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Attentional Control in Early and Later Bilingual Children

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Abstract

This study examined differences in attentional control among school-age children who were monolingual English speakers, early childhood Spanish-English bilinguals who began speaking both languages by age 3, and later childhood Spanish-English bilingual children who began speaking English after age 3. Children's attentional control was tested using the Attention Network Test (ANT). All language groups performed equally on ANT networks; however, when controlling for age and verbal ability, groups differed significantly on reaction time. Early bilingual children responded faster on the ANT compared to both monolingual and later bilingual children, suggesting an attentional monitoring advantage for early bilinguals. These results add to mounting evidence of advantaged cognitive functioning among bilinguals, and are consistent with the possibility that children who begin speaking a second language earlier in childhood have larger advantages due either to differential effects of acquiring a second language earlier during development or due to longer duration of bilingual experience.

Keywords

bilingualism; cognitive control; attentional monitoring; age of acquisition; Attention Network Test

1. Introduction

A growing body of research suggests that bilingual individuals outperform monolinguals on a variety of cognitive measures (Bialystok, 1999; Bialystok, Craik, & Ryan, 2006; Carlson & Meltzoff, 2008; Costa, Hernandez, & Sebastian-Gallès, 2008). These advantages, which have been characterized as advantages in cognitive control, have been documented across the lifespan. Improved cognitive control among bilinguals has been observed in bilingual-exposed infants (Kovàcs & Mehler, 2009a, 2009b), toddlers (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011) bilingual preschool children (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Yoshida, Tran, Benitez, & Kuwabara, 2011), young adults (Costa, Hernàndez, Costa-Faidell, & Sebastiàn-Gallès, 2009; Costa et al., 2008; Prior & MacWhinney, 2010) and older adults (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004). Further, these cognitive control advantages of bilingualism have been demonstrated using multiple cognitive tasks and have been found among bilinguals speaking a variety of language pairs, suggesting that these effects are not

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limited to a single task or particular language pairing (see Adesope, Lavin, Thompson, & Ungerleider, 2010, for recent meta-analysis).

Although bilinguals have outperformed monolinguals in a variety of cognitive skills, two types of cognitive control skills have been consistently reported to be advantaged among bilinguals: *attentional inhibition* and *attentional monitoring*. Attentional inhibition is the ability to ignore distracting or conflicting information in order to focus attention on relevant information. Tasks that measure attentional inhibition often include distracting information that participants must ignore in order to respond successfully. For example, in classic flanker tasks the use of attentional inhibition is necessary on incongruent trials in which the target arrow is oriented in the opposite direction of flanker arrows (→→←→→). On such incongruent trials, successful responding requires participants to ignore the flankers to focus only on the target arrow. Attentional inhibition is not required on congruent trials in which all flankers are oriented in the same direction (→→→→→), as there is no conflicting information to ignore. Typically, responses to congruent trials are faster and more accurate than responses incongruent trials. The difference in reaction time or accuracy between congruent and incongruent trials provides an index of participants' attentional inhibition abilities, with smaller differences between congruent and incongruent trials representing more efficient attentional inhibition, or in other words, less cost of ignoring conflicting information.

Bilingual adults and children have been previously reported to show smaller differences between congruent and incongruent trials (i.e., more efficient attentional inhibition) in flanker tasks (Costa et al., 2008; Costa et al., 2009; Luk, De Sa, & Bialystok, 2011; Toa, Marzecova, Taft, Asanowicz, & Wodniecka, 2011; Yang & Lust, 2004; Yoshida et al., 2011), the Simon task (Bialystok et al., 2005; Bialystok et al., 2004; Bialystok, Martin, & Viswanathan, 2005), and antisaccade tasks (Bialystok, Craik, & Ryan, 2006; Bialystok & Viswanathan, 2009). Such bilingual advantages in attentional inhibition are frequently explained as resulting from the need for bilinguals to keep their two language systems separate. In order to maintain this separation, it is hypothesized that bilinguals must employ attentional inhibition in order to avoid accessing the non-target language and instead access the target language (Green, 1998). However, recent evidence from bilingual-exposed infants who demonstrate cognitive advantages (Kovacs & Mehler, 2009a) suggests that lexical access alone cannot account for these advantages, as pre-verbal demonstrate bilingual advantages over monolingual peers. The source of bilingual advantages in attentional inhibition thus remains under debate, but available evidence suggests that both production and exposure to two languages may underlie these cognitive advantages.

The second advantaged skill, attentional monitoring, refers to the ability to attend and respond to changing task demands. For example, in the previously described flanker task, congruent and incongruent trials are intermixed, resulting in the need for participants to switch back and forth between responding to incongruent trials that require attentional inhibition and responding to congruent trials requiring no attentional inhibition. Attentional monitoring is indexed by the overall reaction time to both congruent and incongruent trials, with a faster reaction time indicating better attentional monitoring (i.e., less cost of switching between responses).

