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Relations of English and Heritage Language Proficiency to Response Inhibition and Attention Shifting in Dual Language Learners in Head Start

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ABSTRACT
This study examined the concurrent relations of English (EL) and heritage language (HL) proficiency to executive functions (EF) among low-income dual language learners (DLLs) from immigrant families. In a sample of 90 children (age = 38–70 months) from Chinese-speaking Chinese American and Spanish-speaking Mexican American families recruited from Head Start preschools, children's EL and HL proficiency was assessed using receptive and expressive vocabulary tests, and EF was assessed using behavioral tasks measuring response inhibition and attention shifting. Multiple regressions were conducted to test the unique and interactive relations of EL and HL vocabulary to EF, controlling for family socioeconomic status and other demographic characteristics. Higher EL and higher HL vocabulary were uniquely associated with higher attention shifting. By contrast, neither EL nor HL vocabulary was uniquely associated with response inhibition. Interaction effects of EL × HL in relation to EF were also found. The results provided some evidence for the dual benefits of EL and HL proficiency on EF (especially attention shifting) among DLLs from low-income, immigrant families.

Introduction

Dual language learners (DLLs) refers to children who are learning two languages at the same time, as well as those learning a second language while continuing to develop their first language (United States Department of Health and Human Services [USDHHS], 2009). According to U.S. Census data, DLLs made up 41.5% of all children enrolled in preschool, and Spanish (59%) and Chinese (3%) were the two most common non-English languages used (Park, O'Toole, & Katsiaficas, 2017). Compared to non-DLLs, DLLs are more likely to come from low-income families (Borjas, 2011). DLLs made up one-third of children served by Head Start, a free early childhood education program for socioeconomically disadvantaged families (National Academies of Sciences, Engineering, and Medicine [NASEM], 2017). Past research has shown that DLLs, especially those from low socio-economic status (SES) families, lagged significantly behind their peers in school readiness at kindergarten entry, and the achievement gap continued to widen (Fry, 2007; Garcia, 2018). Thus, identifying protective factors for DLLs in low-SES families is critical for developing research-based early childhood education programs.

The present study examined the links between dual language proficiency, or proficiency in both English and heritage languages, and executive functions (EF) among DLLs from immigrant families who were attending Head Start. EFs play important roles in children's long-term academic and socioemotional competence (Diamond, 2013). Previous studies have sometimes found that bilingual

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children performed better than monolingual children on EF tasks, suggesting a potential "bilingual advantage" (Bialystok, 2017). However, it remains unclear the extent to which the advantage can be observed in a diverse population of DLLs, including those from low-SES immigrant families. Because the bilingual experience is a dynamic process with substantial heterogeneity in a child's acquisition, proficiency, and use of languages (Luk & Bialystok, 2013), using a dimensional approach to assess dual language proficiency and examining their unique and interactive relations to EF can shed some light on whether and how the bilingual advantage can generalize to the heterogeneous DLL population.

In a sample of 90 preschoolers from Chinese-speaking Chinese American (CA, n = 44) and Spanish-speaking Mexican American (MA, n = 46) families enrolled in Head Start, we assessed children's EL and HL proficiency using vocabulary tests and EF using two behavioral tasks of response inhibition and attention shifting. Specifically, we tested: (a) whether EL and HL vocabulary were uniquely associated with EF; and (b) whether EL and HL vocabulary interacted in relation to EF. We controlled for demographic variables that might confound the language-EF associations (i.e., family SES, cultural group, child age, gender, immigrant status, age of EL acquisition, and length of schooling). By testing the hypotheses separately in different domains of language (receptive vs. expressive vocabulary) and different measures of EF (response inhibition vs. attention shifting), the study can inform theory on the developmental processes underlying the language-EF links.

Dual language learners in Head Start

This study focused on DLLs in Head Start, who are navigating between HL-dominant home and EL-dominant classroom contexts on a daily basis. The language experience of DLLs in Head Start is more typical for the larger DLL population in the United States than the language experience of balanced bilinguals, or bilingual speakers who have relatively similar skills in their respective languages across different domains (NASEM, 2017). More than a third (39%) of Head Start children lived in households where a language other than English was spoken, and Spanish was the most prevalent home language (Aikens, Knas, Malone, Tarullo, & Harding, 2017). At Head Start entry, only half (54%) of DLLs demonstrated sufficient receptive and expressive proficiency in English (Aikens et al., 2017). Although the Head Start curriculum encourages teachers to use children's HL when feasible, the program does not prescribe language of instruction (USDHHS, 2009). In fact, research has found that in Head Start classrooms with a large number of Latino DLLs, the classroom instruction occurred primarily in EL (Jacoby & Lesaux, 2017). A longitudinal study of Head Start children showed significant differences between DLLs and non-DLLs in EL and HL vocabulary, and the differences persisted after two years of schooling (Hammer, Lawrence, & Miccio, 2008).

The achievement gap is further compounded by the low-income status of DLL families. Compared to the monolingual English households enrolled in Head Start, DLL households are more likely to fall at or below the poverty threshold (OPRE, 2013). Specifically, 81% of DLLs in Head Start lived in households with an income at or below 130% of the poverty threshold, as compared to 70% of children from monolingual households attending Head Start (Office of Planning, Research, and Evaluation [OPRE], 2013). DLLs come from less literacy-rich home environments with fewer books, less reading time with family members, and fewer family activities that may contribute to literacy and numeracy skills than children from monolingual English homes (OPRE, 2013). For example, a Head Start child from a monolingual English home on average had 54 books, whereas the Head Start DLL had 25 books (OPRE, 2013). Finally, a nationally representative study of DLLs in Head Start showed that these children had English vocabulary scores over 2 *SD* below the nationally normed mean, and Spanish vocabulary scores 1 *SD* below the national mean (García, 2018).

Despite the achievement gap, DLLs might have developmental assets or protective factors associated with the bilingual experience. A common language profile of the young DLLs is that the HL is the first language acquired by the parents in their native countries and the parents' more proficient language. Young DLLs may first acquire the HL at home and then become more dominant in EL as they enter school. During the preschool period, which is commonly DLLs' first exposure to formal EL education (Hammer et al., 2008), many DLLs are in the dynamic process of developing dual language proficiency. The preschool period is also marked by significant development in self-regulation, including EF (Zelazo & Frye, 1998). Thus, DLLs in Head Start provide an excellent opportunity to study the language-EF relations, and the findings can inform educational programs or interventions aimed at closing the achievement gap.

