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Bilingualism narrows socioeconomic disparities in executive functions and self-regulatory behaviors during early childhood: Evidence from the early childhood longitudinal study

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Bilingualism Narrows Socioeconomic Disparities in Executive Functions and Self-Regulatory Behaviors During Early Childhood: Evidence From the Early Childhood Longitudinal Study

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Socioeconomic status (SES) and bilingualism have been shown to influence executive functioning during early childhood. Less is known, however, about how the two factors interact within an individual. By analyzing a nationally representative sample of approximately 18,200 children who were tracked from ages 5 to 7 across four waves, both higher SES and bilingualism were found to account for greater performance on the inhibition and shifting aspects of executive functions (EF) and self-regulatory behaviors in classroom. However, only SES reliably predicted verbal working memory. Furthermore, bilingualism moderated the effects of SES by ameliorating the detrimental consequences of low-SES on EF and self-regulatory behaviors. These findings underscore bilingualism's power to enrich executive functioning and self-regulatory behaviors, especially among underprivileged children.

A large body of research has demonstrated that a group of adaptive, goal-oriented control processes—inhibition, shifting, and updating of working memory (Miyake et al., 2000)—collectively known as executive functions (EF) are essential for many crucial aspects of childhood development, including school readiness (Blair, 2002), future academic achievement (Bull, Espy, & Wiebe, 2008), socioemotional competencies (Broidy et al., 2003), and physical health (Riggs, Chou, Spruijt-Metz, & Pentz, 2010). In view of the predictive role EF plays in early childhood, scholarly interest in the childhood experiential factors that modulate children's executive functioning has surged (e.g., Diamond, 2012; Hartanto, Toh, & Yang, 2016). Two of these experiential factors are socioeconomic status (SES; e.g., Farah et al., 2006; Mezzacappa, 2004) and bilingualism (e.g., Hartanto & Yang, 2016; Yang & Yang, 2016). Despite numerous studies that have investigated each of these factors, however, much less is known about how they interact and manifest themselves within an individual. Specifically, given the evidence that children from low-SES households are at greater risk of delays in EF development (e.g., Ardila, Rosselli, Matute, & Guajardo, 2005), bilingualism—which has been shown to confer cognitive advantages in EF—might attenuate the substantial gaps in EF skills between children from high-SES and low-SES families. Therefore, we sought to investigate potential interactions between the two experiences (i.e., SES and bilingualism) on executive functioning among 5- to 7-year-old children.

Empirical evidence that supports the relation between SES—which is typically indexed by parental education, income, or occupation—and children's EF has been well established. It is believed that high-SES children are well endowed with material resources, social connections, and positive parenting styles that beneficially contribute to their social and cognitive development (Bradley & Corwyn, 2002). For example, higher SES parents, relative to their lower SES counterparts, more frequently involve their children in cognitively stimulating materials and experiences (e.g., reading); allow for richer conversational exchanges (e.g., contingent responsiveness), and provide enriching teaching experiences that include more scaffolding and complex verbal guidance (Bradley & Corwyn, 2002; Shonkoff & Phillips, 2000).

In contrast, low-SES children have either limited or no access to those resources and are therefore deprived of proper stimulation and support for cognitive development. Accordingly, the literature has suggested that low-SES children perform poorly on

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a wide variety of EF measures. For example, Ardila et al. (2005) found that SES (measured by parental education) was significantly correlated with 5- to 6-year-olds' performance on a variant of the Wisconsin Card Sorting Task, which primarily taps the shifting aspect of EF. Similarly, Mezzacappa (2004) found that compared to their higher SES counterparts, 6-year-old children of lower SES (indexed by income, parental education, and occupation) showed poorer ability to resist interference from competing task demands on the Attention Network Task (ANT), which assesses varying aspects of executive attention (i.e., alerting, orienting, and inhibitory control). Noble, McCandliss, and Farah (2007) found that older children (first graders) from lower SES families (measured by parental education, occupation, and income) performed poorer than those from higher SES families on several EF tasks, including a nonverbal Stroop task—which assessed inhibitory control—and a nonverbal spatial working memory task. In a cohort of 11-year-olds (Farah et al., 2006), children from lower SES families (indexed by parental occupation and education) scored lower than those from higher SES families on a battery of EF tasks that assessed inhibition (i.e., the Number Stroop and Go/No-Go) and updating of working memory (i.e., two-back task). More recently, Hackman, Gallop, Evans, and Farah (2015) demonstrated that kindergarteners, first graders, and third graders from higher SES families (indexed by household income and parental education) exhibited greater working memory capacity, as assessed by the Memory for Sentences subtest of the Woodcock–Johnson Psychoeducational Battery (Woodcock & Johnson, 1989). Together, these findings suggest that disparities in SES play a formative role in children's executive functioning.

A parallel body of research supports the link between children's bilingualism and executive functioning. During bilinguals' language processing, their two languages are simultaneously activated, even when only one language is required (Green, 1998). Thus, bilinguals are subject to considerable linguistic and cognitive demands, due to their constant need to monitor attention to the target language—while suppressing the nontarget language—and efficiently switch from one language to another. These abilities are facilitated, in part, by the executive control system (Luk, Green, Abutalebi, & Grady, 2012; Morales, Calvo, & Bialystok, 2013). Accordingly, the literature suggests that extensive bilingual practice during early childhood may enhance executive functioning. For instance, early studies using the Dimensional Change Card Sort (DCCS; Zelazo, Frye, & Rapus, 1996)—which requires children to flexibly switch attention between two different sorting dimensions—have shown that 3- to 6-year-old bilinguals, relative to their monolingual counterparts, attained a significantly higher number of correct responses on the postswitch phase (e.g., Bialystok, 1999; Bialystok & Martin, 2004). As successful performance on the DCCS entails not only effectiveness in flexible attentional shifting (Kloo & Perner, 2005) but also the ability to inhibit proactive interference from a prior relevant task set (Kirkham, Cruess, & Diamond, 2003), this finding indicates a bilingual advantage in the inhibition and shifting aspects of EF. Replicating this, Carlson and Meltzoff (2008) reported that native English–Spanish bilingual kindergarteners (ages 4–6) outperformed English monolinguals and English second-language learners of Spanish on a battery of EF measures, including the DCCS. In addition, Yang and Yang (2016) found that 5- to 6-year-old Korean-English bilinguals' performance on the ANT was superior to their monolingual counterparts. In another cohort of 8- to 11-year-olds, Sorge, Toplak, and Bialystok (2016) observed that bilinguals outperformed monolinguals on the flanker task, which assesses inhibitory control.

However, the literature suggests that bilingualism may not necessarily benefit all aspects of EF. For instance, studies that examined the effects of bilingualism on working memory processing have revealed somewhat inconsistent patterns. Bialystok and Feng (2010) found that 6-year-old bilinguals and monolingual children showed equivalent performance on a verbal working memory task, which entailed the verbal recall of increasingly long strings of animal names. Similarly, Engel de Abreu (2011) longitudinally tracked the development of working memory from ages 6 to 8 and found that bilinguals' performance was comparable to that of monolinguals on simple and backward digit recall tasks. Taken together, these findings suggest that bilingualism selectively facilitates the inhibition and shifting aspects of EF but not verbal working memory processing.

Considering these individual contributions of SES and bilingualism to EF development, an intriguing question arises about the potential interaction between SES and bilingualism on children's EF. Given that life experiences are regarded as more critical for cognitive development than genetic influences in lower SES children (Turkheimer, Haley, Waldron, D'Onofio, & Gottesman, 2003), previous studies suggest that changes in various aspects of low-SES children's learning environments can significantly influence their cognitive development. For instance, a family-based intervention study of low-SES children demonstrated that basic training that promoted parental involvement—that is, parents' language use with the child and facilitation of the child's attention—significantly enriched low-SES children's neurocognitive attentional processes (Neville et al., 2013). In this vein, early bilingualism, which has been shown to be associated with changes in brain neuronal activation (for a review, see Garbin et al., 2010), likely serves as another form of enriching experience that yields greater cognitive gains for lower SES children than for higher SES children—that is, bilingualism likely attenuates the detrimental effects of low-SES on EF.

Despite the critical importance of these findings, the majority of prior research has not focused on the interactional impact of bilingualism and SES on children's EF (e.g., Carlson & Meltzoff, 2008; Engel de Abreu, 2011). Only a few studies have focused on the relation between SES and bilingualism; contrary to our expectations, their findings suggest an absence of significant interaction between SES and bilingualism. Specifically, Calvo and Bialystok (2014) tested younger children from working- and middle-class families and found that SES (indexed by maternal education) and bilingualism did not interact; instead, they independently accounted for 6- to 7-year-olds' working memory and inhibitory control performance on the frog matrices and flanker tasks, respectively. Specifically, middle-class children outperformed working-class children, and bilingual children surpassed monolingual children on all EF tasks. Krizman, Skoe, and Kraus (2015) found that bilingualism, but not SES (high vs. low; indexed by maternal education), emerged as a significant contributor to 14-year-old adolescents' inhibitory control performance on the Integrated Visual and Auditory Continuous Performance Test, in which participants were required to respond only when the number 1, and not 2, was seen or heard. Taken together, despite the possibility of an interaction between SES and bilingualism, the evidence—though limited—appears to favor the independent and noninteractional contributions of SES and bilingualism to EF development.