As such, based on average reaction time, bilinguals have outperformed monolinguals on attentional monitoring measures including flanker tasks (Costa et al., 2008; Costa et al., 2009; Toa et al., 2011; Yang & Lust, 2004), the Simon task (Bialystok et al, 2005; Martin-Rhee & Bialystok, 2008; Bialystok, Martin, & Viswanathan, 2005; Bialystok et al., 2005), dual dimension classification tasks (Barac & Bialystok, 2012) and antisaccade tasks (Bialystok, Craik, & Ryan, 2006; Bialystok & Viswanathan, 2009). Although bilinguals respond faster to both congruent and incongruent trials when these tasks included mixed trial blocks, this reaction time advantage does not exist on trial blocks of a single trial type that do not require switching between responses, and therefore, do not tax attentional monitoring (Bialystok, 2006; Costa et al., 2009; Martin-Rhee & Bialystok, 2008). The source of bilinguals' advantage in attentional monitoring is proposed to be the need to monitor their linguistic environment in order to select the appropriate language to use with interlocutors (Costa et al., 2009), which occurs both when bilinguals must select one of their languages to use with monolinguals and when they are switching between languages (code-mixing) with other bilinguals.

1.2 Bilingual characteristics that affect attentional advantages

Although a growing research literature supports the presence of attentional advantages among bilinguals, less research has examined the characteristics of those bilingual individuals who demonstrate these advantages. The studies that have addressed this issue have focused on the level of second language (L2) proficiency and balance between first language (L1) and L2 proficiency as potential variables influencing bilingual cognitive control. Such studies have produced somewhat equivocal findings. For example, Bialystok (1988) found that “partially bilingual” children with low L2 proficiency outperformed monolinguals on tasks requiring controlled metalinguistic processing (e.g., sun/moon), suggesting that high L2 proficiency is not a prerequisite for cognitive advantages.

Conversely, Carlson and Meltzoff (2008) reported that the performance of children with six months of L2 immersion experience was equal to their monolingual peers' performance on a battery of attentional inhibition measures, whereas bilingual children outperformed children in both the monolingual and immersion groups. These results suggest that a certain level of L2 proficiency is necessary before cognitive advantages emerge. In addition to L2 proficiency, research has also tested the effect of relative balance between L1 and L2 proficiency on the bilingual advantage in cognitive function. Although few studies have compared bilinguals with varying levels of language balance, converging results suggest that greater balance between a bilingual's languages (i.e., similar proficiency levels in both languages) is associated with larger advantages in cognitive functioning compared to less balance (Bialystok, Craik, & Ruocco, 2006; Vega & Fernandez, 2011).

1.3 Age of second language acquisition

One issue that remains largely unaddressed in this literature is the potential effect of L2 age of acquisition (AoA) on cognitive functioning among bilinguals. Throughout this paper, we consider children who began speaking two languages between birth and three years to be *early childhood bilinguals*, whereas children who acquired a second language beyond the age of three are classified as *later childhood bilinguals* (Genesee, Paradis, & Crago, 2004; McLaughlin, 1984).

For the purpose of the current study, we are measuring AoA based on the age at which parents reported their children began speaking two languages. Although we rely on this specific classification system, it is important to note that alternative definitions for classifying children as early or later bilinguals exist. Some researchers refer to children who are exposed to two languages within the first year of life as simultaneous bilinguals, while referring to children who acquire a second language prior to school entry as early bilinguals (de Houwer 2005). However, because we are classifying children based on the age at which they began speaking an L2 instead of the age at which they were initially exposed to a second language, using the age-range employed by McLaughlin (1984) and Genesee et al. (2004) to define early bilingualism (i.e., speaking the language before age 3) was most appropriate in the current study.

Studies of bilingual cognitive advantages in childhood generally include only early childhood bilinguals who are growing up in a bilingual household. Evidence for a bilingual cognitive advantage comes largely from research including bilingual preschool children who are proficient in both their L1 and L2 at the time of testing (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Yoshida et al., 2011). In order to achieve the proficiency level in their L2 required for study participation by preschool age (i.e., three to five years), these children would presumably be categorized as early bilinguals based on McLaughlin's (1984) definition. Additional support for cognitive advantages of early bilingual language acquisition in childhood comes from studies finding advantages of pre-verbal infants who are exposed to two languages (Kovacs & Mehler, 2009a, 2009b) and bilingual toddlers (Poulin-Dubois et al., 2011). Less is known about the effects of later L2 acquisition on cognitive functioning in childhood.

