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Bilingual experience and executive functioning in young children

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Abstract

Advanced inhibitory control skills have been found in bilingual speakers as compared to monolingual controls (Bialystok, 1999). We examined whether this effect is generalized to an unstudied language group (Spanish-English bilingual) and multiple measures of executive function by administering a battery of tasks to 50 kindergarten children drawn from three language groups: native bilinguals, monolinguals (English), and English speakers enrolled in second-language immersion kindergarten. Despite having significantly lower verbal scores and parent education/income level, Spanish-English bilingual children's raw scores did not differ from their peers. After statistically controlling for these factors and age, native bilingual children performed significantly better on the executive function battery than both other groups. Importantly, the relative advantage was significant for tasks that appear to call for managing conflicting attentional demands (Conflict tasks); there was no advantage on impulse-control (Delay tasks). These results advance our understanding of both the generalizability and specificity of the compensatory effects of bilingual experience for children's cognitive development.

Introduction

Investigators have long been interested in the advantages and disadvantages of learning more than one language for children's linguistic and cognitive development (e.g. Bialystok, 2001; Bloomfield, 1933; Ervin & Osgood, 1954; Hakuta, 1986; Ianco-Worrall, 1972). Bilingual individuals, and children in particular, are valuable to study because of the fundamental issues that can be addressed, such as how language is represented in the mind and brain (e.g. Albert & Obler, 1978; Deuchar & Quay, 1998; Genesee, 1989; Green, 1998; Kim, Relkin, Lee & Hirsch, 1997; Kuhl, 2004, 2007; Meisel, 1990; Neville, 1993; Nicoladis, 1998); whether bilingual children have accelerated metalinguistic awareness compared to monolingual children (e.g. Bialystok, 1991; Bowey, 1988; Bruck & Genesee, 1995; Campbell & Sais, 1995; Cummins, 1978; Feldman & Shen, 1971; Galambos & Goldin-Meadow, 1990; Gathercole, 1997; Hakes, 1980); and how early bilingual experience impacts children's later linguistic activities, such as reading (e.g. Bernhardt, 1991; Bialystok, 1997; Bialystok, Luk & Kwan, 2005; Durgunoglu & Verhoeven, 1998; Edwards & Christopherson, 1988; Oller & Eilers, 2002).

Speculation on broad differences between monolingual and bilingual speakers historically has tended to focus on the *disabling* effects of growing up with two languages (e.g. negative

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effects on certain measures of 'intelligence'), although such speculations have been questioned (for reviews see Bialystok, 2001; Hakuta, 1986). In contrast, examinations of specific areas of cognitive functioning suggest that bilingual children might be at an advantage. These include superior flexibility using a symbol-reorganization task (Peal & Lambert, 1962), understanding the arbitrary nature of numeric symbols (Saxe, 1988), ignoring misleading features of a number concept task (Bialystok & Codd, 1997), understanding object constancy (Feldman & Shen, 1971), superior performance on spatial problems (Bialystok & Majumder, 1998), generating multiple hypotheses on a physical science problem (Kessler & Quinn, 1980), and performing well on nonlinguistic tests of creativity and geometric design (Ricciardelli, 1992).

Bialystok (2001) comprehensively reviewed the research on cognitive differences between bilingual and monolingual children and concluded that the pattern of evidence thus far supports enhancement for a set of specific intellectual abilities. According to this analysis, one aspect of cognitive functioning, namely inhibitory control over attentional resources, develops more rapidly in children with extensive bilingual experience. Specifically, the proposal is that bilingual children are advanced in the ability to control attention to conflicting perceptual or representational features of a problem. Inhibitory processes are instrumental in such tasks because one must inhibit or suppress attention to irrelevant or misleading aspects of a stimulus in the service of attending to the appropriate ones and generating a successful response. Inhibitory control is, in turn, a key component of executive functioning, which refers to the conscious control of thought and action (Posner & Rothbart, 2000). Additional components of executive function traditionally include resistance to interference, set-shifting, working memory (the ability to manipulate contents of short-term memory), and planning ability, all of which also may implicate inhibitory processes (e.g. Diamond, 2002; Engle, 2002; Roberts & Pennington, 1996). There is strong evidence that executive functioning is dependent on the neural systems of the prefrontal cortex (e.g. Luria, 1966; Miller & Cohen, 2001; Stuss & Benson, 1986), although much remains to be learned about the specific brain structure–function relations involved, especially in development (cf. Bunge & Zelazo, 2006).

Executive function has a protracted developmental timetable, but children make dramatic gains in self-control over thoughts, behaviors, and emotions in the preschool period (for overviews see Carlson, 2005; Kopp, 1982; Zelazo & Müller, 2002). Disruptions in executive function are implicated in a number of childhood disorders, including autism and Attention Deficit/Hyperactivity Disorder (for a review see Casey, Tottenham & Fossella, 2002). In contrast, in typically developing children executive function is positively correlated with several important aspects of development, such as social competence (e.g. Hughes, Dunn & White, 1998), moral conduct (e.g. Kochanska, Murray & Harlan, 2000), and school readiness (e.g. Riggs, Blair & Greenberg, 2003). Executive function is robustly related to theory of mind (e.g. Carlson, Mandell & Williams, 2004; Carlson & Moses, 2001; Hughes, 1998; Perner & Lang, 1999), and interestingly, there is some evidence of advanced theory of mind in bilingual compared to monolingual preschoolers (Goetz, 2003). The present investigation seeks to extend our understanding of the possible effects of bilingual experience on young children's executive functioning.

Evidence of advanced inhibitory control in bilingual children

Why would inhibition/selective attention develop comparatively more rapidly in bilinguals? Bialystok (2001) provided a theoretical analysis addressing this question. Contrary to earlier speculation about the two languages in bilinguals 'switching' on and off as the situation calls for it, Guttentag, Haith, Goodman and Hauch (1984) demonstrated that both languages remain active during language processing. Distributed activation, however, raises the probability of interference from the nonrelevant language. According to Bialystok (2001), language intrusions are prevented in bilingual speakers by holding in mind the relevant language and inhibiting the nonrelevant language, thus implicating frontal lobe processes (see also De Groot & Kroll, 1997; Green, 1998). If this analysis is correct, then bilingual children would have extensive, indeed daily, practice with inhibitory control, at least in a linguistic context. Bialystok (1986) found that bilingual children performed significantly better than monolingual speakers on a metalinguistic task (Moving Word) requiring children to ignore perceptual features of a stimulus (see also Bialystok, 1997; Bialystok, Shenfield & Codd, 2000).

Bialystok (1999) reported that this advantage appeared to carry over to other cognitive domains in research using the Dimensional Change Card Sort (DCCS) task, a well-established assessment of executive function for preschool children (Frye, Zelazo & Palfai, 1995; Zelazo, Frye & Rapus, 1996; Zelazo, Müller, Frye & Marcovitch, 2003). In the DCCS, children are given a series of cards to sort by one dimension (e.g. shape) and then asked to switch and sort by a different dimension (e.g. color). Children of 3 years, despite having no difficulty on the pre-switch trials, tend to sort incorrectly on these post-switch trials, perseverating on the old sorting rule. By 4 or 5 years of age, most children switch successfully. Young children's difficulties on the DCCS have been attributed to an inability to represent complex rules (Zelazo *et al.*, 2003) as well as deficits in working memory and inhibitory control (Diamond, Carlson & Beck, 2005; Kirkham, Cruess & Diamond, 2003; Kloo & Perner, 2005; Munakata & Yerys, 2001; Rennie, Bull & Diamond, 2004; Towse, Redbond, Houston-Price & Cook, 2000; Zelazo *et al.*, 2003). In Bialystok's (1999) research, Chinese-English bilingual preschoolers performed significantly better than English monolingual speakers on the DCCS after controlling for differences in verbal ability. The developmental advantage was approximately one year, with bilingual 4-year-olds performing similarly to monolingual 5-year-olds. In follow-up research, Bialystok and Martin (2004) tested 4- to 5-year-old children who were bilingual (Chinese-English, Experiments 1 and 3; French-English, Experiment 2) or English monolingual, using modified versions of the DCCS designed to tease apart the representation and inhibition components of the task. They replicated the basic finding and further specified that the bilingual advantage held up only in task versions that call for 'conceptual inhibition', that is, resisting attention to the previously relevant feature (e.g. color) in order to represent the newly relevant feature. Bilinguals and monolinguals did not differ on the ability to represent complex rules in the *absence* of distracting stimuli or to inhibit a familiar motor response.

Subsequent studies in which bilingual children from heterogeneous language backgrounds were combined corroborated these results. The bilingual advantage extended to the Simon task (in which there is a spatial conflict between stimulus and response; Bialystok, Martin & Viswanathan, 2005), the ambiguous figures task (which can be construed as an executive control task insofar as one must inhibit one perspective in order to apprehend an alternative perspective; Bialystok & Shapero, 2005), and response times on an anti-saccade task in adults (Bialystok, Craik & Ryan, 2006). In each case, bilinguals were better than monolinguals at selectively attending to a stimulus in the presence of distracting information. Given that executive function is recognized as a critical component of cognitive and social development, this research on bilingualism has implications for our understanding of the development of executive function as well as practical issues with respect to second-language instruction in the home and school.

Limitations of prior research

Despite these important implications, extant research on executive function in bilingual speakers has some limitations. The first concerns the language groups tested thus far.

Ideally, the effects would be replicable in any language combination and any laboratory. Bialystok and colleagues have gone a long way toward establishing this in their studies including speakers of Chinese-English, French-English, and heterogeneous language backgrounds (Bialystok, 1999; Bialystok & Martin, 2004; Bialystok, Martin *et al.*, 2005). It is particularly important to replicate the results with non-Chinese samples because of the possibility that aspects of Chinese culture, rather than bilingualism *per se*, promote greater self-control in young children. In fact, Sabbagh, Xu, Carlson, Moses and Lee (2006) reported significantly higher executive functioning scores in *monolingual* preschool children in Beijing, China compared to North American preschoolers, possibly due in part to cultural differences in the early socialization of self-control. For obvious practical reasons, there was not a Chinese-only control group in Bialystok's studies. Choi, Won and Lee (2003), however, tested Chinese monolingual and Chinese-Korean bilingual 4th graders in China and found that bilinguals significantly outperformed their monolingual counterparts on a test of selective attention, suggesting a specific effect of bilingual language experience over and above cultural influences on executive function.