It is premature, however, to reach general conclusions based on only a few studies, which have notable methodological drawbacks. First, a central limitation in studies that have focused on the interaction of SES and bilingualism is the reliance on maternal education as the sole proxy for SES; high school and postsecondary education (e.g., university) were used to signify lower and higher SES, respectively. Although maternal education is perhaps the most pivotal component of SES for developmental outcomes (Bornstein, Hahn, Suwalsky, & Haynes, 2003), it remains unclear whether maternal education sufficiently captures the multidimensional construct of SES, which represents not only financial capital (i.e., material resources) but also human and social capital (i.e., nonmaterial resources such as knowledge, skills, and household connections; Coleman, 1988). Indeed, it has been noted that multidimensional indices—which combine income, education, and occupation—have been found to uniquely explain variance in children's behavioral outcomes (e.g., academic achievement) and approximate SES better than any of the single-dimensional indicators (Bradley & Corwyn, 2002; White, 1982). Moreover, the constituents of SES may represent distinct resources that differentially affect behavioral outcomes.

For example, family income may best represent the material resources available to children, whereas parents' educational attainment may be more important in shaping parent–child interactions; both play important roles in children's cognitive development (Duncan & Magnuson, 2012). Consistently, empirical studies have shown that household income and parental education independently affect EF (Arán-Filippetti & Richaud de Minzi, 2012; Hackman et al., 2015). Therefore, more thorough investigation will be required to determine how each SES component, as well as a composite index of SES, interacts with bilingualism in predicting EF. Second, because previous studies have employed convenience sampling, it is conceivable that the insignificant interaction between bilingualism and SES in previous studies could be attributed to range restrictions on SES levels. Accordingly, a nationally representative sample with broader SES ranges is needed to more precisely estimate the effect of interactions between bilingualism and SES on EF. Third, Paap, Johnson, and Sawi (2015) argue that although the null effects of bilingualism have been documented by studies using small to large sample sizes, significant effects principally appeared when samples were small and were diminished for larger samples. For instance, Antón et al. (2014; n = 360) and Duñabeitia et al. (2014; n = 504) conducted studies on large samples but failed to find bilingual advantages in inhibitory control skills (i.e., ANT and nonverbal Stroop task). These studies suggest that the effects of bilingualism on EF may not be as straightforward as previously assumed. In view of these challenges, large-scale studies would provide more reliable and robust evidence for bilingual advantages in EF (Button et al., 2013).

To tackle the issues addressed above, we identified three goals. The first was to revisit the potential interaction effect of SES and bilingualism on EF development. To better approximate the multidimensional construct of SES, which has conventionally been indexed by a single dimension (e.g., maternal education), we operationalized SES using two approaches. In the first, as commonly used in previous studies (e.g., Farah et al., 2006; Noble et al., 2007), we created a composite index of SES that contained the following dimensions: household income, maternal education, paternal education, maternal occupation, and paternal occupation. However, as this approach cannot identify each SES dimension's unique contributions to children's EF, in our second approach we followed Duncan and Magnuson's (2003) recommendation by considering each component separately. Employing both approaches to operationalize SES allowed us to determine the locus of the interaction between bilingualism and SES. Second, given the inconclusive findings, we aimed to examine the impact of SES and bilingualism on EF with a large sample and longitudinal design, as this would enhance the study's precision and reliability. Third, whereas previous studies have primarily focused on cognitive performance on laboratory-based EF measures, little is known about whether the effects of SES and bilingualism on EF processes could be extended to children's adaptive regulatory behaviors in real-life situations. For instance, behavioral regulation in classroom settings often places demands on executive functioning that are similarly implicated in laboratory-based EF measures: Completing assigned tasks and following instructions often require inhibitory control of impulses, and learning-related behaviors typically rely on working memory capacity to keep track of multiple types of information from teachers (e.g., instructions, lesson content; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009). The association between EF and self-regulatory classroom behaviors has been well researched. For instance, low EF (inhibition, working memory) has been shown to predict teacher-reported behavioral problems such as physical aggression and motoric hyperactivity among kindergarteners and adolescents (McGlamery, Ball, Henley, & Besozzi, 2007; Séguin, Nagin, Assaad, & Tremblay, 2004). Given the link between classroom conduct and executive functioning, it is possible that the SES and bilingual advantages found in laboratory-based measures could be similarly observed in self-regulatory classroom behaviors. Thus, we aimed to examine the effect of SES and bilingualism on teacher-reported children's regulatory behaviors on the dimensions of (a) inhibitory control, which refers to the capacity to plan and suppress inappropriate responses (e.g., lowering one's voice when told to do so), and (b) attentional focusing, which reflects the capacity to maintain focus on task-related channels (e.g., the ability to concentrate while performing tasks).

To achieve these three goals, we sought to analyze a large-scale longitudinal data set from the Early Childhood Longitudinal Study–Kindergarten Class of 2010–2011 (ECLS-K:2011; National Center for Education Statistics; Tourangeau et al., 2015), which tracks a nationally representative sample of approximately 18,200 kindergarten children (5–7 years old) from their status on school entry to their transition and progression through the elementary grades. Although the ECLS contains limited language assessments and does not provide detailed information on various bilingual experiences (e.g., age of acquisition), the main bilingual criterion—that is, the use of a language other than English at home—was sufficiently adequate to assess and infer bilingual status (see Discussion for further details on this issue). We compared monolinguals and bilinguals from a wide SES spectrum—characterized by a comprehensive set of indices—on two tasks: the DCCS and the Numbers Reversed task, which were employed to assess inhibition and shifting and verbal working memory across four waves over a 1.5-year time frame.

We hypothesized that if SES disparities influence executive functioning, this would significantly predict performance on EF tasks across the four waves. In line with the literature, we also hypothesized that if a bilingual advantage exists, bilingualism would significantly contribute to the inhibition and shifting aspects of EF but not verbal working memory. Regarding the interaction between SES and bilingualism, two possibilities exist. Consistent with studies that have examined the simultaneous impact of the two experiential factors (Calvo & Bialystok, 2014; Krizman et al., 2015), one possibility is that SES and bilingualism independently contribute to executive functioning. Alternatively, if SES and bilingualism interact with each other, we conjectured that the benefits of bilingualism would be less pronounced for higher SES children, because their affluent environments may have already provided opportunities to develop appropriate EF skills. Given that experience-related contributions to cognitive development are more pronounced for lower SES children than for their higher SES counterparts (Turkheimer et al., 2003), bilingual advantages are likely heightened among low-SES children—that is, bilingualism would attenuate the adverse effects of low-SES on EF and self-regulation. Last, based on the association between EF and self-regulatory behavior (McGlamery et al., 2007; Séguin et al., 2004), we hypothesized that the effects of SES and bilingualism on EF would extend to classroom behaviors (assessed by the teacher-reported Children's Behavior Questionnaire [CBQ]), and thus SES and bilingualism would significantly predict inhibitory control and attentional focusing behaviors.

Method

Participants

We employed four testing waves of the ECLS–K:2011 public-access data set: the fall of academic year 2010–2011 (Wave 1: Kindergarten Fall); spring of 2010–2011 (Wave 2: Kindergarten Spring); fall of 2011–2012 (Wave 3: First Grade Fall); and spring of 2011–2012 (Wave 4: First Grade Spring). Data from the ECLS were collected across the United States in all 50 states and the District of Columbia to create a nationally representative sample. To standardize the language used for cognitive assessment across monolinguals and bilinguals, we only included participants who spoke English. To ensure that the assessment score was reliable, we excluded participants who were interrupted (e.g., by a fire drill or class) or disturbed (e.g., by noise or another person) during the assessment.

Bilingualism was confirmed if children were reported to: (a) demonstrate sufficient English skills, as determined by their score (16 out of 20) on a language screener (the English version of the Preschool Language Assessment Scales) and (b) speak a language other than English at home. The home language was reported by parents based on interviews conducted during fall 2010–2011 (kindergarten), spring 2010–2011 (kindergarten), and spring 2011–2012 (first grade). Bilingual participants spoke a variety of languages in addition to English, including Asian languages (e.g., Chinese, Japanese, Filipino) and European languages (Spanish, French, German, Italian); of the latter, Spanish was spoken by the majority.

In the data set, participants with missing values for either of our key predictors (bilingualism and composite SES score) were excluded. We sampled 11,288 participants in Wave 1 (monolingual = 10,133, M_{age} = 67.59; bilingual = 1,155; M_{age} = 66.93); 11,618 in Wave 2 (monolingual = 10,246, M_{age} = 73.58; bilingual = 1,372, M_{age} = 72.68); 2,872 in Wave 3 (monolingual = 2,331, M_{age} = 78.58; bilingual = 541, M_{age} = 79.12); and 8,103 in Wave 4 (monolingual = 7,012, M_{age} = 85.55; bilingual = 1,091, M_{age} = 84.56). Table 1 summarizes the characteristics of bilinguals and monolinguals across all four waves. As reported by previous studies in the United States (e.g., Paap & Greenberg, 2013; Prior & Gollan, 2011), monolinguals had significantly higher household income, parental education, parental occupational prestige, and SES composite scores than bilinguals across all four waves, ps < .001. Consistent with previous studies in which bilinguals had lower English proficiency than monolinguals (e.g., Bialystok & Feng, 2009), bilinguals scored significantly lower on the Preschool Language Assessment Scales (*pre*LAS) across all four waves, ps < .001.