The role of language in executive functions in monolingual and bilingual children

Executive functions (EF), a component of self-regulation, refer to effortful top-down mental processes controlling goal-directed behaviors (Diamond, 2013). Among preschool-age children, EF is typically viewed as a unitary construct with dissociable components of inhibitory control, working memory, and attention shifting (Diamond, 2013; Karr et al., 2018). Early developmental theorists posited that language skills play a critical role in facilitating the development of self-regulation, allowing children to reflect on and modify behavior (Vygotsky, 1962). Consistent with these theories, empirical studies conducted with monolingual children showed that symbolic representations learned through language can enable young children to inhibit dominant response and flexibly shift attention (Carlson, Davis, & Leach, 2005). Moreover, a longitudinal study found that higher expressive language at baseline predicted an earlier growth in self-regulation in 3- to 7-year-olds (Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016). Higher EF, in turn, has been identified as a consistent predictor of children's long-term academic success and emotional well-being (Blair, 2002).

The language-EF link can be more complex in DLLs, partly because they are learning two distinct language systems. When studying the language-EF links in DLLs, one needs to consider not only the additive or unique relations of two languages to EF but also their interaction. One key neurocognitive theory on bilingual language production is Green's inhibitory control model (Abutalebi & Green, 2007). According to this theory, to manage the ongoing linguistic experience, bilinguals engage brain areas to reduce interference from the cross-language representations (inhibitory control) while selectively attending to the target language (attention shifting). Thus, researchers have hypothesized that the constant need to exercise executive control might lead to enhancement of EF over time. Indeed, empirical studies found that proficiency in two or more languages were associated with benefits in EF above and beyond proficiency in one language (see Bialystok, Craik, Green, & Gollan, 2009 for a review). A meta-analysis examining the cognitive correlates of bilingualism found the strongest support for attentional control (including attention shifting and inhibitory control) (Adesope et al., 2010). On the other hand, a few studies have shown null effects of bilingualism on working memory (Bialystok, Craik, & Luk, 2008; Engel de Abreu et al., 2012). Specifically, low-income DLL children outperformed monolinguals on EF tasks requiring inhibition of distracting information and attentional control (White & Greenfield, 2017).

However, as reviewed by others (e.g., Paap, Johnson, & Sawi, 2015), there remains inconsistencies in this literature. For example, the "bilingual advantage" was found for some measures of EF (e.g., attentional control) but not others (e.g., response inhibition) (Martin-Rhee & Bialystok, 2008). The effects were found in some groups of bilinguals (e.g., early simultaneous bilinguals) but not others (e.g., early sequential bilinguals) (Luk, De Sa, & Bialystok, 2011). The inconsistencies may further be attributed to multiple factors, such as differences in measures of bilingualism and EF and failure to consider confounding variables (e.g., SES). Thus, further research is needed to clarify whether and how the dual language experience might be beneficial for which aspects of EF.

While previous studies often used a categorical approach to classify bilingualism and compared bilinguals with monolinguals, researchers recently argued that bilingualism is a continuous and multidimensional construct (Luk & Bialystok, 2013). Due to the observed heterogeneity among bilinguals on language proficiency, usage, and learning history, the dimensional approach can allow researchers to test more complex relations. The dimensional language scoring measures EL and HL proficiency using continuous numerical scoring within a bilingual population in contrast to the categorical bilingual versus monolingual populations. Thus, one can test: (a) whether proficiencies in two languages (e.g., EL and HL) are uniquely related to EF; and (b) whether proficiencies in two languages interact (i.e., EL × HL) in relation to EF. Such a dimensional approach is in line with Green's neurocognitive model (Abutalebi & Green, 2007) that EF is engaged to resolve a lexical competition between two languages.

A small number of studies have used such a dimensional approach to examine the language-EF relations (Bialystok & Barac, 2012; Chen, Zhou, Uchikoshi, & Bunge, 2014; Crivello et al., 2016; Gordon, 2016; Thomas-Sunesson, Hakuta, & Bialystok, 2018; Von Bastian, Souza, & Gade, 2016). In a sample of English-Spanish preschoolers, Gordon (2016) found that although the main effects of EL and HL were nonsignificant in relation to performance on mental state reasoning, there was a significant EL × HL interaction, such that EL proficiency was associated with higher task performance at a high (but not mean or low) level of HL. Chen et al. (2014) found a similar EL × HL interaction in a sample of 6–9-years-old Chinese-English DLLs: HL literacy was associated with higher cognitive flexibility at only a high level of EL literacy. Other researchers have measured the degree of bilingual effect using the HL to EL proficiency ratio (e.g., Bialystok & Barac, 2012; Thomas-Sunesson et al., 2018; Von Bastian et al., 2016) and found that a more balanced proficiency in two languages was associated with higher EF. In sum, although researchers have begun to use the dimensional approach to examine the language-EF links, more studies are needed to test these questions in preschool-age DLLs from low-income families.

Factors that might confound the language-EF associations

In testing the relations between language and EF, we found several confounding variables that can be associated with the development of both outcome variables. Previous studies have found that a child's demographic characteristics such as age (Zelazo & Frye, 1998) and gender (Lindholm-Leary & Borsato, 2006; Mazzocco & Kover, 2007) are associated with dual language proficiency as well as EF. The child's family and school environments may further influence their language and EF skills. For instance, DLLs from lower-SES families performed worse on EL and HL language proficiency tests (Dixon, Wu, & Daraghmeh, 2012) as well as EF tasks (Noble, Norman, & Farah, 2005) compared to middle- and high-SES families. Moreover, the length of preschool attendance (Duncan & Magnuson, 2013) and the age at which children learn their first and second languages (Luk et al., 2011; Weber-Fox & Neville, 2001) have been found to predict both outcomes. Finally, cultural factors, such as Asian versus Western ethnic backgrounds of the child (Carlson, 2009; Uchikoshi, 2014) or the family's acculturation levels as measured by immigration status (Chen et al., 2015; Ishizawa, 2004), have been found to influence the development of language and EF.

The present study

The present study tested unique and interactive relations of EL and HL vocabulary to EF in preschool-age DLLs from low-income Chinese American and Mexican American families. A methodological strength was the assessment of EL and HL proficiency using continuous measures of receptive and expressive vocabulary. Because language comprehension and production are asymmetrical processes that require coordination and each uniquely contributes to language development (Hoff, 2017), it is likely that the language-EF links would vary between receptive and expressive vocabulary. Moreover, including two DLL groups (i.e., DLLs from Chinese- and Spanish-speaking families) provided an opportunity to test the generalizability of the language-EF relations across language and cultural groups.

