reported language use (percentage production and exposure) at home and in school, respectively. Although not conclusive, these bilingual features have received some support from the literature regarding their crucial roles in EF outcomes in children; thus, we used them as bilingual indicators to extract the latent profiles of bilinguals.

Age of language acquisition

Prior literature suggests that bilinguals' cognitive advantages are modulated by age of L2 acquisition, since earlier exposure to dual-language use would provide more extensive opportunities to hone EF skills via the concurrent management of two language systems. In support of this, Struys et al. (2015) demonstrated that Dutch–French bilingual children who acquired two languages from birth showed better prepotent response inhibition, as assessed by the Simon task, than those with a later acquisition age (for similar results in adults, see Luk et al., 2011a). However, other studies reported a lack of group differences between early and late bilinguals in working memory and inhibitory control, as assessed by a different set of EF tasks (Kalia et al., 2014; Pelham & Abrams, 2014).

Parent-reported language proficiency

Although a parent-reported measure of a child's language proficiency is useful, previous studies on bilingualism have seldom used parent-reported language proficiency due to its subjective nature. However, Bedore et al. (2011) found that parents' reports of English and Spanish language proficiency reliably correlate with children's language ability scores, which reflect semantic, morphosyntactic, pragmatic, and phonological skills (BESA; Peña et al., 2020). Nicoladis and Mimovic (2022) also suggest that parental report of a child's language dominance corresponds well to his or her vocabulary scores as assessed by a standardized measure of the receptive vocabulary.

Given this, some evidence hints at the role of parent-rated language proficiency in enhancing EF in bilingual children, though

https://doi.org/10.1017/S1366728923000263 Published online by Cambridge University Press

prior research is scant and equivocal. For instance, Sharaan et al. (2021) studied 80 children (aged 4 to 12 years old, comprising both autistic and typically developing children) and found that Arabic–English bilingual children outperformed their monolingual peers on parent-rated sustained attention and interference control when parent-rated language proficiency was used as an indicator of bilingualism. Verhagen et al. (2020) tested 24-month-old bilinguals and monolinguals and found that parental report of a child's degree of balanced language use predicted parent-rated cognitive control. However, they found that parent-reported language proficiency was unrelated to indices of cognitive control, including selective attention and inhibitory control. On the other hand, Hutchison (2010) found that language proficiency failed to reinforce bilingual advantages for inhibition and shifting in 3- to 6-year-old German–English bilingual children. Although these findings are not entirely consistent, bilingual proficiency is irrefutably one of the notable attributes of bilingualism. Thus, we included parent-reported L1 and L2 proficiency for speaking as bilingual indicators for our latent profile analysis. We did not assess a child's literacy skills, since the majority of our child participants were not yet fully literate.

Receptive vocabulary

Studies have shown a positive link between receptive vocabulary and updating and proactive interference suppression abilities (Bialystok & Feng, 2009; Kaushanskaya et al. 2017). Crespo, Gross, and Kaushanskaya (2019) demonstrated that Spanish–English bilingual children with higher expressive and receptive language scores had advantages for shifting indexed by performance on the DCCS. Consistently, Iluz-Cohen and Armon-Lotem (2013) found a positive relation between language proficiency (including vocabulary) and inhibition and shifting abilities in English–Hebrew bilingual children aged 4 to 7. Yim, Jo, Han, and Seong (2016) further demonstrated that 6- to 9-year-old Korean–English bilingual children without vocabulary delay performed better in terms of shifting (assessed by the DCCS task) and nonverbal working memory (assessed by the matrix task) than their counterparts with vocabulary delay. However, longitudinal studies suggest that receptive vocabulary may not have any influence on cognitive outcomes, particularly in bilingual children (Diaz et al., 2021; Weiland et al., 2013). Despite limited research on this subject, receptive vocabulary has been treated as a key covariate in studying the association between bilingualism and EF (e.g., Tran et al., 2019), which suggests its importance for EF.

Parent-reported language use

Although there is a dearth of research on the association between EF and bilinguals' language use (i.e., production and exposure at home and in school), bilinguals' continuous and active use of both languages is regarded as vital for cognitive advantages, since the active use of concurrent language systems would impose greater demands on EF. In line with this notion, Bosma et al. (2017) found that Frisian–Dutch bilingual children's exposure to their L1 at home (i.e., percentage of Frisian input from their father, mother, siblings, and other adults) predicted selective attention and inhibitory control abilities, as assessed by the Sky Search task, and this relation was mediated by balance in language proficiencies. Haft et al. (2021) also found that Mexican-American and Chinese-American preschoolers' exposure to their heritage language (i.e., Mexican/Mandarin) at home (e.g., from books, radio, or TV) predicted attention-shifting abilities, even when age of English acquisition, receptive vocabulary, child generation, and language pair were accounted for. Similarly, the degree to which bilingual toddlers regularly use both languages when interacting with their parents at home has been shown to positively predict parent-rated inhibitory control, attentional shifting, and attentional focusing, as assessed by the Early Childhood Behavior Questionnaire (Verhagen et al., 2020; for similar results in adults, see Yow & Li, 2015). At odds with these results, however, Haft et al. (2021) found that balanced language production in 3- to 5-year-old bilingual children's at-home interactions failed to predict prepotent response inhibition abilities, as evaluated by the Silly Sounds Stroop task. Although various factors may account for these mixed findings, bilinguals' language use at home and in school would certainly delineate central aspects of disparate bilingual practices. Therefore, we examined parent-reported and teacher-reported percentage of time for L1 and L2 usage at home and in school in terms of production (i.e., percentage of time L1 and L2 spoken by the child) and exposure (percentage of time L1 and L2 spoken to the child).