The majority of research on adult bilinguals' cognitive control abilities has not specifically defined bilingual groups based on AoA; instead, the typical criterion for inclusion in adult bilingual groups is frequent use of two languages since adolescence or early adulthood (Bialystok, et al., 2007; Bialystok, Craik, & Ryan, 2006). Thus, in this literature, both early and later bilinguals would fit within the participation criterion, and have likely been pooled within adult bilingual samples. Two notable exceptions are Toa et al. (2011) and Luk et al. (2011), which to our knowledge are the only existing studies that have systematically compared bilingual groups that differ in AoA in order to establish whether any differences exist between the groups' cognitive control abilities.

Toa et al. (2011) compared performance on the Lateralized Attention Network Test (LANT; Greene et al., 2008), a computerized flanker task, among adult bilinguals who had acquired an L2 before age six (early bilinguals), adult bilinguals who acquired an L2 between 12 and 19 years of age (late bilinguals) and monolinguals. Based on their performance on the LANT, Toa et al. (2011) report that early bilingual participants responded significantly faster on all trial types (i.e., congruent and incongruent) compared to monolinguals, which the authors interpret as an attentional monitoring advantage. Late bilinguals did not respond significantly faster than monolinguals, suggesting that unlike early bilinguals, individuals who acquired an L2 after age 12 are not advantaged in attentional monitoring. Both early and late bilinguals had a smaller RT conflict network effect (i.e., less difference in RT to congruent versus incongruent trials) compared to monolinguals, supporting an advantage in attentional inhibition for both bilingual groups. Taken together, these results suggest that both early and late bilinguals have improved cognitive control compared to monolinguals, but only early bilinguals are advantaged in attentional monitoring. Toa et al. (2011) posit that advantages in attentional inhibition among late bilinguals may result from the need to avoid influence from their dominant L1 during L2 acquisition, whereas attentional monitoring advantages may be limited to early bilinguals who develop two languages simultaneously.

Similarly, Luk et al. (2011) divided young adult bilinguals into early versus late groups based on the age at which participants reported becoming actively bilingual (i.e., speaking two languages daily). The group of early bilinguals included participants who reported regularly using two languages before 10 years of age, whereas the late group comprised individuals who began actively using two languages after 10 years of age. Both bilingual groups were compared to a group of age-matched monolinguals on a flanker task containing both congruent and incongruent trials. Luk et al. (2011) report that early bilinguals demonstrated a significantly smaller difference between congruent and incongruent trials (i.e., better attentional inhibition) compared to both late bilinguals and monolinguals, suggesting an attentional inhibition advantage among the early bilingual group, whereas monolinguals and late bilinguals performed equally. Furthermore, Luk et al. (2011) reported a positive correlation between onset age of bilingualism and the flanker effect, such that individuals who began using two languages at younger ages demonstrated a smaller flanker effect (i.e., better inhibition) compared to individuals who began speaking a second language later.

Thus, in agreement with the findings of Toa et al. (2011), Luk et al. (2011) report larger advantages for bilinguals who began using an L2 at younger ages. However, whereas Toa et al. (2011) reported that earlier bilinguals had greater advantages in attentional monitoring, Luk et al. (2011) report that earlier bilinguals are advantaged in attentional inhibition. Unfortunately, because early and late bilinguals in both studies were the same age at the time of testing, neither study can isolate the effects of the maturational age at which individuals became bilingual versus differences in their duration of bilingual experience (i.e., early bilinguals have more bilingual experience at the time of testing than late bilinguals). Noting the confounding nature of these two variables, Luk et al (2011) concluded that in light of their correlational findings, it is likely that both age of acquisition and duration of bilingual experience contribute to the increased cognitive advantages among early bilinguals.

1.3 The present study

The goal of the current study was to assess the effect of L2 AoA on cognitive advantages associated with bilingualism in childhood by comparing attentional control abilities between bilingual children who differ on the age at which they began speaking an L2. The study included three groups of school-age children who differed in their language experience:

monolingual (MON) children who spoke only English, later childhood bilingual (L-BIL) children who were L1 speakers of Spanish and who began speaking English beyond three years of age, and Spanish-English early childhood bilinguals (E-BIL) who began speaking both languages by age three. Like Luk et al. (2011), we used the age at which participants began speaking two languages as the measure of AoA as opposed to relying on the age of first exposure to the L2. These three participant groups were compared on their performance on the Attention Network Test (ANT) modified for children (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Rueda et al., 2004). The ANT, is a computerized flanker task that includes varied cues before each flanker trial and measures three attentional networks: conflict (attentional inhibition), alerting, and orienting. The ANT has been used previously to compare attentional control between bilingual and monolingual adults (Costa et al., 2009; Costa et al., 2008; Toa et al., 2011) and children (Bialystok et al., 2010; Carlson & Meltzoff, 2008; Yang & Lust, 2004; Yoshida et al., 2011). This previous research has yielded evidence of bilingual advantages in the conflict network (Costa et al., 2008; Toa et al., 2011; Yang & Lust, 2004; Yoshida et al. 2011) , overall reaction time (Costa et al., 2009; Costa et al., 2008; Toa et al., 2011), and the alerting network (Costa et al., 2008).