First, we hypothesized that children's higher EL and HL vocabulary would be associated with higher EF, controlling for the covariates. Although no previous empirical studies have examined and found clear differential associations between receptive and expressive vocabulary with EF (e.g., Cascia & Barr, 2017), Green's theoretical model is more relevant to bilinguals' language production than comprehension.

Thus, we hypothesized that the language-EF associations would be stronger in expressive vocabulary than receptive vocabulary. Second, based on the findings from Chen et al. (2014), we hypothesized that EL and HL vocabulary would interact such that the positive association between vocabulary in one language and EF might be stronger among those children with higher vocabulary in the other language. Third, we hypothesized that the language-EF associations would be stronger for attention shifting than inhibitory control, based on a recent review that suggested that tasks that measured attentional flexibility, switching, and monitoring aspects of EF showed more robust effects of bilingual advantages than tasks that measured inhibitory control alone (Bialystok, 2017).

Method

Participants

The sample consisted of 90 children (age = 38 to 70 months, *M* age = 54.37, *SD* = 7.11, 59% girls) and 90 parents (98% mothers) recruited from the Head Start programs in the San Francisco Bay Area. The children were from Chinese-speaking Chinese American families (*N* = 44) or Spanish-speaking Mexican American families (*N* = 46). Of these children, 18% were born outside of the United States (i.e., first-generation), 77% were born in the United States and had at least one foreign-born parent (i.e., second-generation), and 5% were born in the United States and had two U.S.-born parents (i.e., third-generation or above). The children had attended Head Start for an average of 14.4 months (range = 1–32 months, *SD* = 8.0).

The participating parents were between 21 and 46 years of age (*M* age = 34.6, *SD* = 6.38), mostly foreign-born with 46% born in China, 43% born in Mexico, 9% born in the United States, and 2% born in other parts of the world. The parents had lived in the United States for an average of 9.2 years (range = 0 to 28 years, *SD* = 6.2). Average parental education was 10.9 years (education = 5 to 17 years, *SD* = 3.40). Annual per capita income was calculated by dividing the estimated total income for the past year by the number of adults and children living in the household. The average per capita income for the sample (assessed in 2013–2015) was $5,167 (range = $1,000 to $24,167, *SD* = $3,655), which was below the federal poverty level income ($11,490 in 2013 for individuals) (Datta & Meerman, 1980).

On average, the children were first exposed to HL (Spanish or Chinese) at 2.9 months (*SD* = 7.44) and EL at 24.7 months (*SD* = 15.04). A majority of the children were first exposed to the HL (83.3%) in the home environment and EL (56.7%) in a classroom environment (i.e., Early Head Start, Head Start). Parents reported child's language use at home using a 5-point scale (1 = *HL only*, 2 = *both HL and EL but more HL*, 3 = *HL and EL equally*, 4 = *both HL and EL but more EL*, 5 = *EL only*). Children's language use at home was primarily HL (adults speak to children = 1.46–1.53, children speak to adults = 1.85–2.10), whereas language use at school was primarily EL (teachers speak to children = 3.25–3.55, children speak to teacher = 3.51–3.57). There were a few differences between CA and MA groups. At school, MA children spoke more HL with the classroom teacher than CA children (CA = 3.82, MA = 2.69, $p < .01$). Parents rated the importance of children's speaking and writing in HL and EL on a 5-point scale from 1 (*not important*) to 5 (*very important*). MA parents rated the children's speaking (MA = 4.98, CA = 4.66, $p < .01$), reading, and writing in HL (MA = 4.96, CA = 4.30, $p < .01$) as more important than CA parents.

Procedures

Recruitment

Local Head Start centers with a high concentration of CA or MA children were targeted for recruitment. After developing partnerships with the centers, a team of bilingual research assistants visited the centers to introduce the study and distribute fliers (available in Chinese, Spanish, and English). The project was described as a research study to understand language and emotional development of children in Chinese American and Mexican American families. Interested parents filled out a contact form on site. Research staff also introduced the study at the monthly parent meetings and asked classroom teachers to assist with recruitment. Recruitment was conducted at 15 centers, and 229 contact forms were returned.

Screening

A bilingual interviewer conducted a 15-minute phone screening interview in the parent's preferred language to determine the child's eligibility. To be included in the study, the child must: (a) be between 36 and 71 months of age; (b) be currently enrolled at a center-based Head Start program for a minimum of three days per week; (c) understand and speak some English and Spanish, Cantonese, or Mandarin, as reported by parents; and (d) have at least one parent who self-identified as ethnically Chinese or Mexican. Children who were diagnosed with a speech and language disorder or receiving speech and language services were excluded from the study. For families with multiple eligible children, only one child was invited to participate. Of the 194 families (CA = 106, MA = 88) phone screened, 90 children (CA = 44, MA = 46) were found eligible and completed the assessment. Of the 104 children excluded from the study, 26.9% received speech and language services, 32.6% did not meet all four eligibility criteria, and 40.5% were eligible at phone screen but dropped out of the study before assessment. The high dropout rate is likely due to novelty of participating in research studies among some subjects and difficulties in recruiting minority and immigrant families (Roosa et al., 2008).

Assessment

Eligible children were invited to participate in one 2.5-hour assessment with one parent. To minimize fatigue, snack and bathroom breaks were offered to the children between study tasks. The primary caretaker was asked to participate. Of the sample (N = 90), 98% of the children had mothers as the participating parent and 2% had fathers as the participating parent. Because low-income families have limited transportation options, we offered participants the choice of completing the assessment at our university lab (with additional compensation for transportation) or at their own homes with an identical assessment protocol. Of the sample, 68% of families completed the assessment in the lab, and 32% completed the assessment at home.

The full assessment consisted of concurrent (a) parent survey session, and (b) child language and EF testing in two separate areas, followed by (c) parent-child interaction tasks. The survey was administered in the parent's preferred language (Cantonese, Mandarin, Spanish, or English) by bilingual assessors. The majority of parents (90%) completed the surveys in HL, whereas 10% of parents completed the surveys in EL. The EF assessment was administered by bilingual assessors in the child's dominant language (Cantonese, Mandarin, Spanish, or English). Parents reported on the child's dominant language during the phone screening, and this information was confirmed via observation during the first 10 minutes of the assessment. The majority of children (82%) completed the EF assessment in the HL, and 18% of children completed the assessment in EL. The HL and EL language assessments were conducted during the same visit but administered by different bilingual interviewers to minimize code-switching. The orders of language and EF tests were counterbalanced. At the end of the 2.5-hour assessment, children received a small toy prize, and parents received monetary compensation.