Interactional contexts

According to the adaptive control hypothesis, "interactional context" refers to bilinguals' recurrent patterns of conversational exchanges (Green & Abutalebi, 2013). These include (a) a single-language context, in which bilinguals speak one language in one environment and rarely switch languages; (b) a dual-language context, in which bilinguals use both languages within the same context with different interlocutors; and (c) a dense code-switching context, in which bilinguals routinely mix languages within an utterance. The theory posits that bilinguals' interactional contexts implicate different cognitive demands on language control, and thereby differentially alter cognitive control outcomes. Specifically, the dual-language context imposes the most taxing level of language control, and thus confers the most pronounced advantages for shifting and inhibitory control in particular. On the other hand, single-language and dense code-switching contexts require relatively lighter cognitive control demands, which benefit interference control to a lesser degree. In line with this framework, Hartanto and Yang (2016, 2020) found that dual-language-context bilinguals showed significant advantages in shifting, and dense code-switching-context bilinguals showed advantages in inhibitory control. In view of these findings, we included bilinguals' interactional contexts as indicators to extract the latent profiles of bilinguals. In particular, we focused on the frequency of dual-language and dense code-switching contexts, since they – but not the single-language context – have been shown to be associated with cognitive control processes (Hartanto & Yang, 2016, 2020).

The present study

We sought to examine bilingualism as a multidimensional construct (Luk & Bialystok, 2013) by considering 10 bilingual characteristics that have been shown to be associated with EF: age of L1/L2 acquisition, dual-language and dense code-switching contexts, language use (percentage of time L1 and L2 is spoken by and to the child at home and school), parent-reported speaking proficiency for L1 and L2, and English receptive vocabulary size. Based on these bilingual indicators, we sought to identify heterogeneous profiles of bilingual children and examine how different bilingual profiles would predict various facets of EF: shifting, prepotent response inhibition, inhibitory control, and working memory.

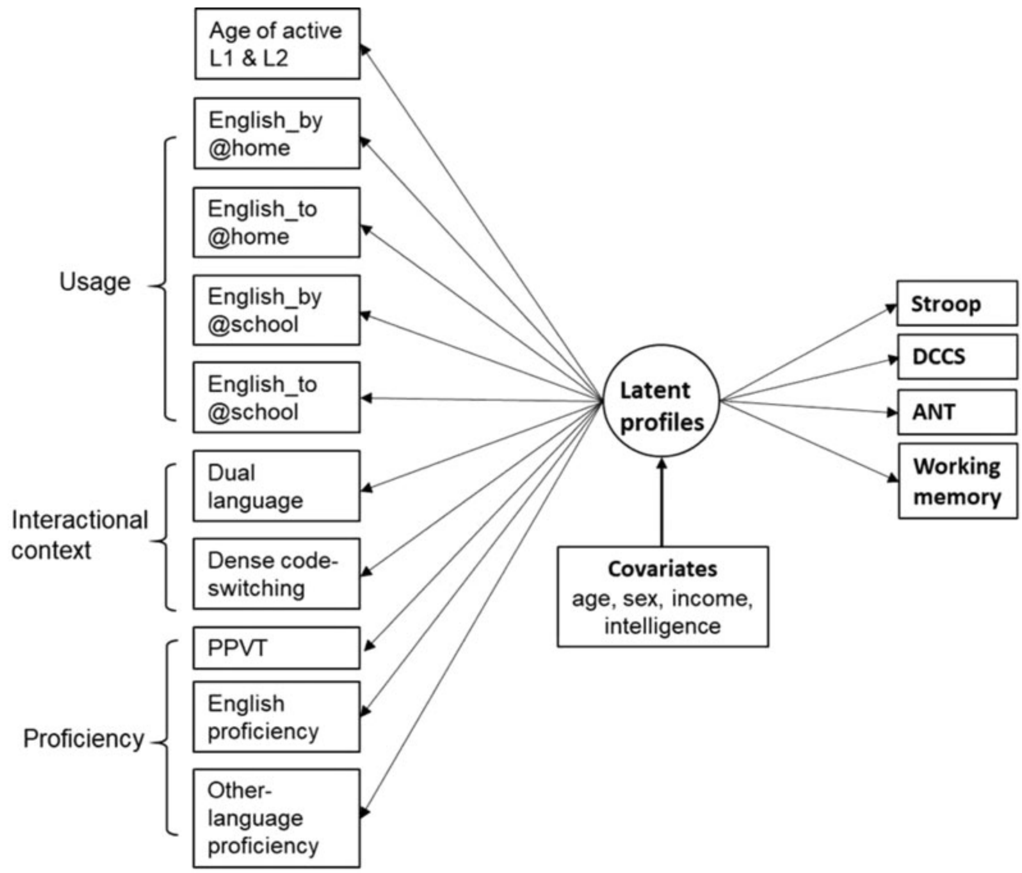

Figure 1. Conceptual model illustrating the latent profile model of bilingual children that predicts each EF outcome variable. Age, sex, income, and intelligence served as covariates in estimating the relation between latent profiles and EF outcomes.

Since we were unable to determine a priori how many bilingual profiles would be extracted through the data, we set only three major research objectives instead of formulating specific hypotheses. First, we sought to determine the number of well-differentiated latent profiles based on multiple bilingual indicators. Our second objective was to elucidate bilingual characteristics that concurrently operate and contribute to forming different profile patterns. Our third objective was to investigate the association between qualitatively distinct latent profiles extracted from numerous bilingual indicators and EF (for our conceptual model, see Figure 1). In all analyses, we controlled for important covariates (age, sex, income, and intelligence).

Method

Participants

One hundred and eighty-nine children aged 4 to 6 ($M_{age} = 61.42$ months, $SD = 8.93$; male = 51.4%) and their parents and teachers were recruited from local preschools across Singapore. Importantly, Singapore is a multilingual country and has a bilingual education policy that requires all students to be taught English – the official language for instruction in schools (Pakir, 1993) – in addition to each student's mother tongue (i.e., Chinese, Malay, Tamil, or a foreign language) based on their ethnicity. Hence, most preschool children are exposed to two languages from birth, with varying degrees of proficiency in each (Ministry of Education, 2013). The majority of participants were Chinese (70.1%) in ethnicity and reported English and Mandarin as their L1 or L2 (88.3%). Only a subset of children (12%) spoke a third language (L3). Two participants whose dominant languages were neither English nor Mandarin were excluded. Participants received $10 as a token of appreciation.