In the current study, we extended this research to a language group that has not been investigated previously with regard to executive functioning. In the US, at least one in 12 kindergartners is exposed to a language other than English in the home, and in approximately 75% of such cases, Spanish is the primary language (August & Hakuta, 1997). Given that Spanish is the most rapidly growing language group in America's kindergarten children, the effect of Spanish-English bilingualism on cognitive abilities is of great interest and practical importance.

A second limitation of prior research is that a small number of executive function measures was used in a given study, thus making it difficult to examine the specificity of the effect. Executive function is a multifaceted set of skills (e.g. Miyake, Friedman, Emerson, Witzki, Howerter & Wagner, 2000; Zelazo, Carter, Reznick & Frye, 1997). Nonetheless, Carlson and Moses (2001) make a useful distinction, based on a factor analysis of executive function measures in preschool children, between 'delay tasks', which require children to delay/ temper a prepotent response, and 'conflict tasks', which require children to make a novel response while inhibiting a conflicting, prepotent response (as in the DCCS). Further research suggested that conflict tasks are more strongly related to working memory capacity than are delay tasks (Carlson, Moses & Breton, 2002; see also Diamond, Kirkham & Amso, 2002). Bialystok's evidence for superior performance by bilingual children on specific tasks suggests that there is an advantage in the conflict domain, but it leaves open the question of whether the benefits are more widespread and would extend to tests of response-suppression and delay-of-gratification. To help investigate the specificity of bilingual children's performance, we included multiple measures of executive function designed to tap both conflict (inhibition and working memory) and delay (inhibition with relatively low working memory demands) in a repeated measures design. Following Bialystok (2001; Bialystok & Martin, 2004), we hypothesized that bilingual speakers would be relatively more proficient on the conflict measures of executive function compared to monolingual speakers, but not on the delay measures, thus supporting specificity in the way that early language experiences map onto the development of cognitive skills.

Definitional issues and challenges

Defining who is 'bilingual' is not straightforward. Language proficiency can be defined as 'the ability to function in a situation that is defined by specific cognitive and linguistic demands, to a level of performance indicated by either objective criteria or normative standards' (Bialystok, 2001, p. 18). However, bilingual children typically have a larger productive and receptive vocabulary in one of the languages and their vocabulary in each language taken individually is usually less than that of a monolingual speaker of the same age (e.g. Ben-Zeev, 1977; Bialystok, 1988; Nicoladis & Genesee, 1997; Umbel, Pearson, Fernandez & Ollie, 1992). Furthermore, although researchers agree that bilingualism is better described as a matter of *degree* than as a categorical variable, currently there are no accepted standards for classifying children on the basis of an objective bilingualism scale. Grosjean (1989, 1998) argued against the view that a bilingual individual is two monolinguals in one person, and instead proposed a pragmatic definition that a bilingual is someone who can function in each language according to given needs. On this definition, functional proficiency in the two languages is equivalent in bilingual individuals: they have conversational skills and can carry out similar activities in each language, even though formal proficiency in either language may not match that of a monolingual speaker.

Furthermore, it is rarely possible to equate bilingual children and monolingual children on all variables aside from the number of languages they speak. Children in North America become bilingual for a variety of reasons, such as having non-native parents but all community activities and schooling in English, or having one parent or extended family member who speaks a language other than English. Bialystok (2001) noted that these conditions tend to correlate with several other factors that are likely to influence the course of social-cognitive development, including parental education level, literacy learning in the home, proficiency in each language, the settings in which the second language is used, and socioeconomic status (SES). Hence, the ideal experimental situation in which bilingual and monolingual speakers have equal proficiency in their common language *and* equivalent social and economic circumstances is not easily attainable in the US today, or, if it could be achieved through extensive screening of participants, the findings would be grossly under-representative of the actual bilingual population found in North America.

Nonetheless, questions about the effects of bilingualism on executive function are pressing and deserve further examination, despite the practical complications. To address these challenges, we included three novel design features in the present study. First, we included three groups of kindergarten children having different degrees of exposure to a second language: native bilinguals (Spanish-English), English monolinguals, and children attending a language-immersion kindergarten program. This design enabled us to examine a range of second-language experience that is more representative than simple ‘bilingual’ and ‘monolingual’ categories. Furthermore, it extends previous research by allowing a preliminary investigation of the impact of early foreign-language immersion education on children’s developing executive function skills. If there are significant advantages of a multi-lingual environment for children’s social-cognitive abilities, then does early (but non-native) exposure confer similar benefits compared to a traditional monolingual school environment? Answering such questions could have a considerable impact on educational theory and practice.

Second, based on prior research we anticipated that native bilingual children would score significantly lower on vocabulary size than the other groups (e.g. Bialystok, 1988; Nicoladis & Genesee, 1997; Umbel *et al.*, 1992). This poses a problem for evaluating the outcome of interest, however, because vocabulary measures are consistently found to be positively related to executive functioning in preschool and kindergarten children (e.g. Carlson & Moses, 2001; Carlson *et al.*, 2002; Hughes, 1998). To control for this confound, we administered the Expressive One-Word Picture Vocabulary Test-Spanish-English Bilingual Edition (Brownell, 2001) and included total scores as a covariate in the major analyses, following Bialystok (1999).

Third, it is of considerable importance to take into account the cultural context in which bilingualism occurs to better evaluate cognitive outcomes. Therefore we documented several relevant contextual factors in the participating families, such as settings of primary and secondary language use, family income, parent education level and number of years living in the US, and home-based reading practices. Also, because cultural or subcultural differences might exist regarding the extent to which conscious control over behavior is valued, we included a new measure of parental attitudes about children's self-control.

To summarize, the present study aimed to address the following questions. First, do Spanish-English bilingual children show accelerated executive functioning similar to that found previously in other languages? Second, does the bilingual advantage extend to multiple executive function tasks that have not previously been assessed? Third, is the effect found for both conflict and delay executive function measures or, as we hypothesize, is it more specific to conflict? Finally, do English-speaking children attending a second-language immersion kindergarten also show similar benefits in executive function, compared to children in a traditional kindergarten?

Method

Participants

Participants included 50 kindergarten children and their parent or legal guardian (*M* age = 72 months, *SD* = 5.68 months, range = 58–83 months; 26 boys, 24 girls). An additional two children participated but were not included in the analyses due to developmental delay (n = 1) and extensive prior exposure to Spanish in one of the supposed non-Spanish Control cases (n = 1).

The *Bilingual group* consisted of 12 children with exposure from birth to Spanish and English. They were recruited with posted fliers and oral presentations at community centers and elementary schools having a substantial Hispanic student population, the Bilingual Orientation Center for the public schools, bilingual reading groups at the public library, worship centers, and by word of mouth. We administered a Language Background Questionnaire to parents (in the parent's preferred language) to examine children's language exposure. In this group, either both parents were native Spanish speakers who spoke both Spanish and English at home and in the community, or one parent spoke Spanish and the other spoke English. Half the parents reported they had lived in the US for less than 10 years; for the other half it was between 10 and 20 years. Six parents reported Spanish as their child's dominant language; five reported English; and one marked 'can't decide'. All children reportedly spoke a mixture of Spanish and English in the home. The majority spoke English with friends and had attended an English-speaking preschool program. Approximately half the parents in this group reported reading to their child in both Spanish and English; the remaining children were evenly divided between English and Spanish. Children were reading on their own or beginning readers in both languages or in English only. These items from the Language Background Questionnaire suggested that our Bilingual group was composed of children with approximately equal exposure to Spanish and English.

The *Immersion group* included 21 kindergarten children attending a language immersion public elementary school (grades K–5) in which children receive instruction in multiple subjects in English for half the day and in either Spanish (n = 13) or Japanese (n = 8) for half the day (approximately three hours in each language). We recruited children into the study regardless of which language they received their immersion in, under the assumption that the potential cognitive benefits of second-language learning should generalize across the languages involved. Nonetheless, we performed analyses comparing the children enrolled in the Spanish and Japanese programs (see Results section). Children were recruited by sending fliers in take-home mail and following up with a telephone call to the families. At the time of testing, children in the Immersion group had received six months of second-language exposure on average. It is important to note that the children in the Immersion group were all English monolinguals when they entered the program and their families spoke only English at home. Thus all study procedures and parent questionnaires could be administered in English to these participants.

The *Control group* included 17 English monolingual children attending traditional kindergarten programs with very limited exposure to a second language at school (30 min per week maximum) or at home. The Immersion and Control groups included White/non-Hispanic children (approximately two-thirds of each sample) as well as children of Asian, Hispanic, and African American origin according to parent report. All parents in these two groups reported English as the child's dominant language, the language of print and television in the home, and preschool programs, with no (or minimal) exposure to a second language (prior to kindergarten for the Immersion group). Table 1 contains detailed demographic information, broken down by each of the three language groups.

Procedure

Children and a parent/guardian visited a university playroom for a single session lasting 1.5–2 hours. Informed written consent procedures (and child oral assent) were followed for all participants according to guidelines of the American Psychological Association and were provided in English or Spanish, according to participant preference. All tasks were administered in English, Spanish, or a combination of the two, as the child preferred. A male experimenter who is a native English speaker with excellent conversational and grammatical fluency in Spanish conducted all sessions. The fixed order of tasks was: Comprehensive Test of Nonverbal Intelligence, Expressive One-Word Picture Vocabulary Test – Spanish/English Bilingual Edition, Dimensional Change Card Sort, Simon Says, <break to watch a video of '*Where the Wild Things Are*' in the child's preferred language>, Delay of Gratification, Kansas Reflection-Impulsivity Scale, Visually Cued Recall, Statue, Gift Delay, and Attention Network Task.[1] Sessions were videotaped for later coding. Families received $20 and parking or transportation reimbursement. Children received a T-shirt and a small prize for participating.