Measures

Family demographics, migration history, and children's language history

Parents completed the adapted version of the Family Demographics and Migration History Questionnaire, which has been used in previous studies of Chinese American and Mexican American immigrant families (Chen et al., 2014; Roosa et al., 2008). The questionnaire included items on child's age, parents's age, parent's country of birth and length of stay in the United States, parent's education, family annual income, household size, and parent's marital status. In addition, parents completed a questionnaire on the child's language history (Leung & Uchikoshi, 2012), which included items on: the child's age and context of EL and HL acquisition, language use across home and preschool with various speakers, as well as parental beliefs about the child's EL and HL proficiency.

English and heritage language vocabulary

Children were individually administered tests of expressive and receptive vocabulary in both EL and HL (Cantonese or Mandarin for CA, Spanish for MA). For both groups, EL receptive vocabulary was assessed using the Peabody Picture Vocabulary Test 3rd edition (PPVT-III; Dunn & Dunn, 1997). In this test, the child was asked to select one picture from an array of four pictures that best matched the spoken word presented by the interviewer. The reported split-half reliability, comparing half of test results to the other half, ranged from .86 to .97. The Chinese version, Peabody Picture Vocabulary Test-Revised (Lu & Liu, 1998), was used to assess Chinese receptive vocabulary for the CA group. The reported split-half reliability standardized on native Chinese-speaking children was .95 (Lu & Liu, 1998. The Spanish version, *Test de Vocabulario Imágenes-Peabody* (TVIP; Dunn, Padilla, Lugo, & Dunn, 1986), was used to measure Spanish receptive vocabulary for the MA group. The reported split-half reliability for TVIP was .94 for 4-year-olds and .93 for 5-year-olds (Dunn et al., 1986). Raw scores were used for all data analysis.

For both CA and MA groups, EL expressive vocabulary was measured using the picture vocabulary subtest of the Woodcock Language Proficiency Battery–Revised (WLPB-R; Woodcock, 1991). This test measured the child's ability to name both familiar and unfamiliar pictures in order of increasing difficulty with each response scored as correct or incorrect by the interviewer. The internal consistency reliability in a native English-speaking sample was .81 (Woodcock, 1991). Because there are no standardized measures for Chinese-speaking DLLs, expressive vocabulary in Chinese was assessed using the pictures on the English WLPB-R picture vocabulary subtest for the CA group. This strategy has been used in a previous study of Chinese school-age DLLs with Cronbach's alpha estimated to be .71 (Uchikoshi, 2014). The Spanish version, *Vocabulario Sobre Dibujos* (Woodcock & Muñoz-Sandoval, 1996), was used to assess Spanish expressive vocabulary for the MA group. The reported internal consistency reliability was .73 for Spanish-speaking 4-year-olds (Woodcock & Muñoz-Sandoval, 1996).

Executive functions

Due to the theoretical emphasis (Abutalebi & Green, 2007) and previous empirical evidence supporting inhibitory control and attention shifting (Adesope et al., 2010; White & Greenfield, 2017), we focused on these two aspects of EF and did not include a measure of working memory. Children were individually administered two tasks from the Preschool Executive Functions Assessment (Willoughby, Blair, Wirth, & Greenberg, 2010): Silly Sounds Stroop (SSS) and Something's the Same (STS) task. The SSS task was designed to assess inhibitory control of a prepotent response. Children were presented with two pictures of a cat and a dog. The assessor instructed the child that in the SSS, dogs make the sound of cats (e.g., "meow") and cats make the sound of dogs (e.g., "woof"). A total of 36 side-by-side illustrations of a cat and a dog were presented randomly to each child. The assessor pointed at each picture and asked what sound this animal made in the SSS game. Children were marked as correct if they were able to follow the SSS rule (i.e., dogs "meow" and cats "woof") and marked incorrect otherwise. Self-corrections were marked as incorrect, as this task measured the ability to rapidly inhibit an incorrect response.

The STS task was designed to measure attention shifting. Each child was shown two pictures that were similar along one dimension (i.e., color, size, or content). The assessor explicitly named the dimension of similarity. The following page presented the same two pictures with a third new picture. The third picture was similar to one of the original two pictures along a new dimension. The child was asked to choose which of the two original pictures was the "same" as the third picture. The task required the child to shift attention from the original dimension of similarity to a new dimension of similarity. A total of 20 trials were administered with dichotomous responses (i.e., correct or incorrect).

In longitudinal studies of preschool-age children from diverse families, both SSS and STS tasks have demonstrated satisfactory reliabilities (>.60) for children with low to average levels of EF (Willoughby, Wirth, & Blair, 2012). In the present study, the split-half reliability of SSS items using the Spearman-Brown coefficient was estimated to be .85 for the full sample (.88 for CA and .76 for MA). The split-half reliability of STS items for the full sample was .70 (.75 for CA and .65 for MA). We compared the performance between those who were administered the tasks in EL (N = 16) and the HL (N = 74), and no difference was found.

Results

Data analyses were conducted in three steps. First, the two language groups (CA and MA) were compared on demographic and study variables. Second, to select the covariates to be included in the main analyses, we examined the pairwise correlations between demographic variables and language and EF variables. Third, multiple regressions were conducted to test the unique and interactive relations of EL and HL vocabulary to EF, controlling for covariates.

Descriptive statistics of sociodemographic and study variables by culture groups

The descriptive statistics for continuous sociodemographic variables, language proficiency, and EF for the full sample and by culture groups are reported in Table 1. Based on the cutoffs of 2 and 7 for skewness and kurtosis respectively, all demographic and outcome variables met the criterion for normality with the exception of family income, which was positively skewed and had a high kurtosis (i.e., there was a concentration of cases with low scores). This was expected given that the present study targeted low-income families from Head Start communities.

To compare mean differences in sociodemographic, language, and EF variables between the CA and MA samples (Table 1), we computed independent-sample t-tests for continuous variables and Pearson chi-square tests of independence for categorical variables (child's gender, generation status, and dominant language; parent's gender, employment, marital status, and preferred language). A few cultural differences were found on demographic variables. First, there was a group difference in children's immigration generation status; the CA children were either first (36.4%) or second generation (63.6%), whereas the MA children were either second (89.1%) or third generation (10.9%) status, $\chi^2(df = 2) = 23.4, p < .001$. Second, the CA sample (93.2%) had a higher proportion of children living in married and two-parent households compared to the MA sample (47.8%), $\chi^2(df = 5) = 23.4, p < .001$. Third, the CA mothers were significantly older than the MA mothers, $t(df = 87) = 6.0, p < .001$. In addition, there was a marginal difference in the mean level of parental education; the parents of the CA children had slightly more years of education than parents of MA children, $t(df = 88) = 1.70, p < .10$. Although the two groups did not differ on EL and HL proficiency accuracy on the EF attention shifting task, the MA sample had a higher accuracy than the CA sample on the EF response inhibition task, $t(df = 82) = 3.4, p < .01$. No other group differences were found across measures.