Measures

Shifting

In the Dimensional Change Card Sort task (DCCS; Zelazo, 2006), child participants sorted 22 picture cards – depicting either a blue truck or red star – into two piles according to either color or shape rules. Within the first two blocks of trials, children sorted each card by a single rule (either its color or shape). In the final mixed block, the two rules were intermixed such that participants sorted the card by its color if a black border appeared on the card; otherwise, they sorted the card by shape. An overall accuracy score across all blocks of trials was computed to index the ability to shift attention.

Prepotent response inhibition

The Stroop task (Stroop, 1935) was used to index prepotent response inhibition, i.e., the ability to suppress a dominant and automatic response (Nigg, 2000). Prior to the task, all participants were screened to ensure that they were able to read aloud and comprehend the target words "RED," "BLUE," "YELLOW," and "GREEN." Thereafter, they were presented with one of these color words at a time on an iPad screen and tasked to identify the ink color of each word while inhibiting its associated meaning. For instance, when shown the word "RED" printed in blue (an incongruent trial), the participant should press a button labeled "BLUE." In a single session lasting 180 seconds, participants responded to as many incongruent trials as they could. Performance was indexed in two ways: (a) the proportion of accuracy score (i.e., number of correct trials / number of trials completed within 180 seconds) and (b) the inverse efficiency (i.e., the proportion of accuracy / average response speed). The latter allowed us to consider both accuracy and response speed.

Inhibitory control

The Attention Network Test (ANT; Fan et al. 2002; Rueda et al. 2004) was administered to assess executive control abilities. Each trial began with a central fixation cross (400 - 1600ms) followed by one of four cues (150ms): no cue, center cue (asterisk displayed at the central fixation location), double cue (two asterisks displayed above and below the fixation location), or spatial cue (asterisk displayed in the position in which the following target would appear). Participants were then presented with either one fish (i.e., neutral trials) or a horizontal row of five fish facing the same direction as the target fish (congruent trials) or the opposite direction (incongruent trials) for 1,700 ms or until a response key was pressed (Fan et al., 2002). Participants were instructed to press the key that corresponded to the direction the central target fish was facing. Further, across the three blocks of 48 trials each, the 12 conditions (i.e., three trial types x four cue conditions) were presented in equal proportions. Following Rueda et al.'s (2004) recommendation, inhibitory control was indexed by executive control network scores – i.e., the difference in accuracy between incongruent and congruent trials.

Working memory

The Backward Corsi Block-Tapping task (Corsi, 1972) was administered using Inquisit software version 3.0.6.0 (Inquisit 3, 2011). Participants were presented with nine blue squares (30 x 30 mm each) on a black screen. In each trial, a fixed sequence of squares flashed in yellow, one at a time, for 1,000 ms each. Participants were then asked to tap on the corresponding squares in reverse order. Beginning with a sequence of two squares, progressively longer sequences of squares were presented with one square added after every two successful trials. The task automatically terminated once participants failed to accurately reproduce two consecutive sequences of equal length. In accordance with Kessels, Van Zandvoort, Postma, Kappelle, and De Haan (2000), working memory capacity was indexed by the total score calculated by multiplying square span (i.e., longest sequence to be reproduced accurately) by the number of correct trials.

English receptive vocabulary

The Peabody Picture Vocabulary Test 5th Edition (PPVT-5; Dunn, 2018) was used to assess English receptive vocabulary size. We tested only English PPVT-5 because English was the official language of instruction in school; the translated and validated measure of the Chinese PPVT was not available at the time of our data collection. In this task, children had to identify the correct picture from an array of four based on the experimenter's question (e.g., Which of these shows "laughing"?). The items were progressively more difficult, and testing was discontinued when participants made six errors within eight consecutive responses. We standardized each child's raw scores according to their age.

English language proficiency

As a measure of language proficiency, parents rated their child's speaking competence in English and the child's other language on a 10-point Likert scale *(*1 = *none*, 10 = *excellent).*

Language use

Parents reported the percentage of time English and other languages (e.g., Mandarin, dialects, Malay, Tamil, etc.) were spoken BY (production) and TO (exposure) the child at home, such that they added to 100; for instance, at home, a child speaks both English (about 80%) and one other language (20%) and is spoken to in English (60%) and the other language (40%). Similarly, teachers reported the percentage of time English and other languages were spoken BY and TO the child at school, such that they add to 100. Since the survey questions did not specify the target audience of the child's speech, there is a possibility that both exposure and production may involve both parents, extended family members, and siblings at home as well as teachers and peers at school. Since the percentage usage of English and other language(s) always add to 100, using the two indices causes multicollinearity; thus, we used only the percentage usage of English spoken by and to the child at both home and school.

Interactional contexts

Parents reported the frequency with which their child engaged in dual-language and dense code-switching contexts on a 5-point Likert scale (1 = *never* to 5 = *always).* The dual-language context was assessed using a single survey item ("How often does your child switch languages between sentences in general, e.g., the child speaks one sentence in English and another sentence in the other language?"). The dense code-switching context was assessed using the following question on the survey: "How often does your child mix words from different languages when speaking in general (e.g., when your child has trouble finding a word in English, he or she tends to immediately replace it with a word from the other language, or vice versa)?" Notably, some aspects of the single-language context were conceptually captured in part by the percentage usage of English at home and school, since a greater percentage of usage of English (e.g., 95%) relative to that of the other language (5%) at home implies that the child is likely to be a single-language-context bilingual.

Covariates

We controlled for a host of key demographic and cognitive covariates – age, sex, household income, and nonverbal intelligence – that have been shown to influence children's EF (Brydges et al. 2012; Gestsdottir et al. 2014; Lawson et al., 2017). Parents reported their gross monthly combined household income (before tax and deductions) using a scale (1 = *$1,000 and below*; 2 = *$1,001 - $3,000*; 3 = *$3,001 - $5,000*; 4 = *$5,001 - $7,000*; 5 = *$7,001 - $9,000*; 6 = *$9,001 and above*). Children's nonverbal intelligence was measured using Raven's Standard Progressive Matrices Test (RSPM; Raven et al., 1998). Participants were shown a geometric pattern of varying shapes and lines with a missing portion and then selected, from six options, the one that would best fit the missing portion. The number of items answered correctly was used to index nonverbal deductive reasoning.