Measures

Socioeconomic Status

SES was computed based on five indicators: household income, maternal and paternal education, and maternal and paternal occupational prestige scores. Indicators were collected twice, during each of the annual parental interviews. Household income, defined as the total income of all household members—including salaries or other earnings, such as interest and retirement—was rated on a scale that ranged from 1 (*less than $5,000*) to 18 (*more than $200,000*). From 1 to 15, income increased in intervals of $5,000; from 15 to 16, in one interval of $25,000; and from 16 to 18, in intervals of $100,000. In 2011, the U.S. Census Bureau's poverty thresholds for three- and four-person households, based on household income, were $35,832 and $46,042, respectively. Parental education level was rated on a scale of 1 (*none*) to 8 (*master's degree or higher*) in the kindergarten year and on a scale of 1 (*none*) to 9 (*doctorate or professional degree*) in the first-grade year. Parental occupation was coded into 22 standard categories using the *Manual for Coding Industries and Occupation* (U.S. Department of Education, National Center for Education Statistics, 1999). Once parental occupations had been classified, they were assigned prestige scores based on the 1989 General Social Survey. All of the five SES components were z-transformed, and then the SES index was computed using the following equation:

Table 1

Characteristics of Bilinguals and Monolinguals Tested in the Fall of Academic Year 2010–2011 (Wave 1: Kindergarten Fall); Spring of 2010–2011 (Wave 2: Kindergarten Spring); Fall of 2011–2012 (Wave 3: First Grade Fall); and Spring of 2011–2012 (Wave 4: First Grade Spring)

	Wave 1: kindergarten fall		Wave 2: kindergarten spring		Wave 3: first grade fall		Wave 4: first grade spring	
	Bilinguals (n = 1,155)	Monolinguals (n = 10,133)	Bilinguals (n = 1,372)	Monolinguals (n = 10,246)	Bilinguals (n = 541)	Monolinguals (n = 2,331)	Bilinguals (n = 1,091)	Monolinguals (n = 7,012)
Age in months	66.93 (4.28)	67.59 (4.46)	72.68 (4.37)	73.58 (4.46)	78.55 (4.28)	79.12 (4.34)	84.56 (4.26)	85.55 (4.41)
Gender (% girls)	50.22	49.00	50.29	48.29	50.28	47.15	49.68	48.59
Weight (pounds)	47.54 (9.87)	47.13 (8.81)	50.42 (10.77)	49.99 (9.85)	54.03 (11.53)	52.99 (10.86)	57.61 (13.45)	57.20 (12.69)
Height (inches)	44.39 (2.07)	44.81 (2.12)	45.53 (2.16)	45.99 (2.19)	46.85 (2.04)	47.05 (2.09)	48.07 (2.25)	48.56 (2.34)
BMI	16.90 (2.81)	16.44 (2.32)	17.01 (2.75)	16.54 (2.70)	17.24 (2.93)	16.76 (2.79)	17.40 (3.17)	16.96 (2.97)
Household income[a]	6.88 (4.69)	11.15 (5.49)	6.60 (4.66)	11.10 (5.50)	5.97 (4.10)	11.05 (5.59)	6.36 (3.34)	11.08 (5.51)
Maternal education level[b,c]	3.23 (1.90)	4.84 (1.79)	3.10 (1.92)	4.83 (1.79)	3.05 (1.82)	4.90 (1.89)	3.09 (1.85)	4.93 (1.87)
Paternal education level[b,c]	3.24 (2.04)	4.79 (1.88)	3.12 (2.07)	4.77 (1.89)	2.77 (1.79)	4.89 (2.01)	2.99 (1.98)	4.90 (2.01)
Maternal occupation prestige[d]	39.14 (9.62)	45.35 (12.11)	38.60 (9.18)	45.28 (12.05)	38.40 (8.60)	45.51 (12.04)	37.83 (8.19)	45.78 (12.17)
Paternal occupation prestige[d]	39.46 (8.92)	44.06 (11.31)	38.88 (8.04)	44.03 (11.26)	37.81 (6.48)	44.21 (11.15)	38.39 (7.78)	44.10 (11.26)
SES composite score	−0.59 (0.74)	0.04 (0.79)	−0.65 (0.74)	0.04 (0.79)	−0.74 (0.61)	0.03 (0.78)	−0.69 (0.64)	0.04 (0.78)
Below poverty threshold (%)[e]	51.70	20.90	21.12	54.98	63.21	23.47	58.85	22.38
*pre*LAS Simon Says[f]	8.62 (1.34)	9.48 (1.19)	9.16 (1.10)	9.73 (0.83)	8.55 (2.07)	9.66 (0.92)	8.55 (2.27)	9.72 (0.82)
*pre*LAS art show[f]	7.93 (1.98)	9.61 (1.10)	8.37 (1.80)	9.76 (0.84)	7.64 (2.37)	9.71 (0.94)	7.88 (2.36)	9.74 (0.88)
*pre*LAS total score[f]	16.56 (2.74)	19.08 (2.01)	17.52 (2.45)	19.49 (1.48)	16.19 (3.98)	19.37 (1.63)	16.42 (4.20)	19.47 (1.49)

*Note. SD*s are shown in parentheses. The combined data set and materials from the ECLS-K:2011 are available from the National Center for Education Statistics (http://nces.ed.gov/ecls/kindergarten2011.asp). *pre*LAS = Preschool Language Assessment Scales; ECLS-K = Early Childhood Longitudinal Study–Kindergarten; SES = socioeconomic status.
[a]Household income was rated on a scale of 1 (*less than $5,000*) to 18 (*more than $200,000*), with intervals of $5,000 for levels 1–15, $25,000 for level 16, and $100,000 for level 17. [b]Parental education level was rated on a scale of 1 (*none*) to 8 (*master's degree or higher*) at Waves 1 and 2, and on a scale of 1 (*none*) to 9 (*doctorate or professional degree*) at Waves 3 and 4. [c]Data were collected in either the fall or spring of the kindergarten year at Waves 1 and 2, and in the fall or spring of first grade at Waves 3 and 4. [d]Prestige scores were assigned to 22 standard occupation categories based on the 1989 General Social Survey. [e]Poverty threshold was determined by comparing total household income reported in the parent interview to the weighted 2011 poverty thresholds from the U.S. Census Bureau, which vary by household size (see Tourangeau et al., 2015). [f]Because English proficiency was not assessed at Waves 3 and 4, the *pre*LAS score obtained at Wave 2 was used in place of scores for the following waves.

$$\mathrm{SES}_i = \frac{\sum_{h=1}^{m} Z_{hi}}{m},$$

where z_{hi} is the z-transformed SES component and m is the number of components. When there were missing values for any of the SES components (e.g., in the case of a single-parent family or unemployed parents), the final SES index was computed by averaging the z-scores of available components (see Tourangeau et al., 2015, for more details on computation and imputation of the SES index).

The Dimension Change Card Sort Task

The DCCS (Zelazo, 2006) was used to assess the inhibition and shifting aspects of EF at all four waves. This task requires children to sort a series of 22 picture cards of either a red rabbit or a blue boat into one of two trays (red boat or blue rabbit) according to the specified rule (color or shape). Children were instructed to sort cards by color in the first block and by shape in the second block. The third block was a border game, in which the sorting rule depended on whether the card had a black border. Each participant completed four practice trials and a total of 18 test trials (i.e., six trials per block). Following the recommendation of the ECLS manual and the developer of the DCCS (Tourangeau et al., 2015), the total score of the three blocks, instead of the single score on the postswitch block, was used as a performance index of inhibitory control and shifting because the former better captures the degree of variability at the lower end of children's performance on the DCCS; a number of children scored zero on the postswitch block at Wave 1 (1,038 cases) and Wave 2 (457 cases).

Numbers Reversed Subtest

The Numbers Reversed subtest of the Woodcock–Johnson III (Woodcock, McGrew, & Mather, 2001) was used to assess verbal working memory. For this task, children were asked to repeat an orally presented sequence of numbers in the reverse order in which they were presented. Children were given five trials of varying set size, that is, sequences of sets that ranged from 2 to 8 numbers. When the child answered three consecutive numbers incorrectly, the task was stopped and performance scores were calculated. Standardized scores with age-normed transformations were used as an index of working memory. The Numbers Reversed subtest was administered across all four waves.

Children's Behavior Questionnaire

Inhibitory control and attentional-focusing behaviors, which are assumed to be essential for adaptive self-regulatory behaviors in the classroom, were assessed by the short form of the CBQ (Putnam & Rothbart, 2006). Using the questionnaire, teachers rated each child on items that assess certain social skills and behaviors related to inhibitory control (e.g., "The child can wait before entering into new activities if he/she is asked to") and attentional focusing (e.g., "When building or putting something together, the child becomes very involved in what he/she is doing, and works for long periods"). Higher scores on the Attentional Focusing subscale indicate that the child is able to focus on cues in the environment that are relevant to the task in hand, whereas higher scores on the Inhibitory Control subscale indicate that the child is able to resist a strong inclination to make inappropriate approach responses. The CBQ was assessed at Wave 1, Wave 2, and Wave 4.

Preschool Language Assessment Scales

The children's English proficiency was measured using the English version of the *pre*LAS (Duncan & De Avila, 1998), which consists of the Simon Says and Art Show tasks. The Simon Says task requires children to follow simple and direct instructions given by the assessor in English. The Art Show task is a picture vocabulary assessment that tests children's expressive vocabulary. Scores for the Simon Says and Art Show tasks were combined, and the total was used as an index of English proficiency. As the *pre*LAS was assessed only at Wave 1 and Wave 2, the score at Wave 2 was used as a proxy of English proficiency at Wave 3 and Wave 4.