Relations between potentially confounding variables and study variables

To identify the covariates for the main analyses examining the associations between dual language proficiency and EF, we first examined pairwise correlations between the theorized potential confounding variables, language, and EF variables reported in Table 2. Among the variables examined, five variables had at least marginally significant correlations with both language proficiency (EL or HL) and EF: child's age, immigration generation, age of English acquisition, length of Head Start attendance, and family income. Thus, these five variables were included as covariates in subsequent analyses testing the unique relations of language to EF (Steiner, Cook, Shadish, & Clark, 2010). Although child gender was correlated with EF (i.e., girls performed higher than boys on both EF tasks), they were unrelated to language proficiency. Similarly, cultural group was correlated with EF (i.e., MA children performed

Table 1. Descriptive statistics of study variables for the full sample and by cultural groups.

	The full sample						CA sample (N = 44)		MA sample (N = 46)	
	Min	Max	Mean	*SD*	Skewness	Kurtosis	Mean	*SD*	Mean	*SD*
Child's age (months)	38	70	54.4	7.1	−.09	.25	53.5	7.2	55.2	7.0
Per capita income (dollars)	1,000	24,166	5,167	3,655	2.63	9.90	5,646	3,407	4,663	3,875
Parental education (years)	5	17	10.9	3.4	−.27	−.94	11.5^{+}	3.4	10.3^{+}	3.3
Child's age of HL exposure	0	36	2.9	7.4	2.93	8.76	3.7	9.0	2.0	5.4
Child's age of EL exposure	0	60	24.7	15.0	−.21	−.98	23.6	14.2	25.7	15.9
Home language (adult to child)	1	5	1.5	1.0	2.17	4.14	1.3	.8	1.6	1.1
Home language (child to adult)	1	5	1.9	1.2	1.35	.96	1.8	1.1	1.9	1.2
School language (main teacher to child)	1	5	3.5	1.3	−.33	−.97	3.7	1.2	3.3	1.3
School language use (child to main teacher)	1	5	3.2	1.5	−.24	−1.46	3.8**	1.4	2.7**	1.5
Child's length of schooling in Head Start (months)	1	32	14.4	8.0	.29	−.91	14.3	8.8	14.6	7.2
English receptive vocabulary (raw score)	1	80	34.1	19.0	.10	−.93	33.4	19.2	34.7	19.0
English receptive vocabulary (standardized score)	40	112	77.1	16.5	−.38	−.42	76.5	17.5	77.7	15.8
English expressive vocabulary (raw score)	0	24	15.2	5.3	−.86	.34	15.5	5.6	15.0	5.1
English expressive vocabulary (W score)	47	469	426.5	45.4	−6.87	57.29	422.2	62.9	430.3	18.6
HL receptive vocabulary (raw score)	3	88	26.4	14.8	1.28	2.78	26.4	15.7	26.4	14.2
HL expressive vocabulary (raw score)	0	24	15.3	4.9	−.79	.33	15.0	5.8	15.7	3.9
Response inhibition accuracy	.03	1.00	.64	.28	−.54	−.72	.54**	.31	.73**	.21
Attention shifting accuracy	.30	1.00	.77	.16	−.56	−.15	.74	.18	.79	.14

Note. HL = Heritage Language (i.e., Spanish for MA children, Chinese for CA children). The mean values marked with $^{+}$ were marginally different by cultural groups according to the independent-sample *t*-test ($p < .10$), the mean values marked with ** were significantly different by cultural groups according to the independent-sample *t*-test ($p < .01$). *Standardized HL scores for the are not reported because score norms are not available.*

Table 2. Correlations between potential confounding variables, language, and EF variables.

	English expressive vocabulary	English receptive vocabulary	Heritage language expressive vocabulary	Heritage language receptive vocabulary	Response inhibition	Attention shifting
Child's age	.57***	.59***	−.03	.31**	.21*	.46***
Per capita income	.22*	.18	.11	−.03	−.04	.20^{+}
Parental education	.02	−.03	.09	.07	−.01	−.01
Cultural group (0 = MA, 1 = CA)	.04	−.04	−.08	.002	−.35**	−.14
Child's length of schooling in Head Start	.36**	.41***	.02	.33**	.12	.26*
Child's gender (0 = Girls, 1 = Boys)	.10	−.001	−.09	−.14	−.23*	−.23*
Child's cultural group (0 = MA, 1 = CA)	.04	−.04	−.08	.002	−.34**	−.14
Child's generation status (1 = 1st, 2 = 2nd, 3 = 3rd)	.22*	.31**	−.01	−.13	.13	.28**
Child's age of English acquisition	−.34**	−.34**	.001	.13	−.02	−.21*
Child's language of EF assessment (0 = EL, 1 = HL)	−.34**	−.40***	.40***	.29**	−.05	−.02

Note. MA = Mexican American, CA = Chinese American; EL = English language, HL = Heritage language. Pearson correlations were reported for correlations between two continuous variables. Binomial correlations were reported for correlations between a dichotomous variable and a continuous variable.
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

better than the CA children on response inhibition task) but unrelated to language proficiency. Importantly, although children's language of EF assessment was correlated with language proficiency (i.e., those who did the EF assessment in HL had higher HL proficiency and lower EL proficiency), it was unrelated to EF. Thus, the remaining three variables were excluded from the subsequent models.

Testing the unique and interactive relations of EL and HL to EF

To test the unique and interactive relations of EL and HL proficiency to EF, four multiple regressions were tested to predict EF (response inhibition vs. attention shifting) simultaneously from the following set of predictors (Table 3): (a) the covariates (child age, family SES, generation status, AoA, length of schooling in Head Start), (b) the main predictors of EL and HL vocabulary, and (c) the interaction term of EL × HL vocabulary. Receptive and expressive vocabularies were tested in separate models. To minimize multicollinearity and to aid interpretation, EL and HL vocabulary as well as the covariates were mean centered prior to computing the interaction terms. Due to the presence of nonnormally distributed family income variable, the regression models were tested in Mplus 7.4 using the maximum likelihood estimation with robust standard errors. A total of 77 out of 90 participants had complete data; missing data were handled using the full information maximum likelihood (FIML) estimation. A power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). Prior studies using a similar dimensional approach to assess language reported effect size estimates (R^2) ranging from small (e.g., .04) to large (e.g., .30) (Chen et al., 2014; Thomas-Sunesson et al., 2018; Von Bastian et al., 2016). The present study had power to detect large (power = .99) and medium effects (.76) but limited power (.46) to detect small effects.