Procedure

The study was conducted over two 45-minute sessions administered in a quiet classroom within the school compound. In the first session the PPVT was administered, followed by the nonverbal intelligence test, ANT, and DCCS task. In a separate session, the Backward Corsi Block-Tapping and Stroop tasks were administered. All cognitive tasks were administered individually by trained experimenters, with breaks after each task to minimize fatigue; stickers were given to build rapport and morale. Parents and teachers received a link to their questionnaire via email, which collected data on the child's language use and other demographics. Informed consent was obtained from participating parents before the study began, and study procedures were approved by the university's institutional review board.

Results

Analytic approach

All latent profile analyses (LPA) were conducted using *Mplus* 8.4 with full information maximum likelihood estimation to account for missing data (Muthén & Muthén, 2015). Tables 1 and 2 show descriptive statistics and zero-order correlations between all variables. We used the three-step LPA estimation procedure to examine potential differences among the profiles for each EF outcome variable (Asparouhov & Muthén, 2014). In step 1, we estimated the LPA model with 10 profile indicators. In step 2, we determined the measurement error, which was used in the subsequent step of the estimation. In the final step, we estimated the desired auxiliary model in which the distal (outcome) variable and covariates were added, with measurement errors set to those computed in the second step.

To extract heterogeneous subgroups of bilinguals, we used 10 bilingual characteristics as profile indicators that have been examined in previous studies (e.g., Hartanto & Yang, 2019): (a) age of L1 and L2 acquisition (speaking); (b) percentage usage of English spoken by the child at home; (c) percentage usage of English spoken to the child at home; (d) teacher-reported percentage usage of English spoken by the child at school; (e) teacher-reported percentage usage of English spoken to the child at school; (f) frequency of a dual-language context; (g) frequency of a dense code-switching context; (h) English PPVT scores; (i) parent-reported English proficiency for speaking; and (j) parent-reported other language proficiency for speaking. All indicators were standardized for comparison purposes.

Since LPA is an inductive approach, the number of profiles is not known a priori. Thus, we started with a two-profile solution and increased the number of profiles extracted until model fit no longer improved (Nylund et al., 2007). As recommended (Foti et al. 2012), six fit statistics were used to evaluate each profile solution: the Akaike information criterion (AIC); Bayesian information criterion (BIC; Nylund et al., 2007); sample-size-adjusted BIC (SSA-BIC; Tofighi & Enders, 2008); Lo-Mendell-Rubin likelihood ratio test (LMR; Lo et al., 2001; Tofighi & Enders, 2008); bootstrapped likelihood ratio test (BLRT); and entropy (see Table 2). We chose the optimal and best-fitting profile solution based on (a) smaller AIC, BIC, and SSA-BIC statistics; (b) an entropy value greater than .70 (ranges from 0.00 to 1.00) for the precision and classification accuracy associated with each profile solution (Jung & Wickrama, 2007; Nylund-Gibson & Masyn, 2016); and (c) significant LMR and BLRT statistics, which compare the fit of the k-profile model with the k - 1 profile model (Berlin et al., 2013; Lo et al., 2001).

After identifying the optimal profile solution, we examined whether the extracted bilingual profiles would differently predict

Table 1. Descriptive Statistics of Bilingual Indicators, Outcome Variables, and Covariates

	M	SD	Range	Skewness	Kurtosis
Age (months)	61.4	8.92	42-77	−.159	−.952
Sex (% male)	51.9	-	-	.075	−2.02
Family income	3.99	1.72	0-6	−.177	−1.204
Nonverbal intelligence	17.7	5.75	6-31	.269	−.631
Age of actively speaking L1 and L2	3.12	1.46	0-6	−.428	−.051
% English spoken by a child at home	64.21	28.93	0-100	−.444	−.955
% English spoken to a child at home	58.06	28.82	0-100	−.272	−.950
% English spoken by a child at school	73.32	19.05	15-100	−.626	.200
% English spoken to a child at school	67.54	25.24	0-100	−1.06	1.34
Dual-language context	2.74	1.08	0-5	−.09	.031
Dense code-switching context	2.99	1.06	0-5	.093	−.194
English PPVT	93.24	14.58	20-120	−1.212	3.150
English proficiency for speaking	7.56	2.20	0-11	−.879	.595
Other language proficiency for speaking	6.41	2.54	0-11	−.432	−.791
Accuracy scores on the DCCS	.795	.146	.44-1.00	−.017	−1.075
Accuracy scores on the Stroop	.829	.203	.07-1.00	−1.87	2.961
Inverse efficiency scores on the Stroop	.310	.154	0−.73	−0.23	−0.48
ANT executive control network scores	.166	.179	−.17−.69	.966	.320
Working memory	15.087	11.41	0-54	.993	.730

https://doi.org/10.1017/S1366728923000263 Published online by Cambridge University Press

https://doi.org/10.1017/S1366728923000263 Published online by Cambridge University Press