We anticipated that we would find larger cognitive advantages among the E-BIL children (compared to the L-BIL group) due to their experience managing the production of two languages earlier during the development of the attentional system, which undergoes rapid growth during the infancy and preschool periods (for review, see Garon, Bryson, & Smith, 2008; Zelazo, Craik, & Booth, 2004). Also, E-BIL children may demonstrate larger attentional advantages because they have been controlling two language systems for a longer duration than their age-matched L-BIL peers have. These possibilities led to our hypothesis that early bilingual experiences would lead to the E-BIL group outperforming both the L-BIL and MON children on the ANT. We anticipated that the E-BIL group would have a faster overall RT (i.e., improved attentional monitoring) and a smaller conflict network score (i.e., improved attentional inhibition) compared to both L-BIL and MON children.

We also hypothesized that the L-BIL children would demonstrate the bilingual advantage in attentional control when compared to the MON children, as evidenced by faster overall RT and lower conflict network scores on the ANT. Because previous research using the ANT with bilingual participants has presented mixed findings regarding the orienting and alerting networks, we did not make specific hypotheses regarding group differences on these attentional networks.

2. Method

2.1 Participants

The study included 79 school-age children ranging in age from 5;8 to 14;11. Four additional children were tested, but one child was excluded from the final sample due to parent report of auditory processing disorder (MON), one child was excluded due to refusal to complete the ANT (MON), and two bilingual children (E-BIL) were excluded because of limited Spanish knowledge (i.e., committing six errors within the first eight items of the Spanish receptive vocabulary test). Based on parent report of the age at which children began speaking English and the child's estimated percentage of daily usage of English/Spanish, participants were classified as MON (*n* = 22; 10 female), E-BIL (*n* = 21; 12 female), or L-BIL (*n* = 36; 23 female). Table 1 provides descriptive participant information. According to parent report, children in the MON group spoke only English with all communication partners. Participants classified in the E-BIL group reportedly spoke both Spanish and English daily at the time of testing and began speaking both languages between one and three years of age. The L-BIL group comprised children whose parents reported that they spoke both Spanish and English daily at the time of testing and began speaking Spanish before the age of three and English after three years. At the time of testing, all participants were enrolled in monolingual English education programs and resided in a small community in northwest Georgia (U.S.).

2.2 Procedure

Each participant completed all the tasks in a single testing session. Session duration was approximately 60 minutes for MON children and approximately 90 minutes for L-BIL and E-BIL children due to the additional Spanish receptive vocabulary test that was only administered to bilingual children.

2.3 Measures

2.3.1 Child Language and Family Background Interview—Parents completed a child language questionnaire regarding their children's language usage and provided family demographic information (e.g., parent education, language spoken by parents, family income, race/ethnicity). Parent questionnaires were provided in English and Spanish, and parents completed the questionnaires in their preferred language. On the child language questionnaire, parents indicated the age at which their child began speaking English and/or Spanish, which languages the child could read and write, and the language(s) their child spoke with a list of common communication partners (e.g., mother, father, siblings, friends, teachers, etc.). Additionally, parents placed an ‘X’ on a line to provide an approximate indication of the percentage (between 0% and 100%) of time that their child spoke English and Spanish on a typical day, in order to confirm that bilingual children were speaking both Spanish and English daily. Parent responses to the questionnaire were used to categorize children into the appropriate language groups. An interview was conducted with each child participant regarding his/her daily language usage in order to verify parent report.

2.3.2 Forward Digit Span Task—Children listened to a series of digit lists of increasing length in English and were asked to repeat the list back to the experimenter in the same presentation order in whichever language (English or Spanish) they preferred. Testing continued with two digit lists of each length until the participant made errors on two consecutive lists of the same length. List length increased from two digits to a maximum of nine digits. One point was awarded for each list the child successfully repeated, and a score of zero was given for each incorrect list repetition. This measure was included in order to ensure that groups were equivalent on short-term memory performance.

2.3.3 Peabody Picture Vocabulary Test-III (PPVT-III)—Every participant completed the PPVT-III (Dunn & Dunn, 1997), a standardized test of English receptive vocabulary in which participants are presented with test plates of four pictures while a word is auditorily presented. Participants then select the picture that best corresponds with the word. Each child's basal score (highest set of twelve stimuli with one or no errors) was established and testing continued with increasingly difficult target words until the child reached ceiling criterion (lowest set of twelve stimuli with eight or more errors).