The regression results are reported in Table 3. In the regression analysis predicting response inhibition from receptive vocabulary (Model 1), neither the main effects of EL nor HL receptive vocabulary was significant. However, there was a significant interaction of EL × HL receptive vocabulary. Simple slopes analysis was conducted to probe the interaction of EL × HL receptive vocabulary for predicting response inhibition. Specifically, the relation between HL receptive vocabulary and response inhibition was estimated at three levels of EL vocabulary: sample mean, 1 *SD* above the sample mean ("high"), and 1 *SD* below the sample mean ("low"). As shown in Figure 1a, none of the simple slopes was statistically significant; the unstandardized slopes of HL proficiency predicting response inhibition at low, mean, and high levels of HL vocabulary were .48, .00, and −.47 respectively, *t*s (df = 67) = .53, .01, and −.79, *p*s = .60, .99, and .43. Regression outliers were examined using Cooks' Distance. Base on a cutoff value of 1, one case was identified as an outlier. After dropping it, the EL × HL interaction was no longer significant.

In the regression predicting attention shifting from receptive vocabulary (Model 2), there were significant main effects of EL and HL receptive vocabulary and a significant interaction of EL × HL receptive vocabulary. Simple slopes analysis was conducted to probe the interaction of EL × HL receptive vocabulary for predicting attention shifting. Specifically, the relation between HL receptive vocabulary and attention shifting was estimated at three levels of EL vocabulary; sample mean, 1 *SD* above the sample mean ("high"), and 1 *SD* below the sample mean ("low"). As shown in Figure 1b, at mean level of EL receptive vocabulary, HL receptive vocabulary was positively related to attention shifting; the unstandardized simple slope was .28, t(df = 67) = 2.48, p = .02. By contrast, at low and high levels of EL receptive vocabulary, the relations between HL vocabulary and attention shifting were nonsignificant; the unstandardized simple slopes were .62 (low) and −.06 (high), *t*s (df = 67) = 1.44 and −.20, *p*s = .15 and .84. Outlier diagnostics identified two cases with Cooks' Distance larger than 1. After dropping these cases, the main effects of EL and HL and EL × HL interaction remained significant.

In the regression predicting response inhibition from expressive vocabulary (Model 3), there was a marginally significant main effect of HL expressive vocabulary; higher HL expressive vocabulary was associated with higher inhibitory control. Finally, in the regression predicting attention shifting from expressive vocabulary (Model 4), both main effects of EL and HL expressive vocabulary were significant; higher levels of EL or HL expressive vocabulary were associated with better attention shifting. The associations were stronger for expressive than receptive vocabulary. In addition, child age uniquely predicted attention shifting such that older children displayed higher attention shifting than younger children.

Because the MA children performed better than the CA children on the EF inhibitory control task, we also computed standardized scores of inhibitory control and attention shifting within each culture group and conducted the regression analyses in Table 3 using group standardized scores. The

Table 3. Multiple regressions predicting EF from English and heritage language vocabulary.

	1. Predict response inhibition from receptive vocabulary		2. Predict attention shifting from receptive vocabulary	
Predictors	*B (SE)*	β	*B (SE)*	β
Covariates				
Age	.91 (0.69)	.23	.57 (.35)	.24
Family income	−.49 (0.84)	−.07	.27 (.42)	.06
Generation status	8.79 (7.13)	.15	5.37(3.57)	.15
Age of EL acquisition	.10 (0.22)	.06	−.08 (.11)	−.07
Length of schooling	.06 (0.55)	.02	−.23 (.28)	−.11
Language proficiency				
Receptive EL	−.04 (0.22)	−.02	**.22**$^{+}$ (.11)	.24
Receptive HL	.003 (0.23)	.001	**.24*** (.11)	.21
Receptive HL × EL	**−.03*** (0.01)	−.23	**−.02**** (.01)	−.27
Total R^2	.14^{+}		.39***	
	3. Predict **response inhibition** from expressive vocabulary		4. Predict **attention shifting** from expressive vocabulary	
Predictors	*B (SE)*	β	*B (SE)*	β
Covariates				
Age	.72 (.71)	.17	**.67*** (.34)	.28
Family income	−.74 (.86)	−.10	.05 (.42)	.01
Generation status	3.65 (6.81)	.06	3.85 (3.29)	.11
Age of EL acquisition	.16 (.23)	.09	−.05 (.11)	−.05
Length of schooling	−.22 (.53)	−.06	−.21 (.26)	−.10
Language proficiency				
Expressive EL	1.22 (.85)	.21	**1.22**** (.39)	.39
Expressive HL	**1.40**$^{+}$ (.75)	.24	**.66*** (.30)	.20
Expressive HL × EL	−.03 (.15)	−.02	.05 (.05)	.09
Total R^2	.12^{+}		.38***	

Note. EL = English, HL = Heritage language (Spanish for MA children and Chinese for CA children), *B* = unstandardized regression coefficient, *SE* = standard error of regression coefficient, β = standardized regression coefficient.
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

results were generally similar to the analyses predicting the raw scores. Importantly, the main and interactive effects of EL and HL proficiency predicting attention shifting remained significant when standardized EF scores were used. Thus, the cultural group difference in inhibitory control did not appear to influence the present findings on the links between language and EF skills.

Discussion

The main goal of this study was to examine the unique and interactive relations of English (EL) and heritage language (HL) vocabulary to executive functions (EF) in preschool-age DLLs from Head Start families. We found evidence for unique associations of EL and HL vocabulary to attention shifting; higher EL and higher HL (both receptive and expressive) vocabulary was associated with higher attention shifting. By contrast, neither EL nor HL vocabulary was uniquely associated with response inhibition. In addition, we found some evidence of EL × HL interaction in relation to EF, although the pattern of the interactions was somewhat different from previous studies.