Table 2. *Bivariate Zero-order Correlations among All Variables*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Age (months)	-																	
2. Sex (% male)	–.03	-																
3. Family income	–.06	–.15	-															
4. Nonverbal intelligence	.51**	–.13	.21*	-														
5. Age of L1 and L2	.23**	–.02	–.06	.08	-													
6. % English spoken by at home	.16†	–.10	.16†	.18*	.11	-												
7. % English spoken to at home	.06	–.05	.14	.16†	.09	.85**	-											
8. % English spoken by at school	.17†	.04	.06	.08	–.05	.34**	.28**	-										
9. % English spoken to at school	–.04	–.03	–.22*	–.23	–.02	–.12	–.10	.36**	-									
10. Dual-language context	–.10	.14	–.03	–.16*	–.07	–.42**	–.40**	–.06	.20*	-								
11. Dense code-switching context	–.06	–.04	–.05	–.07	.07	–.37**	–.32**	–.18†	.02	.69**	-							
12. English PPVT	–.13	–.13	.40**	.22**	–.06	.36**	.41**	.16	–.26**	–.15†	–.11	-						
13. English proficiency for speaking	.19*	–.14	.16†	.26**	.02	.51**	.44**	.28**	–.06	–.12	–.06	.45**	-					
14. Other proficiency for speaking	–.14	.11	–.05	–.10	–.15	–.45**	–.41**	.02	.09	.44**	.39**	–.08	.11	-				
15. DCCS	.34**	.08	.15	.38**	–.03	.18*	.18*	.11	–.01	–.03	–.04	.20**	.30**	–.002	-			
16. Stroop (accuracy)	.25**	.04	.13	.24*	.05	.24**	.20*	.39**	–.06	–.10	–.13	.10	.20**	.00	.26**	–		
17. Stroop (inverse efficiency)	.33**	–.01	.03	.36**	.12	.18*	.12	.33**	–.06	–.14	–.10	.10	.21*	.01	.22**	.79**	-	
18. ANT executive control	–.27**	.07	–.17*	–.32**	–.01	–.01	–.02	–.16	.08	.04	–.06	–.08	–.11	–.14	–.23**	–.09	–.11	-
19. Working memory	.34**	–.18*	.27**	.46**	–.01	.09	.07	.12	–.20*	–.14	–.09	.19*	.14	–.13	.28**	.30**	.38**	–.22**

Note. † p <.06, * p < .05, ** p < .001

each EF outcome variable. To this end, we tested a series of simple auxiliary models by adding each EF measure as a distal variable to the model with a latent profile (class) variable as well as covariates (for our conceptual model, see Figure 1). As an ancillary analysis, we performed a series of one-way ANOVA after fixing individuals' latent profiles according to their highest membership probability.

Latent profile analysis

We evaluated several latent profile solutions to determine the optimal number of profiles across our sample. Table 3 shows results from the profile enumeration process. BIC values decreased from one to three profiles but increased from three to four profiles. LMR, LRT, and BLRT tests were statistically significant when comparing the three-profile and two-profile solutions (ps <.05), which suggests that the three-profile solution was significantly different from the two-profile solution. The three-profile solution, however, was not significantly different from the four-profile solution. Moreover, each profile of the three-profile model included at least 25% of our sample. The three-profile solution had an entropy value of .762, indicating acceptable classification certainty. The mean posterior probabilities values ranged from .85 to .89, indicating reasonable separation between profiles (Asparouhov & Muthén, 2014). Further examination revealed that the four-profile solution produced one profile with a small sample size ($n = 2$; less than 1% of the full sample), which suggests potential overextraction (Petras & Masyn, 2009) and vulnerability to low power and precision (Berlin et al., 2013). In view of these results, a three-profile solution was chosen, since it yielded the best statistical fit and accurately reflected empirically plausible types of bilingual profiles according to Singapore's sociolinguistic context. The three profiles were labeled mixed-interaction, dominant single-language, and balanced dual-language. The profiles' mean scores across 10 bilingual indicators are shown in Figure 2.

Our first profile (class 1; 25.2% of bilingual participants) was labeled the MIXED-INTERACTION profile, since they frequently experienced dense code-switching (i.e., language mixing) and dual-language contexts (language switching with interlocutors), which uniquely differentiated them from those with the dominant single-language context profile (see the description of class 2 below). In terms of language use, bilinguals with the mixed-interaction profile showed patterns opposite to those with the dominant single-language profile. Specifically, the mixed-interaction profile reflected the use of Mandarin as a dominant language in most cases; acquisition of Mandarin and English in separate contexts, with Mandarin at home and English in school; earlier acquisition of L1 and L2 than the dominant single-language profile; predominant exposure to and production of Mandarin at home; and a relatively moderate level of exposure to and production of English in school. Thus, bilinguals with the mixed-interaction profile demonstrated unbalanced proficiency, with the highest speaking proficiency for Mandarin but the lowest proficiency for English and the lowest English PPVT scores of the three profiles.

The second profile, which was also the second largest (class 2; 34.7%), was labeled the DOMINANT SINGLE-LANGUAGE profile, whose bilingual characteristics featured the use of English as a dominant language; acquisition of two languages in distinctively separate contexts, with English predominantly at home and Mandarin in school; prevalent exposure to and production of English at home; and moderate levels of exposure to and production of Mandarin in school, which naturally explained their unequal language proficiency. Of the three profile groups, bilinguals with this profile demonstrated the highest English proficiency and highest scores on English PPVT, but the lowest proficiency in Mandarin. In contrast to the mixed-interaction profile, the dominant single-language profile showed the least frequent engagement in both the dual-language (i.e., language switching) and dense code-switching (i.e., language mixing) contexts, which implies that their predominant interactional context is a single-language context.

Our largest profile (class 3; 40.2% of bilingual participants) was labeled the BALANCED DUAL-LANGUAGE profile, whose bilingual characteristics featured the simultaneous and earliest acquisition of two languages in the same context; similar levels of exposure to and production of English and Mandarin at both home and school; and fairly balanced proficiency in English and Mandarin, with the second highest English PPVT scores of all profiles, followed by the dominant single-language profile. In terms of bilingual interactional contexts, this profile was characterized by the most frequent engagement in a dual-language context.

In terms of covariates (age, sex, household income, and nonverbal intelligence), we found no significant profile differences in either age, $p = .324$, or sex, $p = .194$. However, we found that the three profiles were marginally different in terms of household income, $p = .056$, with the dominant single-language profile having the highest income ($M = 4.42$) followed by the balanced dual-language profile ($M = 3.90$) and the mixed interactional context profile ($M = 3.58$). Similarly, we found significant profile differences in terms of nonverbal intelligence, $p = .024$, with the dominant single-language profile showing the highest nonverbal intelligence ($M_{\text{single}} = 19.37$) followed by other profiles ($M_{\text{balanced-dual}} = 17.04$, and $M_{\text{mixed}} = 16.73$). Specifically, bilinguals with the dominant single-language profile have higher nonverbal intelligence and are from relatively more affluent families than bilingual children with other profiles (see Table 4). These significant group differences in covariates, therefore, are controlled for in assessing the associations between bilingual profiles and specific aspects of EF.