Ten measures were included to assess various aspects of executive functioning including conflict and delay measures. Additionally, the Expressive One-Word Picture Vocabulary Test (EOWPVT) was included to control for group differences in verbal ability. Parents completed Family Information and Language Background questionnaires and two questionnaires assessing household rules and their child's self-control (see Table 1).

All task instructions and questionnaires were translated into Spanish by a native English speaker who is fluent in Spanish, and then back-translated by a native Spanish speaker who is fluent in English and has a PhD in psychology. Finally, two native Spanish speakers who have only limited English language proficiency independently made minor adjustments to the Spanish versions of the consent form, task protocols and parent questionnaires to make their meaning as clear as possible to families who expressed a preference for Spanish.

Coding agreement was established by double-coding eight participants and all dependent measures were reliable within accepted standards (at most 1 disagreement; RTs within .5 sec were considered reliable). Discrepancies were resolved by a third coder. All other sessions were single-coded by trained coders who were blind to the major study hypotheses.

[1]Two additional tasks were administered but later excluded from analyses due to a ceiling effect (Moving Word) and a floor effect (Conservation of Mass).

Parent questionnaires

Rules questionnaire (Smetana, Kochanska & Chuang, 2000; based on Gralinski & Kopp, 1993)—This 29-item questionnaire asks about household rules such as not interrupting when mother is on the phone and eating food that parents serve. The items represent categories including child safety, protection of property, interpersonal manners, obedience/order, food/mealtime routines, family routines/chores, self-care, and parental control over the child's choices in clothing, friends, etc. Item wording was modified slightly to be more appropriate for this older age group of children. Parents indicated first if the item is a 'rule' (formal or informal expectation) for their child, and second how important it is to them that their child complies, on a 5-point scale. Total scores on the rule-importance items were used in analyses.

Children's behavior questionnaire (Rothbart, Ahadi, Hershey & Fischer, 2001)—Four subscales of this temperament questionnaire that were of greatest interest related to executive functioning were included (45 items): Attentional Focusing, Attentional Shifting, Inhibitory Control, and Impulsivity. Parents indicated how true each statement is of their child on a 7-point scale. Next, we asked parents to indicate how important they believe these skills are at their child's present age, such as, 'How important is it to you that your child can focus his/her attention and easily concentrate on a particular task?' followed by, 'How upsetting is it to you when your child does not focus his/her attention on a particular task?' for a total of eight questions (also on a scale of 1–7). Responses to these eight items indicating the importance of self-control according to the parent were summed for analyses.

Verbal ability control measure

EOWPVT-SBE (Expressive One-Word Picture Vocabulary Test – Spanish Bilingual Edition; Brownell, 2001)—This is a norm-referenced test intended for use with children aged 4–12 years who speak Spanish and English with varying levels of proficiency. Instructions are presented in the examinee's dominant language (English for all Immersion and Control children). For Bilingual participants this was determined by parent report and by giving participants examples in each language and then asking which language they preferred to use for this game. (Two children expressed a preference for Spanish and one wanted both English and Spanish. However, in keeping with the EOWPVT protocol, the examiner was permitted to repeat the question in the alternate language if children hesitated or responded incorrectly in their dominant language.) The examiner presented a series of illustrations depicting an object, action, or concept and asked children to name each illustration (e.g. 'What's this?' or 'Qué es esto?'). Testing stopped when children reached a ceiling item (six consecutive errors). Final responses in either language were scored. Standard scores were used in analyses.

Executive function measures

The nine executive function measures in our battery are described below.

Advanced DCCS (Dimensional Change Card Sort; Zelazo *et al*., 1996)—We first administered the standard preschool version, described briefly in the introduction. The pre-switch dimension was shape (rabbits/boats; criterion was five consecutive correct sorts) and the post-switch dimension was color (red/blue; five trials, three of which perceptually conflicted with the old sorting rule, following Frye *et al.*, 1995). Given the age of participants we anticipated that most if not all children would succeed on the preschool version. Therefore, all children were next given the advanced 'stars' version of the DCCS (Hongwanishkul, Happaney, Lee & Zelazo, 2005). For these trials, the experimenter introduced the same types of cards used earlier, except that some of them had a gold star sticker located above the colored shape. After pointing out the stars, he announced, ‘When you see a card with a star on it, you’ll sort it by color. But if the card *doesn’t* have a star on it, then sort it by shape. OK? Let’s practice first. See, here is a red boat, and it *doesn’t* have a star on it. So I’ll sort it by *shape*, and I’ll put it in this box (pointing to the blue boat tray). And here’s another red boat, and it *does* have a star on it, so I’ll sort it by *color*, and I’ll put it in this one (pointing to the red rabbit tray).’ A verbal rule check followed: ‘OK, let’s go over the rules, just to make sure you know how we play this game. So if the card has a star on it, do you sort it by color or shape?’ (Color is correct.) The experimenter corrected any errors, repeated the question, and moved on to inquire about what should happen if the card does not have a star on it (sort by shape), and corrected errors and repeated the question as needed, up to three times. Twenty advanced sorting trials ensued, with a rule reminder given after 10 trials but no feedback on responses. The majority (16) of these cards did not contain a star, and so the correct (now dominant) sorting rule was shape. On four trials, however, a star appeared, and in each case the correct response was in conflict with the shape rule (e.g. put a blue rabbit in the blue boat tray). The number of correct conflict trials on the advanced sorting phase (0–4) was used in data analyses.

Simon Says (Strommen, 1973)—To warm up, children were asked to perform a series of actions while standing opposite the experimenter. Then the experimenter announced that they were going to play Simon Says and reviewed the rules: ‘Whenever I say “Simon Says”, you do what I say. But when I don’t say “Simon Says”, you shouldn’t do anything at all. If I don’t say “Simon Says”, you should try to stay perfectly still.’ Two practice trials ensued (one of each kind), followed by a verbal rule check and 10 test trials. The experimenter performed all actions regardless of whether it was a ‘Simon Says’ trial. He reminded children of the rules halfway through, but did not give feedback. ‘Simon’ trials were coded as follows: 0 = failure to move, 1 = wrong movement or flinch, 2 = partial correct movement, 3 = full correct movement. For non-Simon (non-imitation) trials: 0 = full commanded movement; 1 = partial commanded movement; 2 = wrong movement or flinch; 3 = no movement. Total scores across the five non-Simon trials were analyzed (possible range = 0–15).

Visually cued recall (Zelazo, Jacques, Burack & Frye, 2002)—This task was included as a measure of short-term memory capacity that also requires inhibition of a response to previously selected items. The experimenter introduced children to a puppet ‘Pat’ who likes certain things very much and presented them with 12 different arrays of pictures (three rows of four pictures), one at a time. First he said, ‘I’m going to show you pictures of things that Pat likes. When I finish showing you pictures of things that he likes, I want you to point to them for me. But you can only point to things that Pat likes, OK? See, on this poster, Pat likes the tricycle [simultaneously pointing to the item]. Can you point to the one that Pat likes?’ On two practice trials and the first test trial, only one item had to be remembered. On each subsequent trial, a new array was presented and participants were required to remember one more item than in the preceding array (pointing in the same serial order was not required). Items from previous arrays reappeared on subsequent trials. Hence, this task is related to the updating function of working memory (Baddeley, 1986). The task was discontinued when participants failed two consecutive trials (or when they reached a maximum of 12 items). Final accuracy scores were calculated by subtracting the number of false alarms (pointing to old items) and misses (omitting new items) from the total number of correct hits.

Kansas Reflection/Impulsivity Scale (KRISP; Wright, 1972)—Children were presented with a flip-book arranged vertically and asked to select the drawing from the bottom page that exactly matches a drawing on the top page. The choices differed only slightly from the target drawing and so needed to be inspected carefully before making a selection. After five practice trials, there were 15 test trials of increasing difficulty. The last five trials were added to create a more advanced version for this kindergarten age group. Following Wright (1972), up to three errors were permitted on each trial before moving on. For errors the experimenter said, ‘No, look up here. Can you find the one that is *exactly* like this one up here?’ Accuracy scores (total correct minus number of errors) were used in analyses.

C-TONI (Comprehensive Test of Nonverbal Intelligence; Hammill, Pearson & Wiederholt, 1997)—This test of nonverbal reasoning ability has been validated for use with children who speak English as a second language. It was designed to assess the intellectual ability of individuals for whom most other mental ability tests are either inappropriate or biased. Instructions were provided for oral and pantomime administration to accommodate children with lower verbal ability. The pictorial and geometric categories subscales were included (in that order). The task began with three practice trials in which the experimenter pointed to an array of items (drawings or geometric shapes) at the top of the page, saying, ‘These two are alike in some way. Which one of these [sweeping a finger along the row of alternatives at the bottom of the page] is *most* like these two and should go in the empty box [pointing to the top]? Point to your answer.’ Most of the alternative choices bore some relation to the target items, and often an incorrect choice was more salient perceptually (e.g. physically more similar to the target items) than the correct response (e.g. one that was thematically similar). For example, one of the pictorial category trials included a frog and a rabbit as target items (both depicted on four legs). The choices for ‘most like’ included a kangaroo, beaver on hind legs, ostrich, bear, and bird. The kangaroo was the correct thematic choice (hopping), but the bear was a perceptual distractor because it was the only one depicted with four legs. Hence, the task calls for pattern recognition but also inhibition of salient but interfering response options. If children responded incorrectly on a practice trial, the experimenter corrected them and helped them point to the correct answer. All children demonstrated correct performance by the third practice trial. Test trials followed, with the experimenter continuing these instructions (but without feedback) until children responded incorrectly on three out of the last five items. An identical procedure was followed for the geometric categories. Raw scores for each subtest were calculated by subtracting the number of errors from the ceiling item number, and then summed for a total C-TONI score.