Data Analysis

We employed multiple ordinary least squares regression models for each criterion variable with respect to each time wave (see Table 2 for summary descriptive statistics and reliability estimates of the variables). For our analyses, we included children who had no missing information for our key predictors (bilingualism and SES) and criterion variables (e.g., the DCCS and Number Reversed subtest). Children who were excluded due to missing values on cognitive measures of EF were again included when two other criterion variables—the teachers' assessment of inhibitory control and attentional focusing behaviors—had been analyzed. In each model, we

Table 2
Descriptive Statistics and Reliability Estimates of Predictors, Criteria, and Covariates Across the Four Waves

	n	*M*	*SD*	Min	Max	Skewness	Kurtosis	Reliability
Predictors								
Bilingualism								
Wave 1	11,288	0.10	0.30	0.00	1.00	2.63	4.89	—
Wave 2	11,618	0.12	0.32	0.00	1.00	2.37	3.60	—
Wave 3	2,872	0.19	0.39	0.00	1.00	1.60	0.54	—
Wave 4	8,103	0.13	0.34	0.00	1.00	2.14	2.59	—
SES								
Wave 1	11,288	−0.03	0.80	−2.33	2.60	0.31	−0.41	—
Wave 2	11,618	−0.44	0.81	−2.33	2.60	0.28	−0.46	—
Wave 3	2,872	−0.11	0.81	−2.33	2.37	0.32	−0.53	—
Wave 4	8,103	−0.06	0.80	−2.33	2.37	0.26	−0.53	—
Criteria								
DCCS[a]								
Wave 1	11,250	14.32	3.23	0.00	18.00	−1.67	2.24	.88
Wave 2	11,595	15.16	2.80	0.00	18.00	−2.00	4.46	.86
Wave 3	2,869	15.71	2.40	0.00	18.00	−2.19	6.66	.83
Wave 4	8,093	16.05	2.33	0.00	18.00	−2.43	7.99	.83
Numbers reversed subtest[a]								
Wave 1	10,451	93.94	16.42	47.00	167.00	0.21	−0.98	.93
Wave 2	11,589	95.14	16.94	41.00	175.00	−0.19	−0.60	.91
Wave 3	2,868	93.56	17.08	43.00	181.00	−0.29	0.11	.90
Wave 4	8,092	95.68	17.00	35.00	197.00	−0.53	0.79	.87
Inhibitory control behaviors[b]								
Wave 1	10,460	4.94	1.28	1.00	7.00	−0.44	−0.50	.87
Wave 2	10,745	4.94	1.32	1.00	7.00	−0.49	−0.48	.87
Wave 3	—	—	—	—	—	—	—	—
Wave 4	7,138	5.10	1.27	1.00	7.00	−0.66	−0.20	.86
Attentional focus behaviors[b]								
Wave 1	10,468	4.74	1.31	1.00	7.00	−0.60	−0.22	.87
Wave 2	10,735	5.10	1.28	1.00	7.00	−0.69	−0.13	.87
Wave 3	—	—	—	—	—	—	—	—
Wave 4	7,135	4.91	1.28	1.00	7.00	−0.43	−0.48	.83
Covariates								
Age								
Wave 1	11,288	67.52	4.44	44.81	90.77	0.37	0.52	—
Wave 2	11,618	73.48	4.46	52.21	99.45	0.41	0.55	—
Wave 3	2,872	79.01	4.33	60.66	102.70	0.44	0.69	—
Wave 4	8,103	85.42	4.40	63.88	110.20	0.41	0.64	—
Gender								

controlled for covariates, that is, age at assessment, sex, and English proficiency, that are critical for children's performance on measures of EF and self-regulatory behaviors. We also entered Asian race as a proxy for Asian culture to control for Eastern cultural advantages in executive functioning and self-regulatory behaviors, owing to immersion in sociocultural environments that emphasize behavioral control and inhibition (Tran, Arredondo, & Yoshida, 2015; Yang, Yang, & Lust, 2011).

In Step 1, we included our main predictors (bilingualism and composite index of SES) and covariates (age, sex, English proficiency, and Asian culture) to examine the predictability of bilingualism and SES on each criterion after controlling for covariates. Bilingualism was dummy coded to compare bilinguals (coded 1) to monolinguals reference (coded 0). In Step 2, we included the Bilingualism × SES interaction term to examine the potential moderating effect of bilingualism on the relation between SES and the criterion variables. Subsequently, we conducted simple slopes analyses to further probe the SES × Bilingualism interaction effect using the PROCESS macro (Model 1; Hayes, 2012).

Table 2
Continued

	n	*M*	*SD*	Min	Max	Skewness	Kurtosis	Reliability
Wave 1	11,288	0.49	0.50	0.00	1.00	0.04	−2.00	—
Wave 2	11,618	0.49	0.50	0.00	1.00	0.06	−2.00	—
Wave 3	2,872	0.48	0.50	0.00	1.00	0.09	−1.99	—
Wave 4	8,103	0.49	0.50	0.00	1.00	0.05	−2.00	—
English proficiency (*pre*LAS)[c]								
Wave 1	11,288	18.83	2.23	0.00	20.00	−3.55	18.02	.91
Wave 2	11,618	19.26	1.74	0.00	20.00	−4.61	33.51	.89
Wave 3	2,828	18.76	2.59	0.00	20.00	3.57	10.78	.89
Wave 4	8,005	19.06	2.32	0.00	20.00	−4.43	25.28	.81
Asian culture								
Wave 1	11,288	0.07	0.25	0.00	1.00	3.49	10.17	—
Wave 2	11,618	0.07	0.26	0.00	1.00	3.27	8.72	—
Wave 3	2,872	0.06	0.24	0.00	1.00	3.57	10.78	—
Wave 4	8,103	0.07	0.26	0.00	1.00	3.28	8.73	—

Note. Sample size of Wave 2 is higher than that of Wave 1 due to additional recruitment of eligible students in the spring of the kindergarten year (Wave 2). Sample size in the fall of the first-grade year (Wave 3) was the lowest because the study was conducted only on a subsample of approximately one-third of the full sample. Sample size in each variable may vary due to missing data. Bilingualism was dummy coded with monolinguals as reference (bilinguals = 1, monolinguals = 0); sex was dummy coded with male as reference, and Asian culture was dummy coded with non-Asian culture as reference. For all criterion variables, higher values reflect better performance. *pre*LAS = Preschool Language Assessment Scales; DCCS = Dimensional Change Card Sort; ECLS-K = Early Childhood Longitudinal Study–Kindergarten; SES = socioeconomic status.
[a]Reliability was estimated using a split-half procedure based on even- and odd-numbered trials, which were corrected using the Spearman-Brown prophecy formula. [b]The reliability coefficient was based on the alpha coefficient reported in the ECLS-K:2011 manual (Tourangeau et al., 2015). [c]Because English proficiency was not assessed at Waves 3 and 4, the *pre*LAS scores obtained at Wave 2 were used in place of proficiency scores at Waves 3 and 4.

Following Duncan and Magnuson's (2003) componential approach, we also aimed to examine each constituent of SES separately by employing three additional hierarchical regression analyses, all of which have three steps. In all models, age, sex, English proficiency, and Asian culture were controlled in Step 1 (see Table 4). In Step 2, bilingualism was added simultaneously with additional predictor(s) for each regression model: maternal education (Model 1), household income (Model 2), and maternal education and household income (Model 3). Here, we focused on household income and maternal education, which have been well established as having independent effects on children's achievement (Magnuson & Duncan, 2006). In Step 3, we added the interaction term(s) between bilingualism and SES: Bilingualism × Maternal Education (Model 1), Bilingualism × Household Income (Model 2), and Bilingualism × Maternal Education and Bilingualism × Household Income (Model 3). By analyzing these interactions separately in three models, we aimed to examine the shared and unique effects of maternal education and household income on EF, and their interaction with bilingualism. Collinearity statistics did not show any indication of multicollinearity.

Results

Our primary goal was to evaluate the interaction effects of SES and bilingualism on (a) inhibition and shifting, (b) working memory, and (c) inhibitory control and attentional focusing behaviors. In the context of these goals, we first present our results with respect to each criterion variable by operationalizing SES using a composite index. Subsequently, we present additional analyses employing a componential approach that operationalizes SES using each component separately (Duncan & Magnuson, 2003).

The DCCS

In Step 1 of the ordinary least squares regression model, we entered bilingualism, SES, and multiple covariates of Age, Sex, English Proficiency, and Asian culture. We found that SES emerged as a significant predictor of the DCCS in Wave 1 ($B = 0.46$, $SE = 0.04$, 95% CI [0.39, 0.54], $t = 11.98$, $p < .001$); Wave 2 ($B = 0.42$, $SE = 0.03$, 95% CI [0.36, 0.49], $t = 12.80$, $p < .001$); Wave 3 ($B = 0.40$, $SE = 0.06$, 95% CI [0.28, 0.51], $t = 6.57$, $p < .001$); and Wave 4 ($B = 0.42$, $SE = 0.03$, 95% CI [0.35, 0.48], $t = 12.25$, $p < .001$). Consistently positive coefficients across all four waves indicate that higher SES is beneficial for performance on the DCCS. Similarly, bilingualism also emerged as a significant predictor of the DCCS in Wave 1 ($B = 0.43$, $SE = 0.11$, 95% CI [0.23, 0.64], $t = 4.11$, $p < .001$); Wave 2 ($B = 0.32$, $SE = 0.09$, 95% CI [0.15, 0.49], $t = 3.68$, $p < .001$); Wave 3 ($B = 0.27$, $SE = 0.13$, 95% CI [0.00, 0.53], $t = 1.99$, $p = .047$); and Wave 4 ($B = 0.42$, $SE = 0.09$, 95% CI [0.25, 0.59], $t = 4.90$, $p < .001$). Notably, our results held true when only postswitch scores of the DCCS were examined. Despite the possible range restriction of postswitch scores, bilingualism emerged as a significant predictor of postswitch scores in Wave 1 ($B = 0.17$, $SE = 0.06$, 95% CI [0.05, 0.29], $t = 2.82$, $p = .005$); Wave 2 ($B = 0.19$, $SE = 0.04$, 95% CI [0.10, 0.28], $t = 4.31$, $p < .001$); and Wave 4 ($B = 0.15$, $SE = 0.04$, 95% CI [0.07, 0.22], $t = 3.65$, $p < .001$), and marginally predicted postswitch scores in Wave 3 ($B = 0.12$, $SE = 0.07$, 95% CI [−0.01, 0.25], $t = 1.81$, $p = .071$). These results suggest robust bilingual advantages in the inhibition and shifting aspects of EF (see Table 3). In Step 2, we found a significant interaction between SES and bilingualism in Wave 1 ($B = -0.31$, $SE = 0.13$, 95% CI [−0.56, −0.06], $t = -2.41$, $p = .016$); Wave 2 ($B = -0.24$, $SE = 0.11$, 95% CI [−0.45, −0.03], $t = -2.26$, $p = .024$); and Wave 4 ($B = -0.31$, $SE = 0.12$, 95% CI [−0.53, −0.08], $t = -2.66$, $p = .008$). The only exception was Wave 3, which had the smallest sample size ($B = -0.20$, $SE = 0.18$, 95% CI [−0.55, 0.15], $t = -1.12$, $p = .264$).