Demographic and language characteristics of Spanish-English and Chinese-English DLLs in Head Start

Ethnically Chinese and Mexican children make up the largest proportions of the recent immigrant populations (Connor, Cohn, & Gonzalez-Barrera, 2013). At the national level, children from Chinese immigrant families are more likely to have college-educated parents than those from Mexican immigrant families; children from Mexican immigrant families are also more likely to have no parent with a high school degree (Crosnoe & Lopez-Turley, 2011). Thus, in previous studies that included children from

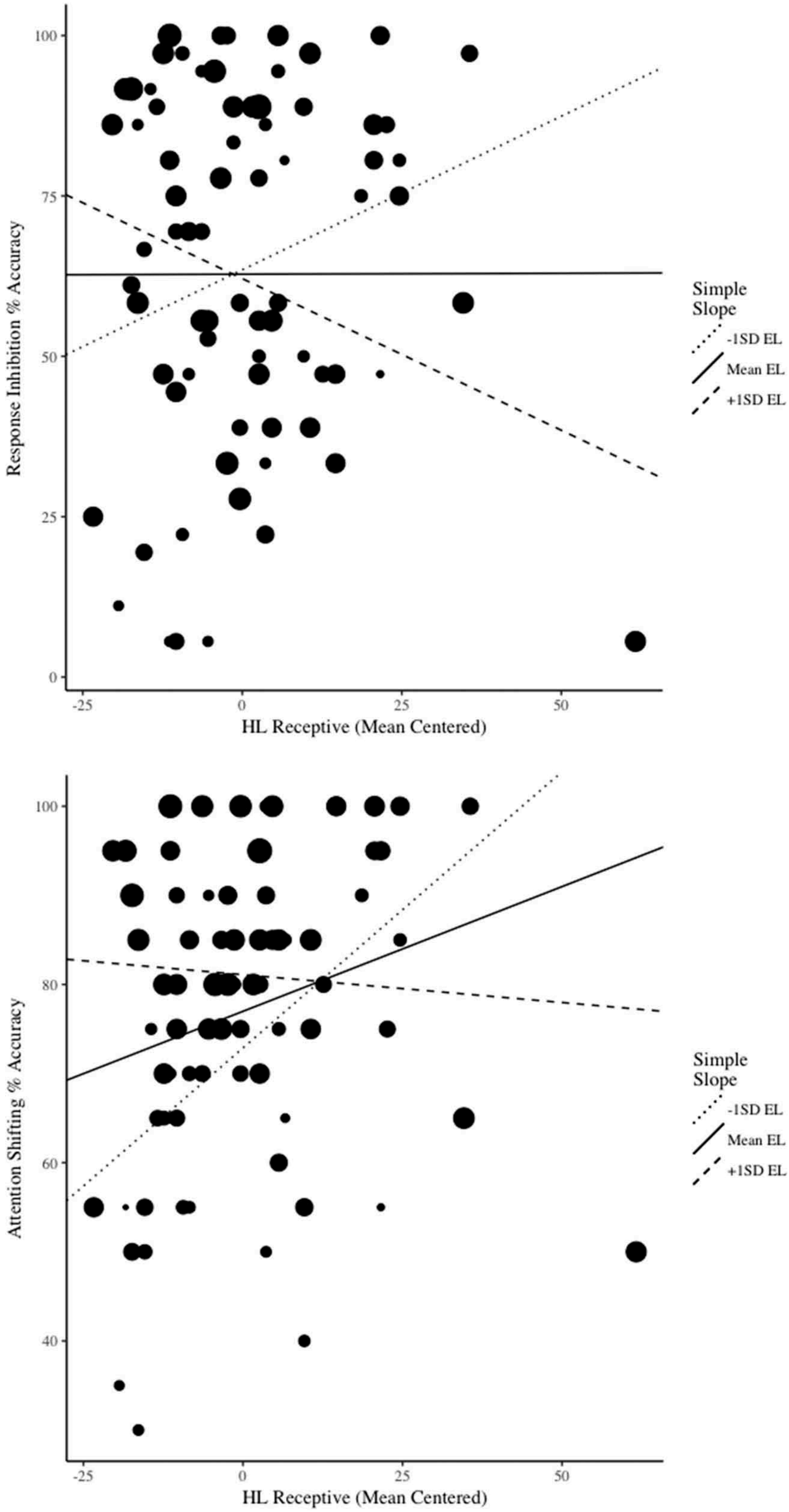

Figure 1. Probing the interactions of heritage language × English receptive vocabulary predicting executive functions. (a) The interaction of HL × EL receptive vocabulary predicting response inhibition. (b) The interaction of HL × EL receptive vocabulary predicting attention shifting.

Chinese and Mexican immigrant families, the culture-related differences found on children's achievement could be attributed to SES differences between the two groups (Kim & Chao, 2009). A strength of the present study is the selection of CA and MA families both enrolled in Head Start, which allows for a comparison of SES-matched sample of DLL from two different cultural and language groups. Comparisons of sociodemographic variables by groups confirmed that the CA and MA families in the present study did not differ on parental income or education. However, the two groups differed on immigration generation status: The CA group included some foreign-born first-generation children (36%), whereas the MA group consisted of all U.S.-born second-generation children.

Despite the few demographic differences, the CA and MA children in our sample did not differ on EL or HL proficiency. This is notable given the reported group difference in EL and HL use in the classroom context. Moreover, in contrast to previous studies (Tran, Arredondo, & Yoshida, 2015), the CA and MA cultural groups did not differ on the attention shifting component of EF. The MA children performed better than the CA children on the response inhibition task. The Chinese-English children in our study showed a similar level of mean performance on the inhibitory control task (M = .54) as the mean performance of another sample of low-income Spanish-English DLLs in Head Start using the same task (M = .55; White & Greenfield, 2017). Thus, replication with a different cross-cultural sample is necessary before drawing further conclusions about the cultural difference. It is possible that the Spanish version of the task was easier than the Chinese version due to the similarity of onomatopoeic words in Spanish (*guau*) and English (*woof*) in contrast to Chinese (*wang*). Due to the study's small sample size, it was not possible to test for measurement equivalence in the EF tasks by culture groups, which is an important direction for future research. Despite the cultural group difference in children's inhibitory control scores, additional analyses conducted using culture group-standardized EF scores showed similar results. Thus, the cultural difference in inhibitory control performance did not appear to influence the language-EF associations.