2.3.4 Test de Vocabulario en Imagenes Peabody (TVIP)—Bilingual participants also completed the TVIP (Dunn, Padilla, Lugo, & Dunn, 1986), which is a standardized test of Spanish receptive vocabulary. Test administration was identical to the PPVT-III (described above) with the exception of differing basal and ceiling criteria. A basal score was established when participants responded correctly to eight consecutive test items and ceiling criterion was reached when participants responded incorrectly to six of eight consecutive test items.

2.3.5 Attention Network Test (ANT)—All children completed the ANT adapted for children (Rueda et al., 2004). This version of the ANT is similar to the task used with adult participants (Fan et al., 2002), but stimulus arrows are replaced with fish that are either oriented toward the left or right in order to make the task more engaging for children. The task was administered via E-Prime software on a Dell Latitude laptop computer and required children to make a key press response to indicate the directional orientation of a central target fish. Participants were seated in front of the computer and each trial began with visual fixation on a center cross on the computer screen for a random duration between 400ms and 1600ms followed by a 150ms cue presentation. Cues were varied such that children either received: no cue before the target presentation (no cue condition); a central asterisk cue replaced the fixation cross (center cue condition); two asterisks were presented above and below the central fixation point (double cue condition); or a single asterisk appeared above or below the central fixation point indicating where the target would appear (spatial cue condition). Each cue type was presented twelve times per trial block for a total of 36 presentations of each cue type across the entire task.

Following the cue presentation and an additional 450ms of central fixation, the target fish appeared in isolation (neutral condition) or with flankers (congruent and incongruent conditions) 1^{o} above or below the central fixation cross, and remained on the screen until the child provided a key press response or 1700ms had elapsed (Rueda et al., 2004). Congruent, incongruent, and neutral flanker conditions were presented equally within each trial block, such that each trial block comprised 16 trials of each flanker type, and each flanker condition was presented 48 times over the course of the entire testing session. The equal distribution of flanker and cue conditions creates the optimal situation for observing both attentional monitoring effects (Costa et al., 2009) and conflict effects (Davidson, Amso, Anderson, & Diamond, 2006). Refer to Figure 1 for an illustration of task presentation order, cue types, and flankers. Children responded to the direction of the target fish using the left and right mouse buttons located on the laptop keyboard below the touchpad. Arrows corresponding to spatial position (e.g., left-pointing arrow on left button) were affixed to the mouse buttons. After each response, children received auditory feedback from the program to indicate if their response was correct (‘woohoo’) or incorrect (buzzer).

Children completed a practice session followed by three experimental sessions. During the practice session, the children heard an explanation of the task and received performance feedback from the experimenter (e.g., ‘Remember to only tell me which way the middle fish is pointing’). Children were instructed to respond to each trial as quickly as possible without sacrificing accuracy. Following the practice session, participants completed three experimental sessions (each 48 trials) with program feedback, but without experimenter feedback.

The ANT yields scores on three attentional constructs—alerting, orienting, and conflict—which are calculated through a series of comparisons of mean RTs to trials with various cue or flanker combinations (Fan et al., 2002; Macleod et al., 2010; Rueda et al., 2004). A recent analysis conducted by Macleod et al. (2010) assessing the psychometric properties of the ANT confirms the reliability of subscore measures.

4. Results

4.1 Preliminary Measures

A comparison of the mean age for the three language groups (L-BIL, E-BIL, MON) revealed that the mean age of the groups was not significantly different, $F(2, 76) = .73$, $p = .49$. An ANOVA comparison of standardized PPVT-III scores indicated that the three groups differed significantly in levels of English receptive vocabulary, $F(2, 76) = 10.34$, $p < .001$, $\eta^2 = .26$. Pairwise comparisons revealed that the MON group had significantly higher PPVT-III scores than the L-BIL ($p < .001$) and E-BIL groups ($p = .004$). The discrepancy in monolingual versus bilingual vocabulary is a common finding when standardized vocabulary tests are used to compare bilingual children's receptive vocabulary in a single language to the vocabulary of monolingual children (Bialystok, 2009; Bialystok, Luk, Peets, & Yang, 2010). However, it should be noted that these inequalities are not always present (Umbel, Pearson, Fernandez, & Oller, 1992), particularly when bilingual children's total conceptual vocabularies (i.e., total number of unique vocabulary items across both languages) are measured instead of relying on standardized vocabulary measures (Loyola, McBride, & Loyola, 1991; Pena, 2007). The PPVT-III scores of the L-BIL and E-BIL groups were not significantly different ($p = .24$), which suggests that the bilinguals groups had equivalent English receptive vocabularies. The L-BIL and E-BIL also had equivalent TVIP scores, $t(55) = 1.08$, $p = .29$, indicating that the two bilingual groups did not differ in receptive vocabulary knowledge in either of their two languages. The three groups did not significantly vary on forward digit span scores, $F(2, 75) = 1.25$, $p = .29$, suggesting that any group differences on ANT were not the result of short-term memory differences among the three groups.