Our analyses of simple slopes (Figure 1) revealed that, among monolinguals, SES was positively associated with performance on the DCCS across all four waves: Wave 1 ($B = 0.49$, $p < .001$); Wave 2 ($B = 0.45$, $p < .001$); Wave 3 ($B = 0.42$, $p < .001$); and Wave 4 ($B = 0.44$, $p < .001$). Among bilinguals, however, the association between SES and DCCS was either weakened or insignificant in Wave 1 ($B = 0.18$, $p = .157$); Wave 2 ($B = 0.21$, $p = .045$); Wave 3 ($B = 0.22$, $p = .208$); and Wave 4 ($B = 0.14$, $p = .251$). Consistent with our hypothesis, these results suggest that bilingualism attenuates the detrimental effect of SES on the inhibition and shifting aspects of EF. Further examination of this interaction revealed that among children from low-SES families, bilingualism emerged as a significantly positive predictor of performance on the DCCS across all four waves: Wave 1 ($B = 0.52$, $p < .001$); Wave 2 ($B = 0.39$, $p < .001$); Wave 3 ($B = 0.33$, $p = .024$); and Wave 4 ($B = 0.50$, $p < .001$). Among children from middle-SES families, the association between bilingualism and DCCS was relatively weaker but still significant in Wave 1 ($B = 0.28$, $p = .026$) and Wave 4 ($B = 0.26$, $p = .014$), marginally significant in Wave 2 ($B = 0.20$, $p = .057$), and not significant in Wave 3 ($B = 0.16$, $p = .308$). However, among children from high-SES families, the association between bilingualism and performance on the DCCS was not significant at any wave: Wave 1 ($B = 0.02$, $p = .902$), Wave 2 ($B = 0.00$, $p = .999$), Wave 3 ($B = 0.00$, $p = .998$), or Wave 4 ($B = 0.01$, $p = .946$). These results suggest that the beneficial effect of bilingualism was more evident among children from lower SES families than those from either middle- or higher SES families—that is, lower SES children reaped more benefits from their bilingual experiences than middle or higher SES children.

Numbers Reversed Subtest

When important covariates were controlled for in Step 1 of a similar ordinary least squares regression analysis, SES emerged as a significant predictor of children's performance on verbal working memory, as assessed by the Numbers Reversed subtest in Wave 1 ($B = 5.16$, $SE = 0.19$, 95% CI [4.79, 5.53], $t = 27.31$, $p < .001$); Wave 2 ($B = 5.22$, $SE = 0.19$, 95% CI [4.85, 5.59], $t = 27.65$, $p < .001$); Wave 3 ($B = 4.44$, $SE = 0.41$, 95% CI [3.64, 5.25], $t = 10.78$, $p < .001$); and Wave 4 ($B = 4.78$, $SE = 0.69$, 95% CI [4.32, 5.25], $t = 20.07$, $p < .001$). In contrast, bilingualism did not significantly predict performance on the Numbers Reversed subtest in Wave 1 ($B = 0.40$, $SE = 0.53$, 95% CI [−0.63, 1.42], $t = 0.75$, $p = .451$); Wave 2 ($B = -0.52$, $SE = 0.50$, 95% CI [−1.49, 0.45], $t = -1.05$, $p = .296$); and Wave 3 ($B = 0.77$, $SE = 0.92$, 95% CI [−1.03, 2.57], $t = 0.84$, $p = .401$). In Wave 4, however, bilingualism significantly predicted performance on the Numbers Reversed subtest ($B = 1.18$, $SE = 0.60$, 95% CI [0.00, 2.36], $t = 1.97$, $p = .049$). In Step 2, in which we considered an SES × Bilingualism interaction, we found a significant interaction across all waves except Wave 3 ($B = -0.81$, $SE = 1.24$, 95% CI [−3.23, 1.62], $t = -0.65$, $p = .515$): It was significant in Wave 1 ($B = -1.40$, $SE = 0.65$, 95% CI [−2.66, −0.13], $t = -2.16$, $p = .031$) and Wave 2 ($B = -1.87$, $SE = 0.61$, 95% CI [−3.06, −0.68], $t = -3.09$, $p = .002$), and marginally significant in Wave 4 ($B = -1.53$, $SE = 0.81$, 95% CI [−3.11, 0.05], $t = -1.90$, $p = .058$).

When simple slopes analysis was performed to examine the SES and bilingualism interaction (Figure 1, bottom panel), we found positive associations

Table 3

Standardized Coefficient Estimates (β) of the DCCS, Numbers Reversed, Inhibitory Control, and Attentional Focusing Behaviors Across the Four Waves

	Wave 1				Wave 2				Wave 3				Wave 4			
Variables	DCCS n = 11,250	RN n = 10,451	IC n = 12,771	AF n = 12,787	DCCS n = 11,595	RN n = 11,589	IC n = 13,972	AF n = 13,978	DCCS n = 2,825	RN n = 2,824	IC	AF	DCCS n = 7,997	RN n = 7,996	IC n = 10,863	AF n = 10,857
Step 1																
Predictor																
Bilingualism	.040**	.007	.081**	.090**	.037**	−.010	.106**	.106**	.043*	.018	—	—	.061**	.024*	.105**	.115**
SES	.115**	.253**	.145**	.189**	.123**	.250**	.141**	.177**	.134**	.211**	—	—	.144**	.227**	.153**	.189**
Covariates																
Age	.075**	−.274**	.068**	.097**	.051**	−.196**	.078**	.100**	.050*	−.149**	—	—	.055**	−.136**	.034**	.046**
Sex	.045**	.025*	.231**	.212**	.050**	.041**	.245**	.216**	.045*	.042	—	—	.044**	.045**	.263**	.223**
English proficiency	.252**	.217**	.122**	.132**	.225**	.208**	.123**	.135**	.159**	.180**	—	—	.173**	.181**	.090**	.100**
Asian culture	.010	.047**	.039**	.050**	.000	.050**	.043**	.063**	−.011	.045*	—	—	.009	.067**	.062**	.084**
Step 2																
Bilingualism × SES	−.028*	−.024*	−.049**	−.051**	−.027*	−.035*	−.067**	−.066**	−.030	−.017	—	—	−.042*	−.029†	−.051**	−.051**

Note. Values reflect standardized coefficient estimates (β) when all predictors and covariates were entered in the ordinary least squares regression models. Values reported in the text are unstandardized beta coefficients (*B*). Bilingualism was dummy coded with monolinguals as reference (bilinguals = 1, monolinguals = 0); sex was dummy coded with male as reference; and Asian culture was dummy coded with non-Asian culture as reference. In all criterion variables, higher values reflect better performance. Sample size was based on participants with no missing values on predictors or relevant criteria. CBQ = Children's Behavior Questionnaire; DCCS = Dimensional Change Card Sort; RN = numbers reversed subtest; IC = inhibitory control subscale of the CBQ; AF = attentional focusing subscale of the CBQ; SES = socioeconomic status.

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

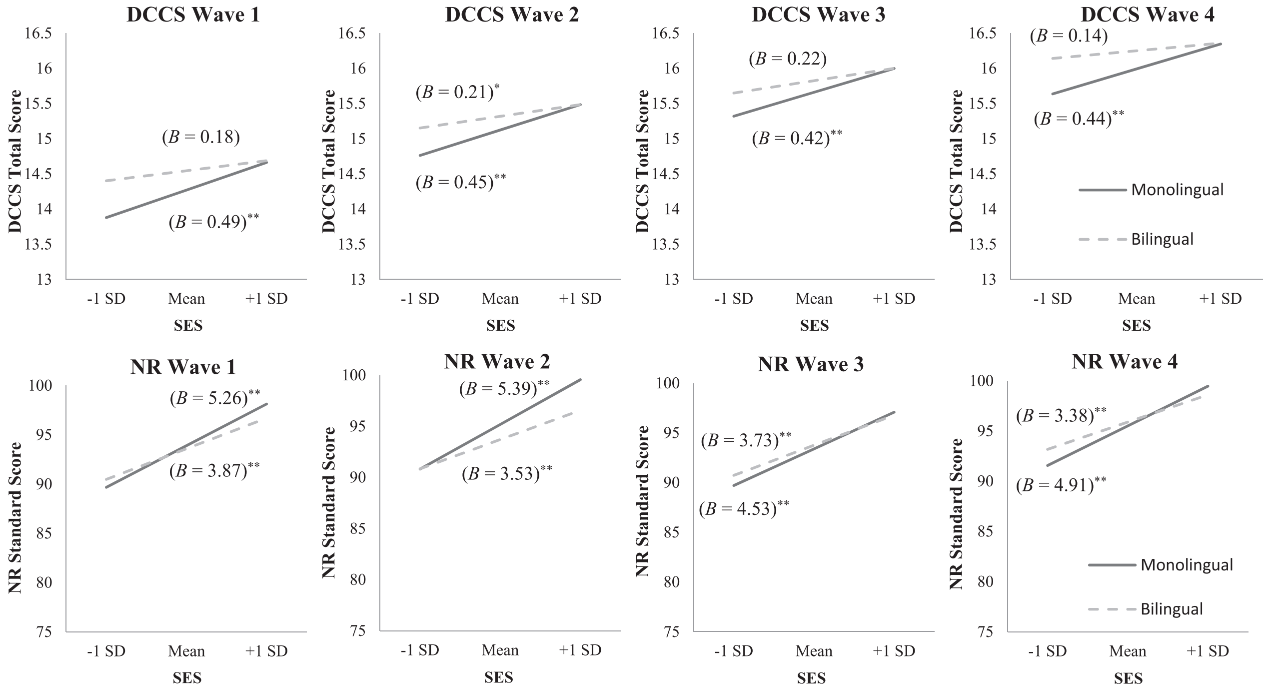

Figure 1. Simple slopes analysis (i.e., unstandardized coefficients) on the moderation effect of bilingualism on the relation between SES and total scores of the DCCS (upper panel) and standard scores of the NR subtest (bottom panel) at values that are 1 *SD* below the mean SES, the mean SES, and 1 *SD* above the mean SES. SES = socioeconomic status; DCCS = Dimensional Change Card Sort; NR = numbers reversed.
$^*p < .05$. $^{**}p < .001$.