Attention Network Task (ANT; Rueda, Fan, McCandliss, Halparin, Gruber, Pappert-Lercari & Posner, 2004)—The children’s version of the ANT was presented in the form of a computerized game (using a Dell Dimension 1850 with a 15-in color screen; programmed in E-Prime, Psychology Software Tools, Inc., 2001). The experimenter introduced the task by telling a story about a hungry fish, using laminated illustrations. The object of the game was to ‘feed’ the fish as quickly as possible when it appeared on the computer screen. If the fish was oriented facing left, children were told to click the left side of a computer mouse, and to press the right side for a right-facing fish. On no-flanker trials, the target fish appeared alone on the screen. On flanker trials, children were instructed that the target fish is always the one in the middle (of a row of five fish). All fish were facing the same direction on congruent trials. On incongruent trials, however, the target was embedded in a school of fish that were facing the opposite direction from it, hence creating attentional conflict. Children had to inhibit the tendency to attend to the direction of the flankers and instead respond according to the direction of the target.

Following a practice block of 24 trials, the test block consisted of 48 trials, including 16 with no flanker, 16 congruent, and 16 incongruent trials (randomly ordered). The fish uttered a ‘woohoo’ sound in an excited voice, wagged its tail, and made bubbles following a successful response. Errors were followed by a buzzer sound and no animation. The warm-up and task took 20 min to complete on average. The task was motivating for children, but given that it occurred at the end of a 1.5-hr session with young participants, we were concerned about a high refusal rate and did not proceed with the three additional test blocks provided with the game. We caution that the reliability of performance may be lower in our sample for this reason. Following Rueda *et al.* (2004), response times exceeding 1700 ms after the target fish was presented were excluded from analysis. (The mean and modal number of trials completed within the time limit was 38, $SD = 6.46$; there were no group differences on the number of trials excluded.) Accuracy (proportion correct) on incongruent trials was used in the present analyses. This task was not yet available for the first eight subjects, who were all in the Immersion group.

Delay of gratification (Mischel, Shoda & Rodriguez, 1989)—This task assesses children’s ability to delay a food reward in order to receive a larger amount. The experimenter placed a hotel-style bell on the table and explained that it can be used to summon him to return to the room whenever the child rings it (with demonstration). Next, he presented a variety of treats (e.g. Goldfish crackers, fruit-flavored cereal) and invited children to try them and say which kind they liked best. He then presented two piles of the preferred treat in shallow bowls – one having two treats and the other having 10 – and asked children which amount they would prefer (all indicated the larger one). Children were told that the experimenter needed to leave the room, and that if they waited in their seats without eating the treats, then they could have the large pile of treats when he returned. However, if they did not want to wait, they could ring the bell at any time and the experimenter would return, but then they could only have the small pile of treats. After checking children’s verbal understanding of the rules, the experimenter placed the bell directly in front of the child, between the two bowls, and exited the room for 8 min or until the child rang the bell or began eating the treats. Children were praised for waiting regardless of performance. Most children (75.6%) waited the entire time without ringing the bell. Therefore, in analyses we used the latency to the first touch to the bell, bowl, or treat as an index of attention deployment toward the tempting stimulus during the delay period, similar to Mischel and colleagues (e.g. Sethi, Mischel, Aber, Shoda & Rodriguez, 2000).

Statue (Korkman, Kirk & Kemp, 1998)—This task measures the ability to suppress motor action during a delay. The experimenter suggested that the child stand up like a statue holding a flag. Children were asked to keep their eyes closed and to be completely still, not to open their eyes, and not to say anything until the experimenter said, ‘Time’s up!’ They were permitted to keep their free hand on the table for support. The experimenter said, ‘begin’ and proceeded to create a distraction four times during the 75-sec delay (dropping a pencil, coughing, knocking on the table, and saying ‘ho hum’, in that order at specified intervals). Body movements, eye opening, and vocalizations were recorded as errors. Each 5-sec interval was scored as 0 (2–3 errors), 1 (1 error), or 2 (no errors). Total interval scores were used in analyses (possible range = 0–26).

Gift delay with cover—We developed this delay-of-gratification task in which children needed to wait and try not to peek inside a gift box while the experimenter was out of the room. The experimenter placed a gift box on the table and announced that he had a present for the child inside. Then he noticed that there was a window on one side of the box with a felt cover placed over it. However, the cover was not fully blocking the window: ‘I think the cover must be broken! It’s falling off. I really want this gift to be a good surprise, so I’m going to go get another cover for the window. I’m going to get a cover that hides the whole window, so no one can peek inside.’ The experimenter arranged the window at a 90-degree angle from the child’s seat. Next he said, ‘Let’s play a game again. Try not to touch this box until I come back, and try not to peek inside, OK? So, see how long you can stay in your seat without touching the box or looking inside it, OK?' He exited the room for 3 min before returning with a cover and inviting the child to open the present. Scores were assigned according to the level of restraint shown in not attending to the box: 1 = removes cover and looks inside box; 2 = looks in window but does not remove cover; 3 = touches box or cover without looking inside; 4 = looks at (but not inside) the box and does not touch box or cover; 5 = never touches or looks at or inside the box.

Composite scores

In addition to individual task scores, we computed a composite score for each participant reflecting the mean of the nine executive function tasks. Individual task dependent variables were converted to *z* scores because they were on different scales, and then averaged to create Composite Executive Function scores. This technique allowed us to assess overall performance without diminishing power due to the small amount of missing data.

Results

All statistical analyses reported were two-tailed, included automatic correction for uneven group sizes, and alpha set to .05. A Bonferroni adjustment was performed for multiple comparisons.

Preliminary analyses

Demographic characteristics—Demographics and parent questionnaires are summarized in Table 1. A one-way ANOVA indicated that the groups differed in age, $F(2, 49) = 4.74$, $p < .05$. This was expected because most children in the Control group were tested in the summer following kindergarten; they were significantly older than children in the Immersion group (Tukey's HSD, $p = .01$) and so age was included as a covariate in the main analyses. The Bilingual group did not differ from the other two groups in age. Groups did not differ significantly in the representation of males and females.

As anticipated, the Bilingual group was significantly socially disadvantaged compared to the other two groups on a number of indicators. These included maternal education, $F(2, 46) = 11.21$, $p < .0001$, family income, $F(2, 45) = 8.74$, $p = .001$, and the amount of time parents read to their children, $F(2, 46) = 12.45$, $p < .0001$. In each case, the Bilingual group differed significantly from the other two groups (Tukey's HSD, *p*s < .01). The Immersion and Control groups did not differ significantly from each other on these measures.

Importance of self-control—We assessed the value parents accord to children's self-control using the Rules Questionnaire and the importance ratings of self-control from the Children's Behavior Questionnaire. These Rules and Importance measures were significantly correlated with one another, $r(45) = .56$, $p < .0001$. Group differences were nonsignificant for Rules Total ($p = .19$); however, there was a significant difference on the Importance-of-Self-Control scores, $F(2, 44) = 4.34$, $p < .05$. Tukey's HSD tests indicated that parents of Bilingual children rated self-control as more important than did parents of children in the Immersion group ($p < .05$); the comparisons between Bilingual and Control and Immersion and Control groups were nonsignificant. These results suggested that family and cultural values pertaining to self-control might be an important factor to weigh in comparisons of children's executive function, and so we included Importance-of-Self-Control ratings as a covariate in secondary analyses.

Verbal ability—As expected from past literature, the groups differed significantly on verbal ability (the EOWPVT-SBE), $F(2, 49) = 26.96$, $p < .0001$ (see Table 1). Bilingual children performed more poorly than the other groups (Tukey's HSD, *p*s < .0001), whereas the Immersion and Control groups did not differ from each other. Hence, verbal ability was included as a covariate in the main analyses.

Effects of age, sex, verbal ability, and SES—The correlations among age, sex, verbal ability, and socioeconomic status (SES) measures are presented in Table 2. As expected, several of the executive function measures were significantly related to these measures. EF Composite scores were significantly correlated with age, $r(50) = .36$, $p = .01$. Correlations between the EF Composite and verbal ability were significant in the sample as a whole, $r(50) = .63$, $p < .0001$, as well as within each group analyzed separately, *r*s = .66–.81, *p*s < .01. EF Composite scores also were significantly related to maternal and paternal education levels, *r*s(47, 46) = .36 and .34, respectively, *p*s < .05. (Maternal and paternal education levels were in turn related to family income, *r*s(47, 46) = .65 and .43, *p*s < .0001 and .01, respectively.) Sex was not related to task performance. Given this pattern of results, we covaried age (in months), verbal scores (EOWPVT-SBE), and maternal and paternal education levels (as a proxy for SES) in later analyses of EF.

Raw scores—Before reporting the analyses in which these demographic variables were adjusted, we provide preliminary analyses with raw scores in Table 3, in order to be comprehensive in characterizing the raw data set. We first carried out a MANOVA on all EF tasks with language group as the between-subjects factor. This analysis was nonsignificant ($p = .33$), and no group comparisons on individual tasks were significant. Also, when we examined the Immersion group separately, there were no significant correlations between the number of months of second-language exposure and performance on any of the EF tasks. There were also no differences between the Spanish- and Japanese-immersion subgroups on any measures, suggesting that it was appropriate to treat this as a single group in subsequent analyses.

Executive function results controlling for age, verbal ability, and SES

In the main analyses, given the influence of age, verbal ability, and SES on task performance, together with the significant group differences on these measures, it was important to control for these factors in our assessment of second-language experience on executive function. In particular, determining whether bilingual children respond differently on executive function measures might be masked by group differences in language proficiency and SES. Therefore, we conducted ANCOVA analyses of group effects on the executive function measures with age, verbal ability, and parent education levels as covariates (see also Bialystok, 1999). These analyses addressed how, given a certain level of language functioning and SES, children in each group performed on the EF tasks. The results are shown in Table 4.

First, we examined overall performance on EF (the composite EF score composed of nine items). As shown in Table 4, the effect of group on Composite EF scores was significant with a moderate effect size, partial $\eta^2 = .28$. Pairwise comparisons (Bonferroni correction) revealed that Bilinguals performed significantly better than both Immersion students and Controls (*p*s < .01 and .05, respectively). This result was robust even when parent ratings of the importance of children's self-control were covaried in addition to age, vocabulary, and parents' education, $F(2, 41) = 7.04$, $p < .01$, partial $\eta^2 = .29$.