Executive functions

We examined whether the three bilingual profiles would differ in various aspects of EF in two ways. First, we considered the probabilistic nature of profile membership and conducted Wald tests for both global and pairwise comparisons between profiles (see Table 4). Second, we conducted traditional one-way ANOVA and post hoc comparisons by assigning individuals to their respective latent profiles according to their highest probability.

Shifting

We found a marginally significant difference between the three profiles, $W\ (2) = 5.301$, $p = .07$, when accuracy scores on the DCCS task were submitted to Wald's test with covariates. Further probing showed that the balanced dual-language profile showed significantly better shifting performance than the mixed-interaction profile, $t = -\ 0.073$, p =.021. Although there was a clear trend in which the balanced dual-language profile outperformed the dominant single-language profile, the two groups did not statistically differ, ps >.36. Of the covariates, only

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Table 3. Latent Profile Enumeration Fit Statistics for 2-, 3-, and 4-class Solutions

	1-Class	2-Class	3-Class	4-Class
AIC	3,390.74	3,095.42	2,984.18	2,984.82
BIC	3,455.36	3,195.58	3,119.89	3,156.07
SSA-BIC	3,392.01	3,097.39	2,986.86	2,988.19
Entropy		.765	.762	.808
Model comparison		Class 1 vs. 2	Class 2 vs. 3	Class 3 vs. 4
VLMR LRT 2 x logL		317.32**	133.23*	21.37
LMR-LRT		311.9**	130.96*	21.00
Bootstrapped LRT 2 x logL		317.32**	133.23**	21.37

Note. AIC = Akaike information criteria; BIC = Bayesian information criteria; SSA-BIC = Sample-size adjusted Bayesian information criteria; VLMR LRT 2 x logL = Vuong-Lo-Mendell-Rubin likelihood ratio test 2 times the log-likelihood difference; LMR-LRT = Lo-Mendell-Rubin likelihood ratio test. * $p < .05$; ** $p < .001$.

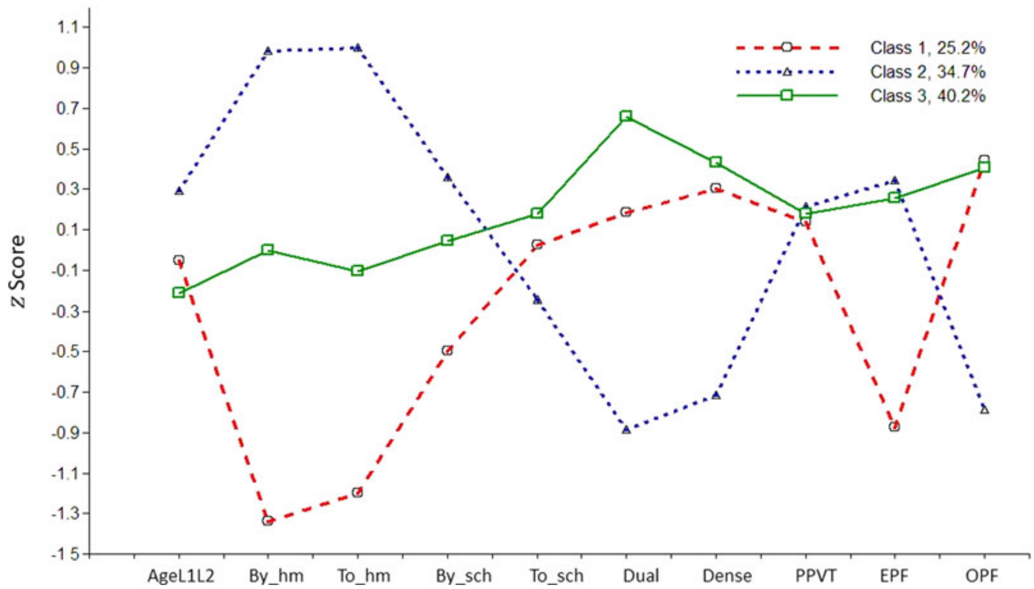

Figure 2. Latent profiles across 10 bilingual indicators: age of speaking L1 and L2 (AgeL1L2); percentage of English spoken by the child at home (By_hm); percentage of English spoken to the child at home (To_hm); percentage of English spoken by the child at school (By_sch); percentage of English spoken to the child at school (To_sch); dual-language tendency (Dual); dense code-switching tendency (Dense); receptive vocabulary (PPVT); English proficiency for speaking (EPF); and other language proficiency for speaking (OPF). Lines represent distinct emergent profiles (classes); classes 1 to 3 are mixed-interaction, dominant single-language, and balanced dual-language bilinguals, respectively.

nonverbal intelligence significantly predicted shifting, $t = 0.08$, $p < .001$.

Next, we ran one-way ANOVA by assigning individuals to their profiles based on their highest membership probability. Since the assumption of homogeneity of variance was violated, $p = .004$, we ran a Welch F-test and found a significant group difference, $F = 8.966$, $p < .001$. When we performed the Games-Howell post hoc test because of the violation of assumptions, we found that bilinguals with both balanced dual-language and dominant single-language profiles performed better than their counterparts with the mixed-interaction profile, $ps = .001$, but the balanced dual-language and dominant single-language profiles did not differ from each other, $p = .914$.

Prepotent-response inhibition

We examined whether the three profiles would differentially predict prepotent response inhibition, as assessed by the accuracy of the Stroop task. We found no significant group differences, $W\ (2) = 1.650$, $p = .44$. When a similar Wald's analysis was performed on the inverse efficiency score of the Stroop, which incorporates both the accuracy and speed of processing, we obtained similar results, $W\ (2) = 0.202$, $p = .90$. Further analysis showed that the three bilingual profiles did not differ from each other, $ps > .20$. None of the covariates were found to be significant, $ps > .11$. Similarly, when a separate one-way ANOVA was conducted with respect to accuracy and inverse efficiency scores, we found that the three bilingual profiles did not differ from one another on accuracy scores, *Welch* $F = 0.953$, $p = .389$, or inverse efficiency scores, *Welch* $F = .128$, $p = .880$. Thus, post hoc analyses were not carried out.