between SES and verbal working memory among both bilinguals and monolinguals across all four waves ($ps < .001$). Further examination of this interaction indicated that among higher SES children, monolinguals significantly outperformed bilinguals only at Wave 2 ($B = .84$, $p = .020$), whereas among lower SES children, bilinguals significantly outperformed monolinguals only at Wave 4 ($B = -1.61$, $p = .012$). No other effects were significant. These results suggest that bilingualism only attenuates the negative effect of low-SES on children's verbal working memory at a later age, especially when bilingual children's verbal abilities improve.

Children's Behavior Questionnaire

We first conducted correlation analyses between our EF measures and classroom behaviors. Supporting the established link between EF and classroom behaviors, we observed that the DCCS and Numbers Reversed subtests were positively associated with the attentional focus and inhibitory control behaviors across all three available waves ($rs = .17–.30$, $ps < .001$). Next, we performed regression and simple slopes analyses for inhibitory control and attentional focusing behaviors, as assessed by the teacher-reported CBQ subscales at Waves 1, 2, and 4.

Inhibitory Control Behaviors

When important covariates were controlled for in Step 1, SES emerged as a significant predictor of inhibitory control behaviors in Wave 1 ($B = 0.23$, $SE = 0.01$, 95% CI [0.20, 0.26], $t = 16.27$, $p < .001$); Wave 2 ($B = 0.22$, $SE = 0.01$, 95% CI [0.20, 0.25], $t = 16.51$, $p < .001$); and Wave 4 ($B = 0.25$, $SE = 0.02$, 95% CI [0.21, 0.28], $t = 15.73$, $p < .001$). Bilingualism also significantly predicted inhibitory control behaviors in Wave 1 ($B = 0.35$, $SE = 0.04$, 95% CI [0.27, 0.43], $t = 8.91$, $p < .001$); Wave 2 ($B = 0.44$, $SE = 0.04$, 95% CI [0.37, 0.51], $t = 12.00$, $p < .001$); and Wave 4 ($B = 0.40$, $SE = 0.04$, 95% CI [0.32, 0.48], $t = 10.04$, $p < .001$). In Step 2, we found a significant interaction between bilingualism and SES across all time points: Wave 1 ($B = -0.22$, $SE = 0.05$, 95% CI [−0.31, −0.12], $t = -4.53$, $p < .001$); Wave 2 ($B = -0.28$, $SE = 0.05$, 95% CI [−0.37, −0.19], $t = -6.25$, $p < .001$); and Wave 4 ($B = -0.20$, $SE = 0.05$, 95% CI [−0.30, −0.10], $t = -3.91$, $p < .001$).

To further examine the SES × Bilingualism interaction effect on inhibitory control behaviors, we performed simple slopes analyses (see Figure 2, upper panel). Among monolinguals, SES was positively associated with inhibitory control behaviors at all available time points: Wave 1 ($B = 0.25$, $p < .001$), Wave 2 ($B = 0.25$, $p < .001$), and Wave 4 ($B = 0.46$, $p < .001$). Among bilinguals, however, SES was not associated with inhibitory control behaviors across the available time points: Wave 1 ($B = 0.03$, $p = .518$), Wave 2 ($B = -0.03$, $p = .451$), or Wave 4 ($B = 0.06$, $p = .212$). Further analyses showed that bilingualism significantly predicted inhibitory control behaviors among children from low-SES families in Wave 1 ($B = 0.42$, $p < .001$), Wave 2 ($B = 0.52$, $p < .001$), and Wave 4 ($B = 0.46$, $p < .001$). Bilingualism also significantly predicted inhibitory control behaviors among children from middle-SES families at all available time points, although the strength of this association was weaker than that found among children from low-SES families: Wave 1 ($B = 0.24$, $p < .001$); Wave 2 ($B = 0.30$, $p < .001$); and Wave 4 ($B = 0.29$, $p < .001$). Among children from high-SES families, however, bilingualism did not significantly predict inhibitory control behaviors in Wave 1 ($B = 0.07$,

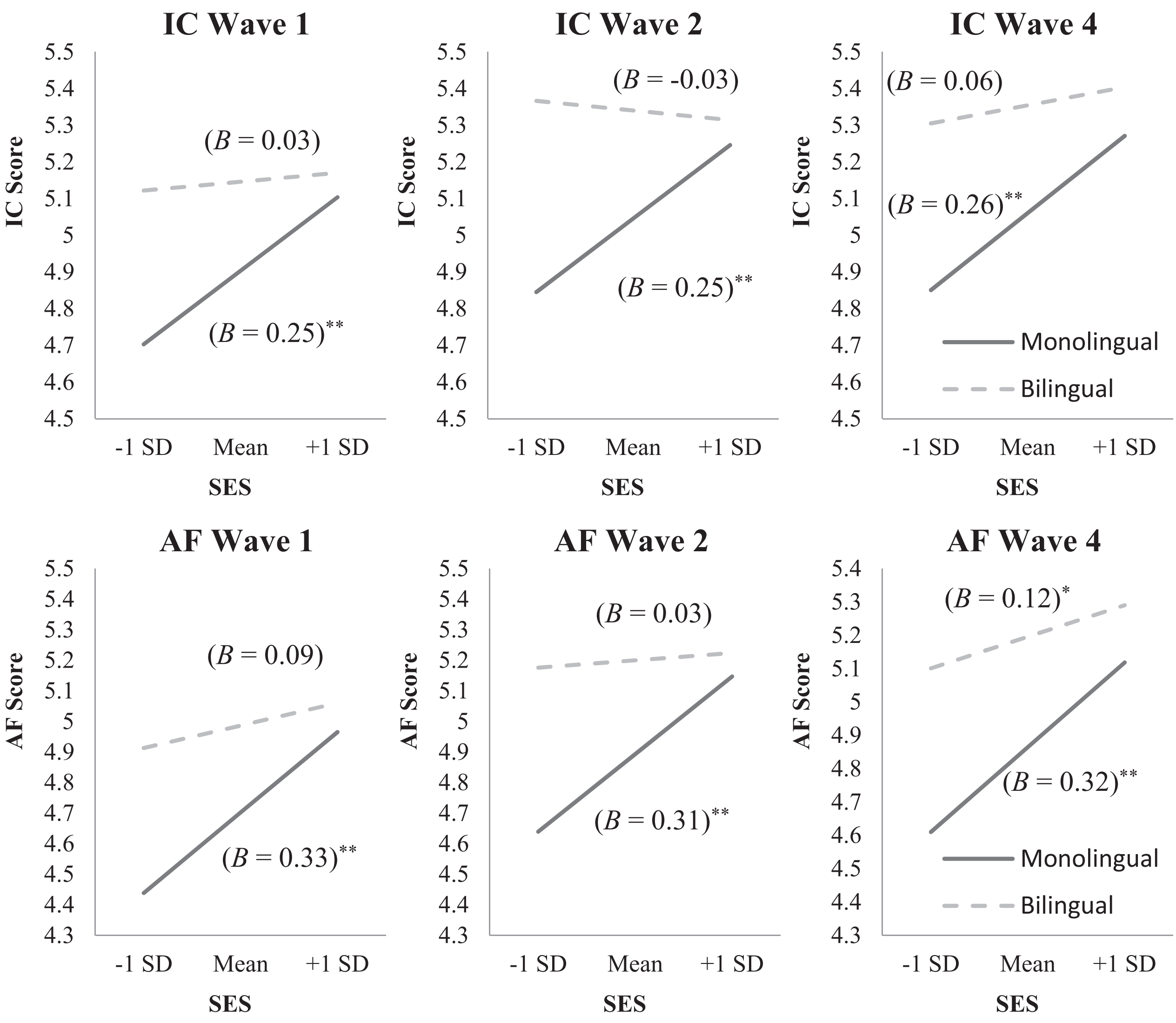

Figure 2. Simple slopes analysis (i.e., unstandardized coefficients) on the moderation effect of bilingualism on the relation between SES and teacher-reported scores of inhibitory control (upper panel) and attentional focus behaviors (bottom panel) at values that are 1 *SD* above the mean SES, the mean SES, and 1 *SD* below the mean SES. SES = socioeconomic status; IC = inhibitory control; AF = attentional focusing.
*$p < .05$. **$p < .001$.

p = .367); Wave 2 (B = 0.07, p = .327); or Wave 4 (B = 0.13, p = .095).