At the individual task level, findings were in the expected direction (Table 4), although less reliable than with the Composite EF scores. There was a significant effect of language group on Visually Cued Recall, the Advanced DCCS, and the C-TONI. These tasks all require inhibition of attention to misleading items or aspects of the stimuli. Pairwise comparisons

(Bonferroni correction) indicated that Bilinguals scored significantly higher than the Immersion group on Visually Cued Recall ($p < .05$), significantly higher than the Control group on the Advanced DCCS ($p < .05$), and marginally better than both of the other groups on C-TONI (ps < .10). All other pairwise comparisons were nonsignificant, indicating no differences between the Immersion and Control groups.

Specificity of the bilingual effect

Finally, to begin to assess the specific aspects of executive functioning that may be influenced by bilingual experience, we submitted the nine EF dependent measures to a principal components analysis with Varimax rotation that converged in three iterations. The analysis resulted in two distinct factors that explained 65% of the variance and were interpreted as representing Conflict and Delay aspects of EF. The factor loadings are presented in Table 5. We subsequently computed a Conflict score for each participant by averaging the six tasks (standardized with z conversion) loading highly on the first factor; similarly, Delay scores were composed of the three tasks loading highly on the second factor. As illustrated in Figure 1, these analyses indicated that the group difference was isolated to the Conflict subscale, $F(2, 45) = 8.15$, $p < .01$, partial $\eta^2 = .30$. Bilinguals scored significantly higher than both the Immersion and Control groups (ps < .01). The Immersion and Control groups did not differ significantly from each other. In contrast, performance on the Delay subscale was unrelated to language group, $F(2, 45) = .24$, partial $\eta^2 = .01$.

Discussion

The aims of the present investigation were to examine the effect of bilingual experience on young children's executive functioning in a previously unstudied language group (Spanish-English), assess the generality of a bilingual advantage to a wide range of executive function measures, and determine the specificity of this effect (taking into account different aspects of executive function and different levels of second-language exposure).

The results showed that the language groups differed on several demographic variables that are likely to affect cognitive and social development. In our sample, the Bilinguals were economically disadvantaged and had lower expressive vocabulary compared to the other two groups. An examination of raw scores on the executive function tasks revealed no group differences. However, consistent with other reports of executive function in young children, performance was influenced by age, verbal ability, and SES. When we controlled for these factors, there was a significant relative advantage of native bilingualism on a composite of all tasks and, in particular, the subset of tasks involving conflicting attention (Conflict EF tasks). There was little evidence for a selective advantage of the early immersion kindergarten program on our measures of executive function. With age, verbal ability, and SES controlled, the Immersion group performed similarly to the Control group on the individual and combined measures.

Doing more with less

Although these results are intriguing and highly consistent with previous research with bilingual children from other language backgrounds, it is a limitation that our language groups were not matched on all variables such as verbal ability, income and parent education levels. In fact, it is extremely challenging to do so for reasons noted in the Introduction. In our sample, the Bilingual group was relatively disadvantaged over the others, but, nonetheless, our results showed that raw scores for executive function were not significantly different. As Bialystok (2001) noted, 'one must not lose sight of the possibility that the impact of bilingualism may not be advantageous but rather detrimental to cognitive performance, so demonstrations of equivalent performance for monolinguals and bilinguals are themselves salutary' (p. 203). Given social disadvantages such as lower parent education levels and the lack of home-based reading, which was particularly striking in our study, Spanish-English bilingual children are at risk for an achievement gap on a number of indices. What our results suggest is that they may be 'doing more with less' in at least one important sphere of cognitive development – executive functioning. In other words, given the well-established relation between verbal ability and executive function, the positive relation between verbal ability and SES (e.g. Hoff, 2006), and recent evidence of a relation between SES and executive function (e.g. Ardila, Roselli, Matute & Guajardo, 2005; Hughes & Ensor, 2005; Mezzacappa, 2004; Noble, Norman & Farah, 2005), our sample of bilingual children would be expected to perform significantly *worse* on executive function measures than monolinguals, but in fact their raw scores were equivalent. Moreover, when we statistically adjusted for these factors following Bialystok (1999), the bilingual children significantly outperformed the other groups. These findings suggest that when bilingual children are not equally matched with their monolingual peers on verbal ability and SES (as is the reality for many Spanish-English bilingual children in US schools today), they may be able to compensate or achieve the same ends by an alternative route, namely, in our view, honing of the cognitive operations involved in language switching.

Neville and her colleagues have shown that there is a great deal of plasticity in developing brain systems dependent on the type of linguistic input infants receive – such as spoken English versus American Sign Language, and one language versus two (Neville, 1993; see also Kuhl, 2004). Neville's research shows that left frontal activation is significant in influencing the way language is processed and develops. Interestingly, Bialystok, Craik *et al.* (2005) showed that the center of activation for responding to the Simon task was in the dorsolateral prefrontal cortex for monolinguals but in Broca's area for bilinguals. This evidence is consistent with Bialystok's (1999) suggestion that frontal cortex is not only involved in shaping language, but also that, in turn, language experiences can influence further development of frontal lobe functions such as inhibition and the control of attention (se also Deák, 2003). Following the evidence summarized here and Bialystok's theory regarding the dual direction of influence between language and executive functioning, our proposal is that early exposure to more than one language may foster the inhibition and working memory skills necessary for cognitive flexibility in a variety of problem-solving situations. The behavioral and brain evidence thus far supports the notion that language switching might be a subset of more generalized executive and behavior-selection processes rather than an isolated linguistic process (cf. Chee, 2006). Children must actively inhibit one way of representing the world (e.g. thinking 'cup') in order to activate an alternative representation and response (e.g. say 'vaso'). Intensive practice forming dual symbols, holding in mind and flexibly suppressing activation of one in favor of the other, might result in more highly honed executive control skills in children with early bilingual exposure than children without this exposure. Further, they might even compensate for relative disadvantages in verbal ability and SES. It remains to be determined whether native bilingualism is crucially distinct from high-level (but non-native) proficiency in producing this effect. Further studies of the manner in which initial dual-language input contributes to brain development are needed (e.g. Kuhl, 2007; Vaid, 2002).

Specificity of bilingual effects

Our findings replicate and extend previous research. Consistent with Bialystok (1999), we found that bilingual children performed significantly better on the DCCS (the advanced version in our study) than monolingual children after accounting for vocabulary differences. We demonstrated this effect in a different language group (Spanish-English), and one that is greatly pertinent to the bilingual population in the US. Also, we found that the relative advantage extended to a large battery of executive function measures. Our study also showed some specificity of the effect, however: The language groups did not differ in the ability to suppress a motor response, delay gratification, or in performance on tasks that can be construed as having relatively low working memory demands. The advantage appeared to be isolated to executive function measures that purportedly require memory and inhibition of attention to a prepotent/distracting response. This finding has both methodological and theoretical significance. First, it allayed concerns that the method of covarying vocabulary and SES might have artificially inflated the performance of bilingual children on *any* measure we included in the study. Verbal scores and SES were correlated with the Delay measures as well as the Conflict measures to a similar degree, and there was sufficient variability in the Delay subscale to detect significant effects. Yet language group did not contribute significantly to this variance even with verbal ability and SES controlled. We would argue, therefore, that the specificity is a genuine result rather than a spurious byproduct of task selection. It should be acknowledged, however, that task intercorrelations in our research were small especially among the Delay measures; this interpretation would be strengthened by replicating the results with a more coherent battery.

The theoretical implication is that the pattern of findings suggests a specific role for conflict inhibition in the link between bilingualism and executive function. The effect did not generalize to all measures involving inhibition. Our interpretation is thus consistent with Bialystok and Martin’s (2004) observation that the bilingual advantage is apparent when the correct response to a problem is embedded in a misleading context and when the conceptual demands are at a moderate level. They highlighted the distinction between inhibition of attention to a mental representation (where there is a bilingual advantage) and inhibition of an action/motor response (where there is not). This distinction maps roughly onto our findings for Conflict and Delay categories of executive function, respectively. Further, however, we believe that taking into account the working memory requirements of the various executive function measures is useful in explaining where advantages of bilingualism are likely to be found (i.e. Conflict tasks). Indeed, recent evidence suggests that bilingual children excel at working memory tasks even when the inhibition demands are relatively low (Feng, Diamond & Bialystok, 2005).

Native versus later exposure

Our study also extended previous research by including children with different degrees of exposure to a second language. The effect was specific to native bilinguals in our study – suggesting that early and intensive exposure to, and mastery of, more than one language may be necessary for a benefit in aspects of executive function to manifest itself. This finding is consistent with previous research showing that outcomes on cognitive performance are dependent on the extent to which an individual is bilingual. Ricciardelli (1992) reported that on several measures of creativity and geometric design, English-Italian bilingual 6-year-olds performed significantly better than both monolinguals *and* English speakers with limited knowledge of Italian. Similarly, Bialystok and Majumder (1998) found that advantages on meta-linguistic tasks depended on the degree of bilingualism in a linear fashion, with children who were fully bilingual performing best after controlling for age and language proficiency. Thus, the pattern of findings suggests that bilingualism must be of a sufficiently high level to confer detectable advantages in cognitive tasks. Six months of second-language immersion for half the school day – as in our Immersion group – might not be enough exposure to produce this level. However, experience-dependent improvement on executive function measures has been found for other skills (e.g. experience with video games enhancing visual search; Castel, Pratt & Drummond, 2005) and in task-specific efforts to ‘train’ executive control skills in young children (e.g. Dowsett & Livesey, 2000; Kloo & Perner, 2003; Posner & Rothbart, 2005; Rueda, Rothbart, McCandliss, Saccomanno & Posner, 2005). Therefore, further research is warranted with longer tracking of language and executive function development in a larger sample of children with and without second-language immersion education to determine more definitively whether (and what kind of) immersion experiences can eventually produce the same relative benefits we observed for native bilinguals. It is also important to note, however, that our findings suggested no marked *disadvantage* of second-language immersion for children's cognitive functioning, as had been hypothesized by Macnamara (1967). Consistent with earlier research on immersion programs in schools examining a variety of cognitive outcomes, the Immersion group was equivalent to the traditional kindergarten Control group on executive functioning.