Inhibitory control

Regarding interference control, as assessed by the ANT, when executive control network efficiency scores (the difference in

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Table 4. Means and SDs of Covariates and Distal Variables According to Latent Profiles

	Balanced dual-language	Mixed-interaction	Dominant single-language	Wald test
Age (in months)	61.82_a (9.42)	59.65_a (8.69)	62.17_a (8.34)	2.395
Sex (% males)	46_a	51.1_a	61.6_a	3.419
Household income	3.90_{ab} (1.67)	3.58_a (1.60)	4.42_b (1.80)	5.960*
Nonverbal intelligence	17.04_a (5.29)	16.73_b (5.88)	19.37_c (5.99)	6.027*
Stroop (accuracy)	$.83_a$ (.20)	$.86_a$ (.16)	$.79_a$ (.25)	1.650
Stroop (inverse efficiency)	$.31_a$ (.15)	$.32_a$ (.15)	$.30_a$ (.19)	0.202
DCCS	$.81_a$ (.13)	$.75_b$ (.14)	$.81_a$ (.16)	5.301†
ANT	$.17_a$ (.18)	$.16_a$ (.18)	$.17_a$ (.19)	0.721
WM	15_a (12.69)	13_a (8.87)	17_a (12.79)	0.435

Note. DCCS = Dimensional Change Card Sort task; ANT = Attention Network Test; WM = Working Memory. Mean scores that share the same subscript in a row indicate that they are not significantly different from each other. † p <.07, * p <.05

accuracy between congruent and incongruent trials) were subjected to Wald's test to examine differences between the three profiles, we found none, W (2) = 0.721, p = .698. Further analysis showed that the three profiles did not differ from one another, ps > .422. Of all covariates, only nonverbal intelligence significantly predicted inhibitory control, t = -0.009, p =.005. Similarly, one-way ANOVA showed nonsignificant group differences in executive control network efficiency scores, F = .646, p = .525.

Working memory

Last, we found that the three profiles did not differ in terms of working memory performance, W (2) = 0.435, p = .804. Further probing with pairwise comparisons confirmed that the three bilingual profiles did not differ from each other in working memory capacity, ps >.519. Similarly, our results from ANOVA showed that the three bilingual profiles were not significantly different, *Welch* F = 1.761, p = .18. Further probing using Games-Howell post hoc tests were not carried out.

General discussion

Using a sophisticated person-centered latent profile approach that allowed us to consider a comprehensive range of bilingual characteristics, we examined the different EF outcomes of three distinct profiles of bilingual children, with each profile characterized by qualitatively unique patterns of bilingual characteristics. We found that bilingual children's multifaceted linguistic experiences modulated the shifting aspects of executive functioning to different extents. Specifically, we found significant group differences, with the balanced dual-language and dominant single-language profiles exhibiting better shifting abilities than the mixed-interaction profile. However, no differences among the profiles were observed for working memory, prepotent response inhibition, or inhibitory control.

Several findings merit discussion. First, given that previous studies predominantly adopted a variable-centered analysis with limited bilingual characteristics (e.g., Hartanto & Yang, 2020; Yow & Li, 2015), our study considered a myriad of qualitative characteristics and successfully identified distinct profiles across preschool-aged bilingual children: mixed-interaction, dominant single-language, and balanced dual-language. Our findings are, in part, consistent with recent studies that use a similar person-centered approach. For instance, Francot, Blom, Broekhuizen, and Leseman (2021) considered indices of L1 and L2 language use and proficiency in preschool-aged Turkish–Dutch children and identified four distinct profiles that varied according to language dominance (dominant vs. dual) and proficiency in both languages (high vs. low). Using a similar method, Lonigan, Goodrich, and Farver (2018) identified nine distinct profiles of young Spanish–English bilingual children according to their varying proficiency levels in L1 and L2. Our study advances these findings by taking into account a more comprehensive set of linguistic markers (e.g., interactional contexts, age of acquisition, receptive vocabulary), which in turn have aided the extraction of empirically more reliable profiles of bilinguals (Wurpts & Geiser, 2014). Further, our study elucidates profile-specific differences in shifting abilities, wherein these characteristics operate concurrently to better predict shifting abilities, particularly in the balanced dual-language and dominant single-language profiles. Together, this underscores the importance of delineating specific bilingual profiles based on a wide spectrum of bilinguals' linguistic practices and their unique influences on different facets of EF.

Our second notable finding is that bilinguals' profile-specific variations showed unique relations with shifting but not with other components of EF. This suggests that bilinguals' distinctive linguistic experiences implicate different cognitive control processes, which lead to different outcomes in specific facets of executive functioning. This account is, in part, consistent with the adaptive control hypothesis, which posits that bilinguals' different interactional contexts of conversational exchanges impose different demands on language control, which in turn adaptively modulate cognitive control processes (Green & Abutalebi, 2013). Our study extends theoretical understanding of adaptive modulation to bilingual demands by considering a wider host of bilingual attributes beyond interactional contexts. Specifically, our findings indicate that the overall shape of the balanced dual-language profile (based on diverse features of simultaneously acquiring both languages early in the same context, displaying equivalent language proficiency, and using both languages both at home and in school) imposes heavier cognitive demands on the shifting aspects of EF than do other profile types. This implies that the influence of bilingualism on EF is experience-specific, and thus warrants further investigation of the link between bilinguals' multifaceted and heterogeneous experiences and EF.

Third, contrary to the theoretical prediction of the adaptive control hypothesis, we found that the dominant single-language

https://doi.org/10.1017/S1366728923000263 Published online by Cambridge University Press

profile predicted better switching than the mixed-interaction profile. Several interpretations can be suggested to explain this. First, although the adaptive control hypothesis is silent regarding potential factors that might moderate the theorized impacts of interactional contexts on bilingual advantages in cognitive control, several notable factors – such as bilinguals' language proficiency and age – deserve further empirical attention. Specifically, previous studies on bilingual adults suggest that bilingual proficiency modulates bilingual advantages in shifting (Tao et al. 2011). Considering that our dominant single-language bilinguals showed higher English PPVT scores than the other profile groups, it is likely that dominant single-language bilinguals' high English proficiency (as well as unequal language proficiency) might have imposed greater demands on switching than those with a mixed-interaction profile. Second, the adaptive control hypothesis posits that not only linguistic demands via interactional context but also meta-control demands can influence cognitive control processes. Although the nature of meta-control demands is not clear, this additional source of meta-control demands on switching processes may be more pronounced, especially during early childhood when children's language and literacy skills have not yet reached the fully fledged, advanced fluency stage. Given this, it is possible that bilingual children with the dominant single-language profile may undergo unique meta-control demands that could affect their switching performance.