Attentional Focusing Behaviors

When multiple covariates were controlled for in Step 1, SES emerged as a significant predictor of attentional focusing behaviors in Wave 1 (B = 0.31, SE = 0.02, 95% CI [0.28, 0.34], t = 21.27, p < .001); Wave 2 (B = 0.29, SE = 0.01, 95% CI [0.26, 0.32], t = 20.82, p < .001); and Wave 4 (B = 0.30, SE = 0.02, 95% CI [0.27, 0.33], t = 19.33, p < .001). Similarly, bilingualism was a significant predictor of attentional focusing behaviors at all available time points: Wave 1 (B = 0.40, SE = 0.04, 95% CI [0.32, 0.48], t = 10.03, p < .001); Wave 2 (B = 0.45, SE = 0.04, 95% CI [0.38, 0.52], t = 12.07, p < .001); and Wave 4 (B = 0.44, SE = 0.04, 95% CI [0.36, 0.52], t = 10.99, p < .001). Furthermore, in Step 2, we found a significant SES × Bilingualism effect on attentional focusing in Wave 1 (B = −0.24, SE = 0.05, 95% CI [−0.33, −0.14], t = −4.78, p < .001); Wave 2 (B = −0.28, SE = 0.05, 95% CI [−0.37, −0.19], t = −6.18, p < .001); and Wave 4 (B = −0.199, SE = 0.05, 95% CI [−0.30, −0.10], t = −3.89, p < .001).

When we performed simple slopes analysis to probe this interaction (Figure 2, bottom panel), we found that among monolinguals, SES was positively associated with attentional focusing behaviors across all available waves: Wave 1 (B = 0.33, p < .001), Wave 2 (B = 0.31, p < .001), and Wave 4 (B = 0.26, p < .001). However, among bilinguals, the association between SES and attentional focusing behaviors varied: It was marginally significant in Wave 1 (B = 0.09, p = .055), not significant in Wave 2 (B = 0.03, p = .503), and significant in Wave 4 (B = 0.12, p = .017). Furthermore, among children from low-SES families, simple slopes analysis demonstrated significantly positive associations between bilingualism and attentional focusing behaviors across all available time points: Wave 1 (B = 0.47, p < .001); Wave 2 (B = 0.54, p < .001); and Wave 4 (B = 0.49, p < .001). Similarly, among children from middle-SES families, the association between bilingualism and attentional focusing behaviors was significant in Wave 1 (B = 0.29, p < .001), Wave 2 (B = 0.31, p < .001), and Wave 4 (B = 0.33, p < .001). However, among children from high-SES families, the association between bilingualism and attentional focusing behaviors was significant only in Wave 4 (B = 0.17, p = .031) and not significant in Wave 1 (B = 0.10, p = .205) or Wave 2 (B = 0.08, p = .279). Taken together, these results suggest that bilingualism reliably attenuates the negative effects of low-SES on children's inhibitory control and attentional focusing behaviors. Our results also suggest that the beneficial effect of bilingualism on self-regulatory behaviors is more evident among children from low- and middle-SES families.

Componential SES

As addressed earlier, three additional hierarchical regression analyses were conducted for each criterion to examine the shared and unique effects of maternal education and household income on EF and their interactions with bilingualism. Results of these additional analyses are summarized in Table 4; several are important. First, the Bilingualism × SES interactions we identified using the SES composite measure (see Table 3) were replicated when maternal education or household income were employed as single-dimensional SES indices (see Models 1 and 2 of Table 4). The results provide substantial evidence that bilingualism attenuates the negative repercussions of low maternal education and household income on the inhibitory and shifting aspects of EF and self-regulatory behaviors.

Second, as shown in Step 2 of Model 3, maternal education and household income simultaneously emerged as significant predictors in all of our criterion variables (ps < .001)—the DCCS, Numbers Reversed subtest, and inhibitory control and attentional focusing behaviors—across all of the four waves. The significant unique effects of maternal education and household income on all of our EF measures suggest that maternal education and household income, which tap into distinct resources, may influence EF through different mechanisms. Notably, the predictability of maternal education and household income were substantially lower in Model 3 than in Models 1 and 2, demonstrating that children's EF were also accounted for by the variance shared by maternal education and household income.

Third, as shown in Model 3 (Table 4), where the interaction terms of Bilingualism × Household Income and Bilingualism × Maternal Education were simultaneously included, we observed some trends by which the unique effects of maternal education and household income on EF and self-regulatory behaviors were attenuated differently by bilingualism. For the DCCS, we observed that the Bilingualism × Household Income (B = −0.03, SE = 0.02, 95% CI [−0.01, 0.01], t = −1.34, p = .180) and Bilingualism × Maternal Education (B = −0.09,

Table 4

Standardized Coefficient Estimates (β) of the DCCS, Numbers Reversed, Inhibitory Control, and Attentional Focusing Behaviors Across the Four Waves With Bilingualism, Maternal Education, and Household Income as Predictors

Variables	Wave 1				Wave 2				Wave 3				Wave 4			
	DCCS n = 11,250	RN n = 10,451	IC n = 12,771	AF n = 12,787	DCCS n = 11,595	RN n = 11,589	IC n = 13,972	AF n = 13,978	DCCS n = 2,825	RN n = 2,824	IC	AF	DCCS n = 7,997	RN n = 7,996	IC n = 10,863	AF n = 10,857
Step 1 (covariates for all models)																
Age	.069**	−.292**	.061**	.088**	.047**	−.201**	.070**	.090**	.049*	−.149**	—	—	.050**	−.140**	.028**	.039**
Sex	.045**	.022*	.231**	.210**	.049**	.037**	.245**	.216**	.044*	.039*	—	—	.044**	.044**	.263**	.223**
English proficiency	.270**	.285**	.134**	.152**	.244**	.281**	.121**	.142**	.182**	.240**	—	—	.188**	.238**	.087**	.101**
Asian culture	.034**	.093**	.070**	.090**	.022*	.089**	.072**	.098**	.009	.076**	—	—	.030*	.096**	.089**	.116**
Model 1																
Step 2																
Bilingualism	.038**	.006	.075**	.085**	.035**	−.013	.098**	.101**	.035	.003	—	—	.059**	.014	.096**	.106**
Maternal education	.091**	.223**	.101**	.144**	.104**	.216**	.098**	.142**	.108**	.166**	—	—	.129**	.179**	.115**	.151**
Step 3																
Bilingualism × Maternal Education	−.035*	−.039*	−.052**	−.060**	−.036*	−.055**	−.072**	−.076**	−.044†	−.050*	—	—	−.043*	−.044*	−.052**	−.062**
Model 2																
Step 2																
Bilingualism	.037**	−.004	.078**	.085**	.029*	−.025*	.103**	.099**	.043*	.005	—	—	.057**	.014	.103**	.107**
Household income	.106**	.208*	.145**	.175**	.100**	.210**	.145**	.164**	.142**	.180**	—	—	.142**	.209**	.154**	.169**
Step 3																
Bilingualism × Household Income	−.028*	−.034*	−.043**	−.046**	−.037*	−.038*	−.062**	−.056**	−.050†	−.028	—	—	−.069**	−.049*	−.033*	−.038*
Model 3																
Step 2																
Bilingualism	.042**	.012	.082**	.092**	.038**	−.005	.106**	.108**	.049*	.018	—	—	.067**	.027*	.109**	.119**
Maternal education	.046**	.152**	.030*	.068**	.070**	.141**	.027*	.074**	.045†	.097**	—	—	.073**	.093**	.044**	.084**
Household income	.082**	.128**	.130**	.140**	.064**	.137**	.131**	.125**	.118**	.129**	—	—	.104**	.161**	.131**	.125**
Step 3																
Bilingualism × Maternal Education	−.020	−.017	−.027*	−.035*	−.016	−.032*	−.040*	−.049**	−.009	−.027	—	—	−.004	−.008	−.032*	−.043*
Bilingualism × Household Income	−.018	−.025†	−.030*	−.028*	−.029*	−.022†	−.043**	−.032*	−.044	−.012	—	—	−.065**	−.042*	−.018	−.016

Note. Values reflect standardized coefficient estimates (β) when all predictors and covariates were entered in the ordinary least squares regression models. Values reported in the text are unstandardized beta coefficients (*B*). Bilingualism was dummy coded with monolinguals as reference (bilinguals = 1, monolinguals = 0); sex was dummy coded with male as reference; and Asian culture was dummy coded with non-Asian culture as reference. In all criterion variables, higher values reflect better performance. Sample size was based on participants with no missing values on predictors or relevant criterions. CBQ = Children's Behavior Questionnaire; DCCS = Dimensional Change Card Sort; RN = numbers reversed subtest; IC = inhibitory control subscale of the CBQ; AF = attentional focusing subscale of the CBQ.

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

SE = 0.06, 95% CI [−0.20, 0.03], *t* = −1.43, *p* = .154) interactions were not significant in Wave 1. As these interactions terms were significant when they were included separately in Model 1 (*B* = −0.15, *SE* = 0.05, 95% CI [−0.25, −0.05], *t* = −2.94, *p* = .003) and Model 2 (*B* = −0.05, *SE* = 0.02, 95% CI [−0.09, −0.01], *t* = −2.41, *p* = .016), the results suggest that bilingualism only attenuate the shared negative effects of household income and maternal education on the inhibitory and shifting aspects of EF. However, the Bilingualism × Household Income interaction in Model 3 was significant in Wave 2 (*B* = −0.04, *SE* = 0.02, 95% CI [−0.08, −0.00], *t* = −2.18, *p* = .029) and Wave 4 (*B* = −0.07, *SE* = 0.02, 95% CI [−0.11, 0.03], *t* = −3.79, *p* < .001). A similar pattern emerged in Wave 4 on the Numbers Reversed subtest, in which only the Bilingualism × Household Income interaction was significant (*B* = −0.34, *SE* = 0.13, 95% CI [−0.60, −0.08], *t* = −2.55, *p* = .011). This implies that bilingualism significantly attenuates the negative unique effects of household income on the inhibition, shifting, and verbal working memory aspects of EF at a slightly later age.