Cultural socialization of executive function skills

Lastly, unlike previous studies on this topic, we assessed parental attitudes about self-control in addition to children's executive function performance. The parents of Bilinguals (most of Hispanic origin) indicated that children's self-control is more important to them than did the other parents in our study. This suggests that the child-rearing culture might contribute to the development of self-control. Indeed, as noted earlier, cultural differences have been found between monolinguals of Chinese versus North American origin (Sabbagh *et al.*, 2006). This is a potentially interesting cultural difference in itself, but it is important to note we found that the bilingual advantage in executive function held up even after controlling for these cultural-attitudinal scores. This result strongly suggests that there are genuine cognitive differences in the ability to resolve conflicting attentional demands in bilingual versus monolingual speakers, which do not simply boil down to socio-cultural parental attitudes, but may be due specifically to the cognitive 'exercise' of thinking in two languages: holding in mind the relevant language and inhibiting activation of the nonrelevant language.

It is possible that unmeasured cultural factors influenced our results. In particular, we note that many bilingual children are also *bicultural*-facile, not only in switching between languages but also in switching between cultural contexts, such as strikingly different home and school environments, rules, customs, values, and expectations. Much more evidence is needed on socio-cultural factors related to executive function development before we will have a full accounting of the sources of the observed differences in executive functioning (Carlson, 2003). By further careful studies of development in bilingual children, we stand to deepen our understanding of the role of language, culture, and symbol systems in social and cognitive development more broadly.

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References

Albert, ML.; Obler, LK. The bilingual brain: Neuropsychological and neurolinguistic aspects of bilingualism. New York: Academic Press; 1978.

Ardila A, Roselli M, Matute E, Guajardo S. The influence of parents' educational level on the development of executive functions. Developmental Neuropsychology. 2005; 28:539–560. [PubMed: 15992255]

August, D.; Hakuta, K., editors. Improving schooling for language-minority children: A research agenda. Washington, DC: National Academy Press; 1997.

Baddeley, A. Working memory. New York: Oxford University Press; 1986.

Ben-Zeev S. The influence of bilingualism on cognitive strategy and cognitive development. Child Development. 1977; 48:1009–1018.

Bernhardt, EB. Reading development in a second language: Theoretical, empirical, and classroom perspectives. Norwood, NJ: Ablex; 1991.

Bialystok E. Factors in the growth of linguistic awareness. Child Development. 1986; 57:498–510.

Bialystok E. Levels of bilingualism and levels of linguistic awareness. Developmental Psychology. 1988; 24:560–567.

Bialystok, E., editor. Language processing in bilingual children. London: Cambridge University Press; 1991.

Bialystok E. Effects of bilingualism and biliteracy on children's emerging concepts of print. Developmental Psychology. 1997; 33:429–440. [PubMed: 9149922]

Bialystok E. Cognitive complexity and attentional control in the bilingual mind. Child Development. 1999; 70:636–644.

Bialystok, E. Bilingualism in development: Language, literacy, and cognition. New York: Cambridge University Press; 2001.

Bialystok E, Codd J. Cardinal limits: evidence from language awareness and bilingualism for developing concepts of number. Cognitive Development. 1997; 12:85–106.

Bialystok E, Craik FIM, Grady C, Chau W, Ishii R, Gunji A, Pantev C. Effect of bilingualism on cognitive control in the Simon task: evidence from MEG. NeuroImage. 2005; 24:40–49. [PubMed: 15588595]

Bialystok E, Craik FIM, Ryan J. Executive control in a modified anti-saccade task: effects of aging and bilingualism. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2006; 32:1341–1354.

Bialystok E, Luk G, Kwan E. Bilingualism, biliteracy, and learning to read: interactions among languages and writing systems. Scientific Studies of Reading. 2005; 9:43–61.

Bialystok E, Majumder S. The relationship between bilingualism and the development of cognitive processes in problem solving. Applied Psycholinguistics. 1998; 19:69–85.

Bialystok E, Martin MM. Attention and inhibition in bilingual children: evidence from the dimensional change card sort task. Developmental Science. 2004; 7:325–339. [PubMed: 15595373]

Bialystok E, Martin MM, Viswanathan M. Bilingualism across the lifespan: the rise and fall of inhibitory control. International Journal of Bilingualism. 2005; 9:103–119.

Bialystok E, Shapero D. Ambiguous benefits: the effect of bilingualism on reversing ambiguous figures. Developmental Science. 2005; 8:595–604. [PubMed: 16246250]

Bialystok E, Shenfield T, Codd J. Languages, scripts, and the environment: factors in developing concepts of print. Developmental Psychology. 2000; 36:66–76. [PubMed: 10645745]

Bloomfield, L. Language. New York: Holt; 1933.

Bowey, JA. Metalinguistic functioning in children. Geelong, Victoria: Deakin University Press; 1988.

Brownell, R. Expressive One-Word Picture Vocabulary Test – Spanish-English Bilingual Edition. Novato, CA: Academic Therapy Publications; 2001.

Bruck M, Genesee F. Phonological awareness in young second-language learners. Journal of Child Language. 1995; 22:307–324. [PubMed: 8550725]

Bunge S, Zelazo PD. A brain-based account of the development of rule use in childhood. Current Directions in Psychological Science. 2006; 15:118–121.

Campbell R, Sais E. Accelerated metalinguistic (phonological) awareness in bilingual children. British Journal of Developmental Psychology. 1995; 13:61–68.

Carlson SM. Executive function in context: development, measurement, theory, and experience. Monographs of the Society for Research in Child Development. 2003; 68(3, Serial No. 274):138–151. [PubMed: 14723274]

Carlson SM. Developmentally sensitive measures of executive function in preschool children. Developmental Neuropsychology. 2005; 28:595–616. [PubMed: 16144429]

Carlson SM, Mandell DJ, Williams L. Executive function and theory of mind: stability and prediction from age 2 to 3. Developmental Psychology. 2004; 40:1105–1122. [PubMed: 15535760]

Carlson SM, Moses LJ. Individual differences in inhibitory control and children's theory of mind. Child Development. 2001; 72:1032–1053. [PubMed: 11480933]

Carlson SM, Moses LJ, Breton C. How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. Infant and Child Development. 2002; 11:73–92.

Casey BJ, Tottenham N, Fossella J. Clinical, imaging, lesion, and genetic approaches toward a model of cognitive control. Developmental Psychobiology. 2002; 40:237–254. [PubMed: 11891636]

Castel AD, Pratt J, Drummond E. The effects of action video game experience on the time course of inhibition of return and the efficiency of visual search. Acta Psychologica. 2005; 119:217–230. [PubMed: 15877981]

Chee MWL. Dissociating language and word meaning in the bilingual brain. Trends in Cognitive Sciences. 2006; 10:527–529. [PubMed: 17049907]

Choi H, Won Y, Lee K. Comparison of selective attention between Chinese monolinguals and Korean-Chinese bilinguals. Bilingualism. 2003; 23:113–135.

Cummins J. Bilingualism and the development of metalinguistic awareness. Journal of Cross-Cultural Psychology. 1978; 9:131–149.

Deák GO. The development of cognitive flexibility and language abilities. Advances in Child Development and Behavior. 2003; 31:271–327. [PubMed: 14528664]

De Groot, AMB.; Kroll, JF. Tutorials in bilingualism. Mahwah, NJ: Erlbaum; 1997.

Deuchar M, Quay S. One vs. two systems in early bilingual syntax: two versions of the question. Bilingualism: Language and Cognition. 1998; 1:231–243.

Diamond, A. Normal development of prefrontal cortex from birth to young adulthood: cognitive functions, anatomy, and biochemistry. In: Stuss, D.; Knight, R., editors. Principles of frontal lobe function. New York: Oxford University Press; 2002. p. 466-503.

Diamond A, Carlson SM, Beck DM. Preschool children's performance in task switching on the Dimensional Change Card Sort task: separating the dimensions aids the ability to switch. Developmental Neuropsychology. 2005; 28:689–729. [PubMed: 16144433]

Diamond A, Kirkham NZ, Amso D. Conditions under which young children can hold two rules in mind and inhibit a prepotent response. Developmental Psychology. 2002; 38:352–362. [PubMed: 12005379]

Dowsett SM, Livesey DJ. The development of inhibitory control in preschool children: effects of 'executive skills' training. Developmental Psychobiology. 2000; 36:161–174. [PubMed: 10689286]

Durgunoglu, AY.; Verhoeven, L., editors. Literacy development in a multilingual context: Cross-cultural perspectives. Mahwah, NJ: Erlbaum; 1998.

Edwards D, Christopherson H. Bilingualism, literacy, and metalinguistic awareness in preschool children. British Journal of Developmental Psychology. 1988; 6:235–244.

Engle RW. Working memory capacity as executive attention. Current Directions in Psychological Science. 2002; 11:19–23.

Ervin S, Osgood C. Second language learning and bilingualism. Journal of Abnormal and Social Psychology Supplement. 1954; 49:139–146.

Feldman C, Shen M. Some language-related cognitive advantages of bilingual 5-year-olds. Journal of Genetic Psychology. 1971; 118:235–244.

Feng, X.; Diamond, A.; Bialystok, E. Development of executive functions in monolingual and bilingual children: Separating working memory and inhibitory control. Poster presented at the biennial meeting of the Cognitive Development Society; San Diego, CA. 2005 Oct.

Frye D, Zelazo PD, Palfai T. Theory of mind and rule-based reasoning. Cognitive Development. 1995; 10:483–527.

Galambos SJ, Goldin-Meadow S. The effects of learning two languages on levels of metalinguistic awareness. Cognition. 1990; 34:1–56. [PubMed: 2302940]

Gathercole VCM. The linguistic mass/count distinction as an indicator of referent categorization in monolingual and bilingual children. Child Development. 1997; 68:832–842.