We anticipated differences in length of bilingual experience because the groups differed significantly in their age of L2 acquisition, $t(55) = -12.50$, $p < .001$, $\eta^2 = .74$, but were the same age at the time of testing. Therefore, we expected that children with younger L2 AoAs would have a longer duration of L2 experience at the time of testing, which was confirmed in our analyses. The E-BIL children had a significantly longer period of bilingual experience (84.9 months) than the L-BIL children (59.1 months), $t(55) = 3.35$, $p = .001$, $\eta^2 = .17$. Because children in the two bilingual groups differ significantly in both the age at which they began speaking a second language and the duration of bilingualism at the time of testing, the effects of each of these variables on ANT performance cannot be isolated in the current study (see discussion for further consideration).

In order to assess group differences in SES, parent education level was compared among the three language groups. Because parents reported their education levels on a descriptive scale ranging from "no high school" to "master's degree or higher" this variable is not continuous. Due to the non-parametric nature of the measure, a Kruskal-Wallis test was used to compare parent education between language groups, and revealed significant group differences in parent education, $\chi^2(2, N = 76) = 43.07$, $p < .001$. Pairwise comparisons indicate that the group differences arise from significantly higher parent education among the MON group compared to both the L-BIL group, $\chi^2(1, N = 57) = 38.07$, $p < .001$, and E-BIL group, $\chi^2(1, N = 42) = 23.40$, $p < .001$. However, the bilingual groups were equal on the parent education measure, $\chi^2(1, N = 54) = 2.19$, $p = .14$. Thus, the overall pattern of SES reveals that monolingual children were advantaged as compared to both groups of bilingual children, who were from families of equal SES.

4.2 ANT Reaction time and accuracy

Previous comparisons of bilingual and monolingual children in the U.S. (Carlson & Meltzoff, 2008) have included verbal ability and SES as covariates in analyses due to the influence of these variables on cognitive control (Mezzacappa, 2004; Noble, Norman, & Farah, 2005). Due to the range of ages represented in the current sample, and the significant correlation between age and ANT performance ($r = -.55$, $p < .001$), age is covaried in the following analysis. Additionally, verbal ability as indexed by standardized PPVT-III scores is significantly different among the language groups and significantly correlated to reaction time performance on the ANT ($r = -.34$, $p =.002$), and therefore z-transformed PPVT-III scores are included as a covariate in the following analyses. Although SES has been previously reported to be related to attention measures, in the current sample SES and ANT performance were not significantly correlated, and therefore this variable is not controlled in the reported analyses. However, due to the significant group differences in SES, the analyses were also conducted with parent education included as a covariate, and the same pattern of results reported here was found.

Prior to conducting the following analyses, trials with RT faster than 250ms were removed, as these were considered anticipatory responses. This resulted in removal of approximately 0.3% of trials. Only correct response trials were included in RT analyses. Response time and accuracy rates on the ANT were compared among the three language groups in using ANCOVAs. The results of an ANCOVA comparing overall ANT RT (i.e., averaged across all flanker and cue conditions) among the three language groups indicate a significant main effect of language on RT, $F(2, 74) = 3.17$, $p = .048$, $\eta^2 = .08$, when controlling for age and PPVT-III, which supports our hypothesis that groups would differ in attentional monitoring. In order to further test our hypothesis that bilinguals would outperform monolinguals, and the E-BIL group would show the largest advantage, pairwise comparisons were conducted and revealed that the L-BIL group's RT was significantly faster than the MON group ($p = .02$) and marginally faster than the E-BIL group ($p = .08$). However, the MON and L-BIL groups were not significantly different on RT ($p = .39$). Although the language groups differed on RT, they were not significantly different in overall ANT accuracy, $F(2, 74) = .51$, $p = .43$. Thus, the E-BIL group does not display a time/accuracy tradeoff in their faster responding, which suggests that this group is responding most efficiently to the task. Unadjusted means for RT and accuracy for each ANT flanker and cue condition by group membership are presented in Table 2.

4.3 ANT attentional networks

4.3.1 Alerting—We conducted a repeated measures ANCOVA to compare the within-subject variable of RT (correct trials only) on no cue trials to RT on double cue trials and the between-subject variable of language group. This analysis was used to compare the alerting network among the three language groups while controlling for age and English receptive vocabulary. Across all three language groups, participants responded faster to double cue trials than no cue trials, $F(1, 74) = 18.62$, $p < .001$, $\eta^2 = .20$, supporting a significant effect of the alerting network in the expected direction (i.e., faster responding on cued trials). The interaction between alerting and language group was not significant, $F(2, 74) = .059$, $p = .943$, which indicates that all language groups demonstrated an equal alerting network effect.