In contrast, for self-regulatory behaviors in Model 3, we observed that the Bilingualism × Household Income and Bilingualism × Maternal Education interactions were significant in all available waves (*p*s < .05; see Table 4), except for Bilingualism × Household Income interaction in Wave 4 for both inhibitory control (*B* = −0.01, *SE* = 0.01, 95% CI [−0.03, 0.01], *t* = −1.20, *p* = .232) and attentional focusing behaviors (*B* = −0.01, *SE* = 0.01, 95% CI [−0.03, 0.01], *t* = −1.12, *p* = .262). This suggests that the unique negative effects of household income and maternal education on self-regulatory behaviors were mostly attenuated by bilingualism, with the exception of household income in Wave 4.

Discussion

Using the largest sample size and longitudinal data, our analysis revealed three main findings. First, across all four waves, both higher SES and bilingualism were positively associated with better inhibitory and shifting aspects of EF. However, only SES, and not bilingualism, reliably predicted verbal working memory performance. Our finding that SES and bilingualism affect performance on the DCCS for kindergarten through elementary ages converges with studies that have demonstrated the beneficial effects of SES (Ardila et al., 2005; Farah et al., 2006; Mezzacappa, 2004; Noble et al., 2007) and bilingualism (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Poarch & Van Hell, 2012) on inhibition and shifting. Second, in classroom settings, both higher SES and bilingualism accounted for more adaptive self-regulatory behaviors (i.e., inhibitory control and attentional focusing). Last, bilingualism significantly attenuated the negative effects of SES on the inhibitory and shifting aspects of EF and self-regulatory behaviors. Notably, the results held true even when we controlled for a host of common confounding variables such as age, sex, language proficiency, and culture.

Our additional analyses, using a componential approach to SES, revealed independent effects of maternal education and household income on EF. These results support the notion that maternal education and household income, which tap into distinct resources, may influence EF through different mechanisms (Duncan & Magnuson, 2003). For example, higher household income may facilitate children's EF development by increasing the family's ability to provide a more cognitively stimulating environment, whereas higher maternal education may shape a more effective parent–child interaction that enhances EF development, such as engaging in richer conversational exchanges and providing enriching teaching experiences. Interestingly, we also found that children's executive functioning was accounted for by the variance shared by maternal education and household income. As discussed by Noble et al. (2015), it is plausible that this shared variance taps into the ability of more highly educated parents to earn a higher income, which allows them to create a more cognitively stimulating environment. This suggests that maternal education may not only have a unique effect on EF through positive parent–child interaction but may also influence EF through its shared effect with household income.

Our finding that bilingualism did not affect verbal working memory, particularly for early childhood (5.5–6.5 years old), is consistent with previous studies that have used similar verbal working memory tasks (Bialystok & Feng, 2010; Engel de Abreu, 2011). The absence of a bilingual advantage in verbal working memory can be attributed to the fact that verbal working memory tasks—which demand higher language skills than nonverbal tasks—tend to disadvantage bilinguals, who are generally linguistically less proficient than their monolingual counterparts (e.g., Bialystok, Luk, Peets, & Yang, 2010). Indeed, studies that have employed nonverbal working memory tasks tend to report bilingual advantages (Morales et al., 2013). For instance, using the frog matrices task, which requires recollection of a sequence of movements by a frog in a three-by-three grid, Sorge et al. (2016) found that bilingualism is a significant predictor of spatial working memory and that being more bilingual (i.e., greater degree of bilingualism) is associated with greater improvement on this task. In this vein, our finding of significant positive effects of bilingualism on verbal working memory among older children (age 7) suggests that working memory, relative to the inhibitory and shifting aspects of EF, likely requires more extensive bilingual experience to manifest. Given that cognitive processes vary in terms of malleability (e.g., Hartanto et al., 2016), various cognitive processes may not be similarly sensitive to the same extent of bilingual experience. Further research is necessary, therefore, to determine the mechanisms that underlie bilingual advantages in verbal and nonverbal working memory.

We demonstrated that the SES and bilingual advantages found in laboratory-based EF measures could be similarly observed in children's day-to-day self-regulatory behaviors in school. Moreover, our finding of positive correlations between EF measures and classroom behaviors across all three available waves ($ps < .001$) support the link between EF and classroom behaviors. These results dovetail with previous studies that have shown a correlation between EF tasks and positive classroom behaviors (e.g., self-reliance, compliance, attention, and engagement; Brock et al., 2009; Séguin et al., 2004). The ability to effectively execute classroom activities that require EF (e.g., adhering to instructions, exercising restraint or concentrating on assigned tasks) is a precursor to optimal learning and scholastic achievement (Blair, 2002). Hence, our finding that SES and bilingualism contribute to positive self-regulatory behaviors sheds light on the importance of intervention—for instance, structured language immersion—for low-SES children and bilingual education.

Our key finding that bilingual advantages in EF and self-regulatory behaviors were more pronounced for lower SES children than higher SES children suggests that bilingualism cognitively enriches lower SES children. Our results reliably demonstrate that the negative effects of low-SES on inhibition, shifting, and self-regulatory behaviors were attenuated or even nonexistent among bilinguals. This outcome diverges from previous studies that failed to find any interaction between SES and bilingualism (Calvo & Bialystok, 2014; Krizman et al., 2015). A likely explanation could be that, unlike previous studies that relied on a limited range of SES groups (e.g., middle vs. working class), use of a large, nationally representative group of participants from low- to high-SES families allowed us to capture nuances in the relation between SES and bilingualism that were not observed in previous studies. Indeed, our finding is congruent with studies in which low-SES children, likely owing to their relative lack of opportunities for cognitive development, were more receptive to experiential factors than were their higher SES counterparts (Neville et al., 2013; Turkheimer et al., 2003). Relatedly, our results build on Engel de Abreu, Cruz-Santos, Tourinho, Martin, and Bialystok's (2012) findings that bilingualism boosts the performance of low-SES 8-year-olds on inhibitory control as assessed by the flanker task but not working memory tasks (e.g., dot matrix). Although their findings were limited to low-SES children, we demonstrate that lower SES children benefit more from bilingualism than do higher SES children, which suggests that bilingualism offers protection against at least some of the detrimental cognitive consequences of growing up in a low-SES environment.

In view of the multidimensional construct of SES, our analyses reveal that the Bilingualism × SES interactions we found using the SES composite measure were replicated when maternal education or household income were employed as single-dimensional SES indices. Our results, therefore, imply that it is unlikely that the lack of interaction in previous SES/bilingualism studies was due to reliance on single-dimensional SES indicators, such as maternal education or household income. Nevertheless, we still recommend that future studies go beyond single-dimensional indicators of SES, as they may not sufficiently capture the complex, multidimensional nature of SES. This is evident from the significant unique effects of maternal education and household income on all of our EF and self-regulatory behavior measures. Thus, employing more than one SES measure could maximize the variance of EF that would be accounted for by SES.

Despite the large-scale longitudinal nature of our study, it is not without limitations. First, owing to the limitations of the ECLS, we lack sufficient information on various dual-language experiences (e.g., bilingual interactional contexts) that have been demonstrated to modulate bilingual advantages (Yang, Hartanto, & Yang, 2016a, 2016b). Therefore, we were unable to ascertain the nature of dual-language experiences responsible for the bilingual advantages documented in the study. To this end, future studies should incorporate more extensive assessments of specific bilingual profiles and linguistic experiences. Second, given that the DCCS assesses more than one EF component (i.e., inhibition and shifting), it would be ideal for future research to employ multiple tasks that measure each EF component individually—rather than conjointly—to avoid the task-impurity problem (Miyake et al., 2000). Third, the lack of experimental controls (e.g., randomization of language groups) in our study restricts assertions about causality, which, in turn allows for alternative interpretations. Specifically, bilinguals' superior performance on EF tasks could be the result of either speaking two languages or higher motivation to acquire a second language in children whose executive functioning is already advanced. We reason, however, that for several reasons the latter is less likely to be true. To illustrate, bilinguals in our data set spoke a mother tongue other than English at home with their families, which implies that they grew up with two languages and acquired their non-English language involuntarily, due to their domestic language environment rather than voluntary commitment or motivational efforts. This would account for the consistency in bilingual status between the first and fourth waves ($r = 1.0$); that is, monolingual children with already advanced executive functioning were still in a single-language mode at Wave 4. In addition, evidence from randomized training studies, though limited, suggests that positive findings in favor of bilingualism are attributable to bilingual practice (rather than motivation per se). For instance, Janus, Lee, Moreno, and Bialystok (2016) offered 4- to 6-year-old children a 20-day second-language training and observed significant improvement on verbal and nonverbal EF tasks. Together with this evidence, our study suggests that bilinguals' superior performance in EF and adaptive self-regulatory behaviors are likely attributable to bilingual experiences. Nevertheless, an avenue for future research could be whether cognitive gains among children who were exposed to bilingualism domestically differ from those who receive formal language training.

To summarize, our findings suggest that bilingualism could potentially be a valuable element of intervention programs for children in impoverished circumstances. Crucially, given the vital role EF plays in school readiness, self-regulated behaviors, and academic competence (e.g., Blair & Razza, 2007; Brock et al., 2009), the power of bilingualism to enrich executive functioning could go a long way toward improving the educational outcomes of underprivileged children, especially when bilingualism begins in early childhood.

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