The links between dual language proficiency and executive functions

Using a dimensional approach to quantify DLLs' proficiency in two languages, we found that higher EL and HL proficiency was uniquely related to higher attention shifting. This result was consistent with previous findings among school-aged DLLs (Chen et al., 2014). Although we found some evidence for the EL × HL interaction in relation to EF, the pattern of interaction differed from previous studies (Chen et al., 2014; Gordon, 2016). In contrast to the interaction pattern found in Chen et al. (2014) and Gordon (2016), which showed that proficiency in one language was more strongly associated with higher EF at a high (compared to mean or low) level of proficiency in the other language, the interaction effects found in our study seemed to suggest the opposite pattern; proficiency in the HL was more strongly associated with higher EF at a low or mean (compared to high) level of proficiency in EL. It is important to consider the sample differences between our study and previous studies when interpreting these differences. Chen et al. (2014) used a sample of school-age Chinese-English DLLs, and most children were fluent EL speakers. Gordon (2016) recruited DLLs from local university preschools, and the average parental education of the sample was 15.2 years. In contrast, the DLLs from Head Start in the present study had an average parental education of 10.9 years (Table 1). For many DLLs from low-income families, preschool (e.g., Head Start) is the child's first exposure to formal EL instruction. In the present sample, we found that most children were first exposed to the HL shortly after birth and subsequently exposed to EL around age 2. Thus, the DLLs in our sample were still in the process of acquiring EL and are best characterized as emerging bilingual speakers. Indeed, the average EL proficiency (standardized score = 77 for English receptive vocabulary, Table 1) in the present sample was considerably lower than other samples measuring EL in preschool-age DLLs (e.g., 98 in Gordon, 2016). The DLLs in this sample scored 1.5 *SD* lower than the DLLs in Gordon's study who were not significantly different from their monolingual age-matched peers. While Gordon's DLLs were balanced bilinguals, on average, the DLLs in the present study were just starting to acquire English. Therefore, we did not find the typical pattern of bilingual effect (i.e., significant EL × HL effect on EF). White and Greenfield (2017) similarly found this differential effect of bilingual proficiency on EF between emerging versus fluent bilingual speakers.

Our results suggest that EF skills, especially attention shifting, are enhanced temporarily during the acquisition of the second language among emerging bilingual speakers. In contrast, established language skills in two languages among proficient bilingual speakers may require greater use of inhibitory control to suppress dominant languages. A recent longitudinal study of bilingual and monolingual school-age children (ages 8-12) found that EF components are differentially sensitive to the effects of bilingual experience at different developmental timepoints (Park, Weismer, & Kaushanskaya, 2018). In this study, the children who were proficient in both EL and HL demonstrated steep improvements in inhibitory control across time, but not attention shifting. Attention shifting may be most taxed in our younger sample of preschool-age bilingual children who are using HL at home and acquiring EL in the classroom. This requires the child to constantly shift attention to monitor their languages in different environments and choose which language is appropriate to use for communication (Costa et al., 2009). In older school-age children who are already highly proficient in both the HL and EL, there may be a stronger need to inhibit one language over the other. An alternative interpretation is that having a larger vocabulary supports attention shifting regardless of bilingualism; however, this interpretation is inconsistent with Green's theory of bilingual production involving lexical competition (Abutalebi & Green, 2007) and previous empirical studies examining translation equivalence between two languages (Crivello et al., 2016).

The lack of significant associations between vocabulary and inhibitory control was consistent with previous research comparing bilingual and monolingual children. Prior studies showed that preschool-age bilinguals performed better than monolinguals on tasks requiring interference suppression but not on tasks requiring response inhibition alone (e.g., gift delay) (Martin-Rhee & Bialystok, 2008). In our study focusing on within-group differences among DLLs, children's expressive HL is marginally related to response inhibition. Unlike the traditional Day-Night task (Gerstadt, Hong, & Diamond, 1994), the task used in the present study presents side-by-side pictures of the cat and the dog and may demand a small degree of interference suppression. Children who are more proficient at expressive language (i.e., those showing earlier growth) may be more equipped to perform well on the EF tasks. Unlike previous studies that primarily measured either receptive or expressive language (e.g., White & Greenfield, 2017), the direct comparison across language domains allowed us to observe nuanced effects.

In sum, we found that the language-EF associations were stronger for attention shifting than for response inhibition. This is consistent with the review by Bialystok (2017), which reported more robust bilingual effects on EF tasks assessing attentional flexibility, switching, and monitoring (or tasks assessing general ability to control attention and integrate information from different sources) than EF tasks that assessed inhibitory control. Especially among young children who are still in the process of acquiring two languages (i.e., emerging bilingual children), the ability to flexibly monitor and attend to either or both representational systems depending on contextual demands may be more necessary than inhibition of one dominant language. Consistent with this view, researchers have found that prelinguistic infants exposed to bilingual contexts use visual cues to attend to and accurately determine when a speaker has switched to speaking a different language, unlike infants exposed to monolingual contexts alone (Sebastian-Galles, Albareda-Castellot, Weikum, & Werker, 2012). These findings, together with our results, suggest that the inhibitory control model of language selection may not fully apply to emerging bilingual children.

Limitations, future directions, and implications

The present study had several limitations. First, only two individual EF tasks were used, which might not fully capture the individual differences in EF. While some researchers argue for the unitary view of EF among young children (Karr et al., 2018; Willoughby et al., 2012), Green and Abutalebi (2013) have identified eight cognitive control processes that may be impacted by bilingual language ability and use. Thus, future studies should employ multiple measures of EF. Second, the study used older versions the standardized measures of language proficiency (e.g., PPVT-3), which might not accurately capture variances in language development in DLLs. Relatedly, although the EF measures used in the present study have been validated on diverse samples of low-income preschool-age DLL (Willoughby et al., 2012) and used to measure EF among Spanish/English DLL (White & Greenfield, 2017), previous empirical evidence using study tasks on Chinese/English DLL is lacking. Third, the cross-sectional design does not allow us to examine the directionality of the language-EF associations. While language abilities can promote or facilitate EF development, it is also possible that children with higher EF are more effective at acquiring the second language, thereby more likely to become bilingual (i.e., bidirectional). Longitudinal or experimental designs can provide more rigorous tests of the directionality of the language-EF relations. Finally, based on our power analysis, the study's sample size was underpowered for detecting interaction effects (e.g., HL × EL). Thus, the interaction findings should be interpreted with caution, and replication using larger samples is an important future direction.

In conclusion, the present study showed that higher EL and HL vocabulary was uniquely associated with higher attention shifting in preschool-age DLLs from low-income immigrant families. Thus, even among these children who are emerging bilinguals, there are some EF benefits associated with EL and HL acquisition, especially on attention shifting during the preschool period. Despite the academic challenges faced by DLLs in low-income environments, dual language proficiency is a unique and protective asset that these children can benefit from. Rather than excluding such cultural assets through monolingual-focused practices, the development of the HL while promoting EL among DLLs in early childhood can be viewed as an effective strategy to close the achievement gap and respond to the increasingly diversifying and linguistically rich population of young children.

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