4.3.2 Orienting—Reaction time on center cue trials was compared to RT on spatial cue trials (within-subject variable) in a repeated measures ANCOVA including language group as the between-subjects variable in order to measure the effect of the orienting network within each group. Again, these analyses controlled for effects of age and English receptive vocabulary. In all language groups, participants responded significantly faster to spatial cue trials than double trials, $F(1, 74) = 5.45$, $p = .02$, $\eta^2 = .07$. Thus, children in all language groups demonstrated a significant effect of the orienting network, but there was no significant interaction between orienting and language group, $F(2, 74) = 0.22$, $p = .80$, suggesting that orienting effects were equal for children across language groups.

4.3.3 Conflict—A third repeated measures ANCOVA was conducted in order to assess the conflict attentional network through a comparison of RT between incongruent and congruent flanker trials (within-subjects) among the three language groups (between-subjects) controlling for age and PPVT-III. Across language groups, participants responded significantly faster to congruent trials compared to incongruent trials, $F(1, 74) = 21.0$, $p < .001$, $\eta^2 = .22$, which is the expected effect of the conflict network. The crucial comparison for our hypothesis of bilingual advantages in attentional inhibition was a comparison between the conflict network effect among language groups, which revealed no significant interaction between the conflict network and language group, $F(2, 74) = .35$, $p = .71$, indicating equal attentional inhibition for all three language groups.

4.4 Early versus later bilingual comparisons

Because the E-BIL and L-BIL group were not significantly different on PPVT-III scores these groups were compared to one another in a series of ANCOVA analyses with only age included as a covariate. The results of these comparisons mirrored the previous analyses, which included all three language groups and covaried both age and PPVT-III scores. Specifically, a comparison of overall ANT RT revealed that the E-BIL group responded significantly faster to ANT trials than the L-BIL group, F (2, 54) = 5.80, p = .019, η^2 = .097, supporting a E-BIL advantage in attentional monitoring. Also in line with prior analyses, the E-BIL and L-BIL groups performed equivalently on ANT accuracy, F (2, 54) = .146, p = .704, and there were no significant interactions between language group and any of the ANT network scores (all *p*s > .05). Thus, these analyses comparing only the E-BIL and L-BIL groups' performance support the results from the three-group analyses that indicate an advantage in RT among the E-BIL children, but no group differences in ANT accuracy or network performance.

5. Discussion

The results of this study of attentional control among monolingual English-speaking children (MON), later Spanish-English bilingual children (L-BIL), and early Spanish-English bilingual children (E-BIL) provide additional evidence for attentional advantages among bilingual children and are consistent with the possibility that the age at which a child begins speaking a second language influences cognitive functioning. The cognitive advantage found among early bilingual children may stem either from a more pronounced influence of bilingualism on attention earlier in development or from their longer duration of bilingual experience at the time of testing. Although we hypothesized that children's age at the time they began speaking an L2 would affect both their attentional inhibition and attentional monitoring skills, the current results only support an advantage among earlier L2 speakers for attentional monitoring. Some salient aspects of the findings are discussed in turn below.

5.1 Attentional Monitoring

Comparisons between the three participant groups on ANT performance controlling for participant age and verbal ability revealed significant group differences in ANT response speed averaged across all trial types. These differences were driven by faster responding among E-BIL children compared to both the MON and L-BIL children, whereas the L-BIL and MON groups did not significantly differ on response speed. It is important to note that although E-BIL children were faster at responding to ANT trials compared to the MON and L-BIL groups, all three groups had equal accuracy rates, indicating that the E-BIL group did not suffer time/accuracy tradeoff in their faster responding.

Based on the outcomes of group RT comparisons, we interpret these findings to represent an attentional monitoring advantage in the E-BIL group over both the MON and L-BIL groups. Although the E-BIL group was significantly faster at responding than the MON group, the L-BIL group was equal in response speed to the MON children. Thus, only the E-BIL group demonstrated a bilingual advantage over monolinguals in attentional monitoring. This pattern of findings mirrors the results of Toa and colleagues' (2011) comparison of attentional monitoring between early and late adult bilinguals and monolinguals, which indicated that only early adult bilinguals were advantaged in attentional monitoring, and suggests that these previous findings with adults may also extend to child bilinguals.

We note that the faster RT among the E-BIL group may be attributed to a more general improvement in processing speed instead of a specific advantage in attentional monitoring.