Fourth, despite uniquely different patterns of bilingual profiles, we found no group differences in terms of prepotent response inhibition, inhibitory control, or working memory. This suggests that the three bilingual profiles' disparate bilingual experiences may not necessarily impose different cognitive demands on inhibition and working memory. Previous research has established that both of bilinguals' languages are jointly activated and compete with each other for selection, even when only one language is used exclusively (e.g., Marian & Spivey, 2003; Thierry & Wu, 2007). Given that this simultaneous coactivation requires inhibition to suppress substantial interference from the nontarget language, bilinguals are thought to actively exercise inhibition despite their disparate bilingual experiences. In favor of this notion, our results imply that bilinguals' linguistic practice similarly imposes substantial demands on inhibition and thereby accounts for the lack of group differences in inhibition.

Similar explanations can be given for working memory. Bilingualism has been suggested to confer advantages for working memory capacity, even in early childhood (Blom et al., 2014; Daubert & Ramani, 2019). This is because the management of competing languages requires working memory resources to monitor attention to the target language (Luk et al., 2011b) and update information in the face of concurrent processing, distraction, and attention shifts (Baddeley & Hitch, 1974; Engle et al. 1999). Given this, our findings suggest that bilinguals deploy working memory resources to a similar degree regardless of their specific profiles. However, given that the varying attentional-control demands placed on working memory tasks moderate bilingual advantages in working memory capacity (Yang & Yang, 2017), future studies should examine whether the lack of group differences in working memory can be attributed to task-specific factors, such as a task's different demands for controlled processing. Further, with respect to the issue of task impurity (Miyake et al., 2000), task-specific or nonexecutive demands could account for the lack of relations between the bilingual profiles and EF performance.

Our findings are not without limitations. First, although there are no specific guidelines regarding the required sample size for latent profile analysis, a larger sample size is useful to estimate latent profiles more reliably by reducing potential classification error. Although our profile enumeration procedure ensures a substantial proportion of bilingual children for each class, future studies will need to replicate our findings with a larger sample from distinct bilingual populations to more reliably extract different profiles.

Our second limitation is that our latent profiles were based, by and large, on young bilingual children's verbal (speaking and listening) activities and not on other possible indicators, such as phonological skills or mastery of orthography. Although considering as many profile indicators as possible enables the extraction of more reliable and diverse profiles that can capture qualitatively different bilingual experiences (Wurpts & Geiser, 2014), it also requires a larger sample size. Further, it is important to note that profile indicators should be chosen carefully in light of both the theoretical framework and empirical evidence, such that the extracted profile outcome is more accurately reflective of real-life classifications of bilinguals (Spurk et al. 2020). Given that the bilingual profiles found in our study closely resemble those that are easily observed in a local context, this lends further support to the validity of our indicators and strengthens the ecological validity of our findings.

Third, there are several measurement issues. We used the PPVT as an objective measure of receptive vocabulary in English, but we did not assess that of Mandarin Chinese. Previous research suggests that mother tongue (e.g., Mandarin) vocabulary and English vocabulary are closely related among children in Singapore, likely due to its multilingual context and state-sponsored bilingualism (Dixon, 2010). However, given that the frequencies and complexities of Chinese receptive vocabulary may differ from those of English, it is crucial to use an objective and standardized measure of Chinese. Thus, future studies should use standardized measures of receptive vocabulary in both English and Chinese to more accurately delineate bilingual profiles and their associations with EF outcomes. We also asked parents to report on their child's English and Chinese proficiency for speaking. However, it is possible that parents of bilingual children may not be bilingual themselves, and thus may not have sufficient expertise to accurately assess their child's language proficiency. Future research should therefore ensure that parents have sufficient bilingual proficiency to rate their child's bilingual proficiency. Also, our reliance on parent- and teacher-reported measures of children's bilingualism (i.e., language exposure and use) is limited, since this may introduce reporting bias. For instance, working parents may not have full knowledge of the child's language use during the day and may under- or overreport their child's language production and exposure. Hence, future studies should document language exposure and use through more accurate methods such as Peña et al.'s (2020) BIOS interview tool, which captures the child's language exposure and use across different days of the week and contexts.

Fourth, given that most tasks that assess EF involve not only EF-related variance but also task-specific variance that is not relevant to EF, the task-impurity problem has been acknowledged in the literature to be a critical issue. For instance, the Stroop task has been widely used to assess prepotent response inhibition, but it also requires the ability to read words and discriminate colors, which are not necessarily pertinent to executive functioning. Therefore, it is crucial that future studies control for those measurement errors inherent to EF tasks. To this end, a latent variable approach has been widely used, since it allows researchers to capture the common variance shared across multiple measures of EF that purportedly assess the same EF skills. Although this method is desirable, we were unable to employ it because it requires a number of EF tasks (ideally, nine or more) to reliably estimate the required latent variables that correspond to each facet of EF. Hence, future studies should address the task-impurity problem by combining a latent variable approach with LPA to account for both task impurity and bilinguals' heterogeneity issues.

Taken together, using a multi-method (survey and behavioral tasks) and multi-informant (parents and teachers) approach, as well as more refined and sophisticated statistical methodology, our study emphasizes the notable heterogeneity evident across bilinguals and their unique influence on EF outcomes in young children. Our study implies that bilinguals' dissimilar experiences should be given more weight in investigating the cognitive advantages of bilingualism in children.

Acknowledgement. This study was supported by a Lee Kong Chian fellowship and a grant from the Ministry of Social and Family Development (MSF 132-06-237D (45)) awarded to Hwajin Yang; from the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2018S1A5A8027819) awarded to Sujin Yang.

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