Genesee F. Early bilingual development: one language or two? Journal of Child Language. 1989; 16:161–179. [PubMed: 2647777]

Goetz PJ. The effects of bilingualism on theory of mind development. Bilingualism: Language and Cognition. 2003; 6:1–15.

Gralinski JH, Kopp CB. Everyday rules for behavior: mothers' requests to young children. Developmental Psychology. 1993; 29:573–584.

Green DW. Mental control of the bilingual lexicosemantic system. Bilingualism: Language and Cognition. 1998; 1:67–81.

Grosjean F. Neurolinguists, beware! The bilingual is not two monolinguals in one person. Brain and Language. 1989; 36:3–15. [PubMed: 2465057]

Grosjean F. Studying bilinguals: methodological and conceptual issues. Mental control of the bilingual lexicosemantic system. Bilingualism: Language and Cognition. 1998; 1:131–149.

Guttentag RE, Haith MM, Goodman GS, Hauch J. Semantic processing of unattended words in bilinguals: a test of the input switch mechanism. Journal of Verbal Learning and Verbal Behavior. 1984; 23:178–188.

Hakes, D. The development of metalinguistic abilities in children. New York: Springer-Verlag; 1980.

Hakuta, K. Mirror of language: The debate on bilingualism. New York: Basic Books; 1986.

Hammill, DD.; Pearson, NA.; Wiederholt, JL. Comprehensive Test of Nonverbal Intelligence (C-TONI). Austin, TX: Pro-Ed; 1997.

Hoff E. How social contexts support and shape language development. Developmental Review. 2006; 26:55–88.

Hongwanishkul D, Happaney KR, Lee WSC, Zelazo PD. Assessment of hot and cool executive function in young children: age-related changes and individual differences. Developmental Neuropsychology. 2005; 28:617–644. [PubMed: 16144430]

Hughes C. Finding your marbles: does preschoolers' strategic behavior predict later understanding of mind? Developmental Psychology. 1998; 34:1326–1339. [PubMed: 9823515]

Hughes C, Dunn J, White A. Trick or treat? Uneven understanding of mind and emotion and executive function among 'hard to manage' preschoolers. Journal of Child Psychology and Psychiatry. 1998; 39:981–994. [PubMed: 9804031]

Hughes C, Ensor R. Executive function and theory of mind in 2-year-olds: a family affair? Developmental Neuropsychology. 2005; 28:645–668. [PubMed: 16144431]

Ianco-Worrall A. Bilingualism and cognitive development. Child Development. 1972; 43:1390–1400.

Kessler, C.; Quinn, ME. Positive effects of bilingualism on science problem-solving abilities. In: Alatis, JE., editor. Current issues in bilingual education: Proceedings of the Georgetown round table on languages and linguistics. Washington, DC: Georgetown University Press; 1980. p. 295-308.

Kim KHS, Relkin N, Lee K, Hirsch J. Distinct cortical areas associated with native and second languages. Nature. 1997; 388:171–174. [PubMed: 9217156]

Kirkham NZ, Cruess L, Diamond A. Helping children apply their knowledge to their behavior on a dimension-switching task. Developmental Science. 2003; 6:449–467.

Kloo D, Perner J. Training transfer between card sorting and false belief understanding: helping children apply conflicting descriptions. Child Development. 2003; 74:1823–1839. [PubMed: 14669898]

Kloo D, Perner J. Disentangling dimensions on the dimensional change card sorting task. Developmental Science. 2005; 8:44–56. [PubMed: 15647066]

Kochanska G, Murray KT, Harlan ET. Effortful control in early childhood: continuity and change, antecedents, and implications for social development. Developmental Psychology. 2000; 36:220–232. [PubMed: 10749079]

Kopp CB. Antecedents of self-regulation: a developmental perspective. Developmental Psychology. 1982; 18:199–214.

Korkman, M.; Kirk, U.; Kemp, S. NEPSY: A developmental neuropsychological assessment manual. San Antonio, TX: The Psychological Corporation; 1998.

Kuhl PK. Early language acquisition: cracking the speech code. Nature Reviews Neuroscience. 2004; 5:831–843.

Kuhl PK. Is speech learning ‘gated’ by the social brain? Developmental Science. 2007; 10:110–120. [PubMed: 17181708]

Luria, AR. Higher cortical functions in man. 2. New York: Basic Books; 1966. (Original work published in 1962)

Macnamara J. The bilingual’s linguistic performance: a psychological overview. Journal of Social Issues. 1967; 23:58–77.

Meisel, J., editor. Two first languages: Early grammatical development in bilingual children. Dordrecht: Foris; 1990.

Mezzacappa E. Alerting, orienting, and executive attention: developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. Child Development. 2004; 75:1373–1386. [PubMed: 15369520]

Miller EK, Cohen JD. An integrative theory of prefrontal cortex function. Annual Review of Neuroscience. 2001; 24:167–202.

Mischel W, Shoda Y, Rodriguez ML. Delay of gratification in children. Science. 1989; 244:933–938. [PubMed: 2658056]

Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wagner TD. The unity and diversity of executive functions and their contributions to complex ‘frontal lobe’ tasks: a latent variable analysis. Cognitive Psychology. 2000; 41:49–100. [PubMed: 10945922]

Munakata Y, Yerys BE. All together now: when dissociations between action and knowledge disappear. Psychological Science. 2001; 12:335–337. [PubMed: 11476102]

Neville, HJ. Neurobiology of cognitive and language processing: effects of early experience. In: Johnson, MH., editor. Brain development and cognition: A reader. Oxford: Blackwell; 1993. p. 424-448.

Nicoladis E. First clues to the existence of two input languages: pragmatic and lexical differentiation in a bilingual child. Bilingualism: Language and Cognition. 1998; 1:105–116.

Nicoladis E, Genesee F. Language development in preschool bilingual children. Journal of Speech-Language Pathology and Audiology. 1997; 21:258–270.

Noble KG, Norman MF, Farah MJ. Neurocognitive correlates of socioeconomic status in kindergarten children. Developmental Science. 2005; 8:74–87. [PubMed: 15647068]

Oller, DK.; Eilers, R., editors. Language and literacy in bilingual children. Clevedon, UK: Multilingual Matters; 2002.

Peal E, Lambert W. The relation of bilingualism to intelligence. Psychological Monographs. 1962; 76(Serial No 546):1–23.

Perner J, Lang B. Development of theory of mind and executive control. Trends in Cognitive Sciences. 1999; 3:337–344. [PubMed: 10461196]

Posner MI, Rothbart MK. Developing mechanisms of self-regulation. Development and Psychopathology. 2000; 12:427–441. [PubMed: 11014746]

Posner MI, Rothbart MK. Influencing brain networks: implications for education. Trends in Cognitive Sciences. 2005; 9:99–103. [PubMed: 15737817]

Rennie D, Bull R, Diamond A. Executive functioning in preschoolers: reducing the inhibitory demands of the dimensional change card sort task. Developmental Neuropsychology. 2004; 26:423–443. [PubMed: 15276903]

Ricciardelli LA. Bilingualism and cognitive development in relation to threshold theory. Journal of Psycholinguistic Research. 1992; 21:301–316. [PubMed: 1403995]

Riggs N, Blair C, Greenberg M. Concurrent and 2-year longitudinal relations between executive function and the behavior of 1st and 2nd grade children. Child Neuropsychology. 2003; 9:267–276. [PubMed: 14972705]

Roberts RJ Jr, Pennington BF. An interactive framework for examining prefrontal cognitive processes. Developmental Neuropsychology. 1996; 12:105–126.

Rothbart MK, Ahadi SA, Hershey KL, Fisher P. Investigations of temperament at three to seven years: the Children's Behavior Questionnaire. Child Development. 2001; 72:1394–1408. [PubMed: 11699677]

Rueda MR, Fan J, McCandliss BD, Halparin JD, Gruber DB, Pappert-Lercari L, Posner MI. Development of attentional networks in childhood. Neuropsychologia. 2004; 42:1029–1040. [PubMed: 15093142]

Rueda MR, Rothbart MK, McCandliss BD, Saccomanno L, Posner MI. Training, maturation, and genetic influences on the development of executive attention. Proceedings of the National Academy of Science. 2005; 102:14931–14936.

Sabbagh MA, Xu F, Carlson SM, Moses LJ, Lee K. The development of executive functioning and theory of mind: a comparison of Chinese and US preschoolers. Psychological Science. 2006; 17:74–81. [PubMed: 16371147]

Saxe, GB. Linking language with mathematics achievement: problems and prospects. In: Cocking, RR.; Mestre, JP., editors. Linguistic and cultural influences on learning mathematics. Hillsdale, NJ: Erlbaum; 1988. p. 47-62.

Sethi A, Mischel W, Aber JL, Shoda Y, Rodriguez ML. The role of strategic attention deployment in development of self-regulation: predicting preschoolers' delay of gratification from mother–toddler interactions. Developmental Psychology. 2000; 36:767–777. [PubMed: 11081700]

Smetana JG, Kochanska G, Chuang S. Mothers' conceptions of everyday rules for young toddlers: a longitudinal investigation. Merrill-Palmer Quarterly. 2000; 46:391–416.

Strommen EA. Verbal self-regulation in a children's game: impulsive errors on 'Simon Says'. Child Development. 1973; 44:849–853.

Stuss, DT.; Benson, DF. The frontal lobes. New York: Raven Press; 1986.

Towse JN, Redbond J, Houston-Price CMT, Cook S. Understanding the dimensional change card sort: perspectives from task success and failure. Cognitive Development. 2000; 15:347–365.

Umbel VM, Pearson BZ, Fernandez MC, Oller DK. Measuring bilingual children's receptive vocabularies. Child Development. 1992; 63:1012–1020. [PubMed: 1505238]

Vaid, J. Bilingualism. In: Ramachandran, VS., editor. Encyclopedia of the human brain, Vol. 1. San Diego, CA: Elsevier; 2002. p. 417-434.

Wright, JC. KRISP (Kansas Reflection-Impulsivity Scale for Preschoolers). Lawrence, KA: University of Kansas; 1972.

Zelazo PD, Carter A, Reznick JS, Frye D. Early development of executive function: a problem-solving framework. Review of General Psychology. 1997; 1:1–29.

Zelazo PD, Frye D, Rapus T. An age-related dissociation between knowing rules and using them. Cognitive Development. 1996; 11:37–63.

Zelazo PD, Jacques S, Burack J, Frye D. The relation between theory of mind and rule use: evidence from persons with autism-spectrum disorders. Infant and Child Development. 2002; 11:171–195.

Zelazo, PD.; Müller, U. Executive function in typical and atypical development. In: Goswami, U., editor. Handbook of childhood cognitive development. Oxford: Blackwell; 2002. p. 445-469.

Zelazo PD, Müller U, Frye D, Marcovitch S. The development of executive function in early childhood. Monographs of the Society for Research in Child Development. 2003; 68(3, Serial No. 274)

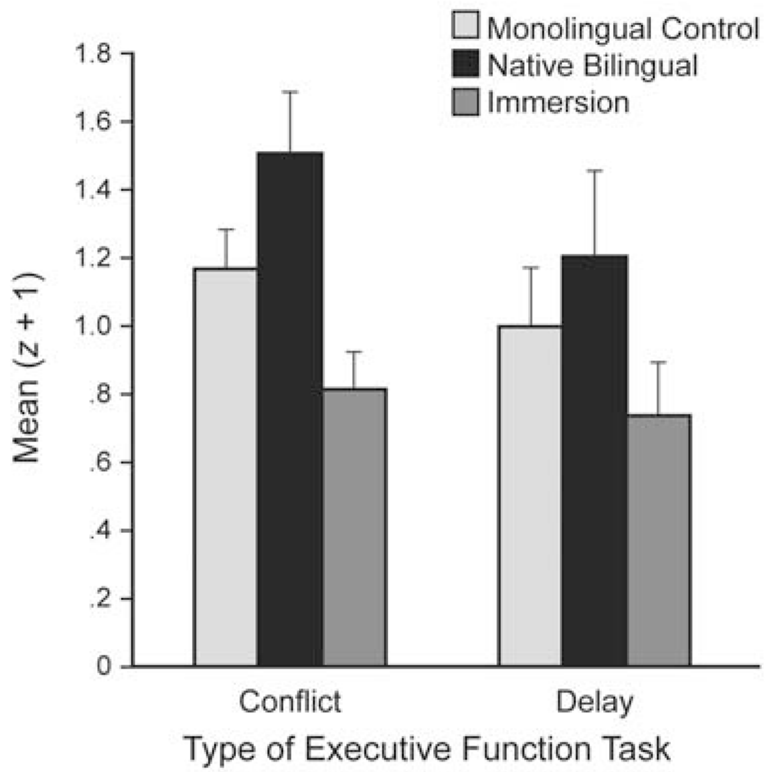

Figure 1.
Performance on conflict and delay measures of executive function according to language group. Scores shown are estimated means after adjusting for group differences in age, verbal ability, and parent education levels. Bars represent standard errors.

Table 1

Demographic characteristics and parent questionnaires

	Language group		
Variable	**Bilingual**	**Immersion**	**Control**
Age (months)			
Mean (*SD*)	72 (6.44)	70 (5.4)	75 (4.15)
Range	58–80	63–81	70–83
Sex	8m, 4f	10m, 11f	8m, 9f
Verbal Ability (EOW-PVT)			
Mean (*SD*)	100 (20.19)	136 (11.14)	135 (14.34)
Range	73–145	115–145	103–145
Mother Education (median)			
	High School	College	College
Father Education (median)			
	High School	College+	College
Annual Family Income (average)			
	$20–30,000	$70–80,000	$60–70,000
Hours/Week Child is Read To			
Mean (*SD*)	2.60 (1.17)	3.81 (.51)	3.87 (.50)
Rules Questionnaire (Sum)			
Mean (*SD*)	105.5 (28.36)	90.43 (22.21)	95.24 (13.68)
Range	79–134	63–146	48–118
Importance of Child's Self-Control to Parent (Sum)			
Mean (*SD*)	43.22 (4.71)	35.0 (8.56)	37.20 (5.48)
Range	36–45	27–50	7–42

Note: Bilingual $n = 12$; Immersion $n = 21$; Control $n = 17$.

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Table 2

Correlations among measures

Variable	Age	Sex	EOWPVT	M. Educ.	F. Educ.	C-TONI	KRISP	VCR	DCCS+	Simon S	ANT	DoG	Gift D	Statue
Age	–													
Sex	−.27†	–												
EOWPVT	.06	.14	–											
M. Educ.	−.04	.18	.63***	–										
F. Educ.	.00	.02	.53***	.56***	–									
C-TONI	.22	−.02	.50**	.26†	.29†	–								
KRISP	.30*	.03	.26†	.09	.24	.45**	–							
VCR	.37**	−.08	.08	.15	−.12	.24†	.04	–						
DCCS+	.26†	.11	.35*	.35*	.26†	.22	.10	.31*	–					
Simon S	.07	.20	.30*	.18	.16	.21	.10	.19	.00	–				
ANT	.20	−.10	.38**	.20	.20	.33*	.07	−.03	.18	.39*	–			
DoG	.08	.02	.29*	.16	.12	.10	−.01	.06	−.14	.11	.23	–		
Gift D	−.21	−.08	.26†	.23	.42**	.20	.21	−.09	.12	−.18	−.06	−.02	–	
Statue	.21	.01	.18	−.10	−.14	.01	.22	.15	.01	.12	.10	.18	.02	–

Note: $n = 50$. EOW-PVT = Expressive One-Word Picture Vocabulary Test. C-TONI = Comprehensive Test of Nonverbal Intelligence. KRISP+ = Kansas Reflection-Impulsivity Scale (advanced version). VCR = Visually Cued Recall. DCCS+ = Dimensional Change Card Sort (advanced version). ANT = Attention Network Task. DoG = Delay of Gratification.

$^{***}p < .001$;

$^{**}p < .01$;

$^{*}p < .05$;

$^{†}p < .10$.

Table 3

Descriptive statistics on each executive function task by language group (raw scores)

	Language group		
Task	**Bilingual (*n* = 12)**	**Immersion (n = 21)**	**Control (*n* = 17)**
Visually Cued Recall (final score)			
Mean (*SD*)	23.33 (10.13)	17.9 (7.16)	24.00 (9.82)
Range	5–38	7–32	6–40
C-TONI (total standard score)			
Mean (*SD*)	20.36 (4.88)	21.52 (3.31)	22.06 (4.74)
Range	14–32	13–28	10–28
KRISP (accuracy)			
Mean (*SD*)	39.25 (2.83)	39.1 (2.98)	39.41 (3.57)
Range	35–43	33–45	30–44
Dimensional Change Card Sort Advanced (post-switch incongruent trials correct)			
Mean (*SD*)	2.27 (.91)	2.69 (1.01)	2.41 (1.06)
Range	1–4	1–4	0–4
Simon Says (anti-imitation trial total correct)			
Mean (*SD*)	7.25 (5.06)	7.95 (4.71)	10.35 (2.89)
Range	0–13	0–15	4–15
Attention Network Task (incongruent flanker trial accuracy)			
Mean (*SD*)	.71 (.22)	.77 (.19)	.84 (.15)
Range	.36–1.0	.5–1.0	.45–1.0
Statue (total interval score)			
Mean (*SD*)	12.64 (2.87)	13.06 (2.41)	13.35 (2.03)
Range	7–16	9–17	8–15
Delay of Gratification (RT to first touch in seconds)			
Mean (*SD*)	354 (181.63)	383 (162.14)	437 (104.22)
Range	0–480	8–480	107–480
Gift Delay (touch score)			
Mean (*SD*)	3.27 (1.35)	3.65 (1.22)	3.53 (.87)
Range	1–5	2–5	2–5

Note: Bilingual *n* = 12; Immersion *n* = 21; Control *n* = 17.

Table 4

Performance on executive function measures by group, controlling for age, verbal ability, and parent education

Task/Variable	Language group: Bilingual	Immersion	Control	*F*	Effect size η^2
Composite test scores (*z*)					
EF Composite	.46 (.13)	−.19 (.08)	−.02 (.08)	7.23**	.28
Individual tasks					
Visually Cued Recall	30.91 (3.40)	17.25 (2.11)	21.67 (2.05)	4.69*	.20
Advanced DCCS	3.26 (.35)	2.52 (.22)	2.12 (.21)	3.49*	.16
C-TONI	25.38 (1.57)	20.34 (.98)	20.62 (.95)	3.34*	.15
Simon Says	9.29 (1.83)	6.94 (1.14)	10.31 (1.11)	2.25	.11
ANT	.83 (.07)	.72 (.04)	.82 (.04)	1.75	.08
KRISP	40.80 (1.20)	39.12 (.75)	38.29 (.72)	1.49	.07
Delay of Gratification	439.02 (65.4)	348.33 (40.6)	416.38 (39.5)	0.91	.05
Statue	12.95 (.97)	13.37 (.60)	12.87 (.59)	0.19	.01
Gift Delay	3.62 (.44)	3.42 (.27)	3.48 (.27)	0.06	.00

Note: Bilingual $n = 12$; Immersion $n = 21$; Control $n = 17$. Means are estimated after controlling for age in months, verbal ability (Expressive One-Word Picture Vocabulary Test scores), and parent education levels using ANCOVA.

** $p < .01$;

* $p < .05$;

† $p < .10$.

Table 5

Factor loadings (principal components analysis) for conflict and delay measures of executive function

Task	Factor 1 'Conflict'	Factor 2 'Delay'
C-TONI	.75	.27
ANT	.72	.14
Simon Says	.65	.25
KRISP	.60	.06
DCCS	.55	−.12
Visually Cued Recall	.48	.14
Delay of Gratification	−.06	.60
Statue	−.03	.40
Gift Delay	−.38	.39

Note: $n = 50$.