However, without the possibility of comparing ANT RT with a separate measure of RT that does not make any attentional monitoring demands, we cannot differentiate between these two possibilities within our own data. Previous research comparing bilinguals and monolinguals' performance speed on versions of the same task that differ only on attentional monitoring demands (e.g., single versus mixed trial blocks) reveal bilingual advantages in high-monitoring tasks, but no differences in low-monitoring tasks (Bialystok, 2010; Bialystok, Craik, & Ryan, 2006; Bialystok & Viswanathan, 2009; Costa et al., 2009; Martin-Rhee & Bialystok, 2008). These findings suggest that bilinguals are faster on high-monitoring tasks and not simply faster responders overall. Although the current data cannot definitively rule out differences based on simple speed of processing, when considering these previous findings along with the complex attentional demands of the ANT, we believe that characterizing the ANT reaction time differences as evidence of superior attentional monitoring among the E-BIL group may best account for the current findings.

The present findings have both theoretical and practical implications for research in the area of cognitive advantages of bilingualism. Theoretically, these results suggest that the relationship between bilingualism and cognition may be moderated, to some extent, by the age at which individuals begin speaking a second language. Specifically, the relationship between AoA and attentional monitoring reported here supports the possibility that earlier L2 acquisition results in larger cognitive gains than later L2 acquisition, either as a result of differential effects of bilingual acquisition at younger maturational ages or due to the increased length of bilingual experience among younger learners as compared to later learners. Practically, these findings indicate that researchers should consider participants' AoA when testing the cognitive effects of bilingualism. Indeed, ignoring AoA could lead researchers to overstate the size of an effect of bilingualism on cognition (e.g., by testing primarily early childhood bilinguals) or understate this effect (e.g., by testing primarily later childhood bilinguals).

5.2 ANT networks

In this study, bilingual and monolingual children were not significantly different in their performance on the networks of the ANT when compared on both RT and accuracy. These findings run contrary to the body of evidence supporting a general bilingual advantage in attentional control and specific advantages on ANT network scores (Costa et al., 2009; Costa et al., 2008; Toa et al., 2011; Yang & Lust, 2004). Counter to our hypothesis, bilingual children showed no advantages over monolinguals in their attentional inhibition abilities, as indexed by the ANT conflict network. However, this pattern fits with the possibility proposed by Costa et al. (2009) that the bilingual advantage in attentional monitoring may be a more robust effect than advantages on ANT network scores. Costa et al. (2009) summarized the results of 25 studies comparing bilinguals and monolinguals on tasks that measure both attentional inhibition and attentional monitoring and found that 12 studies reported bilingual advantages in attentional monitoring (i.e., overall RT advantages), whereas only 6 studies reported significant attentional inhibition advantages (i.e., less cost of ignoring conflict). Furthermore, attentional inhibition advantages were only found in studies that also found attentional monitoring advantages, whereas six studies reported attentional monitoring advantages in the absence of attentional inhibition effects.

5.3 Limitations and Caveats

The current findings support an advantage in attentional monitoring for early bilingual children, and provide initial evidence that AoA effects previously reported in adult bilinguals (Luk et al., 2011; Toa et al., 2011) extend to children. However, differences between the two bilingual groups in the attentional monitoring advantage must be interpreted with caution because the E-BIL and L-BIL children differ both in *age* of second language acquisition and *duration* of bilingual experience at the time of testing. These variables are intertwined in the current study because children in the three language groups were the same age at the time of testing, but the E-BIL children acquired English approximately two years earlier than the L-BIL children did. Thus, the E-BIL children had two additional years of bilingual experience, and this difference in length of bilingual experience could be driving the observed attentional monitoring advantage, rather than AoA per se.

Despite the differences in length of experience, the E-BIL and L-BIL groups did not differ significantly on measures of English or Spanish receptive vocabulary, which provides some evidence against the possibility that differences in language proficiency account for the current results. However, without a more stringent test of English proficiency beyond a measure of receptive vocabulary, the possibility remains that differences in English proficiency between the L-BIL and E-BIL groups may have contributed to the group differences in ANT performance. Future comparisons of cognitive control between groups of bilingual individuals who differ only on either AoA or duration of bilingual experience will be necessary in order to disentangle the relationship between each of these variables and attentional control abilities among bilinguals. Additionally, although the current study has divided bilingual children based on the age of L2 production, future research considering differences in cognitive outcomes based on the age at which children were first exposed to a language is warranted as L2 language production and exposure may have differential effects on cognitive outcomes.

5.4 Conclusion

In conclusion, the present study compared ANT performance among monolingual, later bilingual, and early bilingual school-age children. Significant differences emerged in attentional monitoring, which is indexed by ANT response speed and provides a measure of one's ability to adjust response strategies in response to changing trial types. Specifically, when controlling for age and receptive vocabulary, early bilinguals significantly outperformed both monolinguals and later bilinguals on this measure. Therefore, these results suggest that the early bilingual children perform more efficiently on the ANT than monolingual and later bilingual children. The differences between the early and later bilingual groups provide evidence for a possible moderating role of AoA on attentional monitoring advantages in bilingual children.

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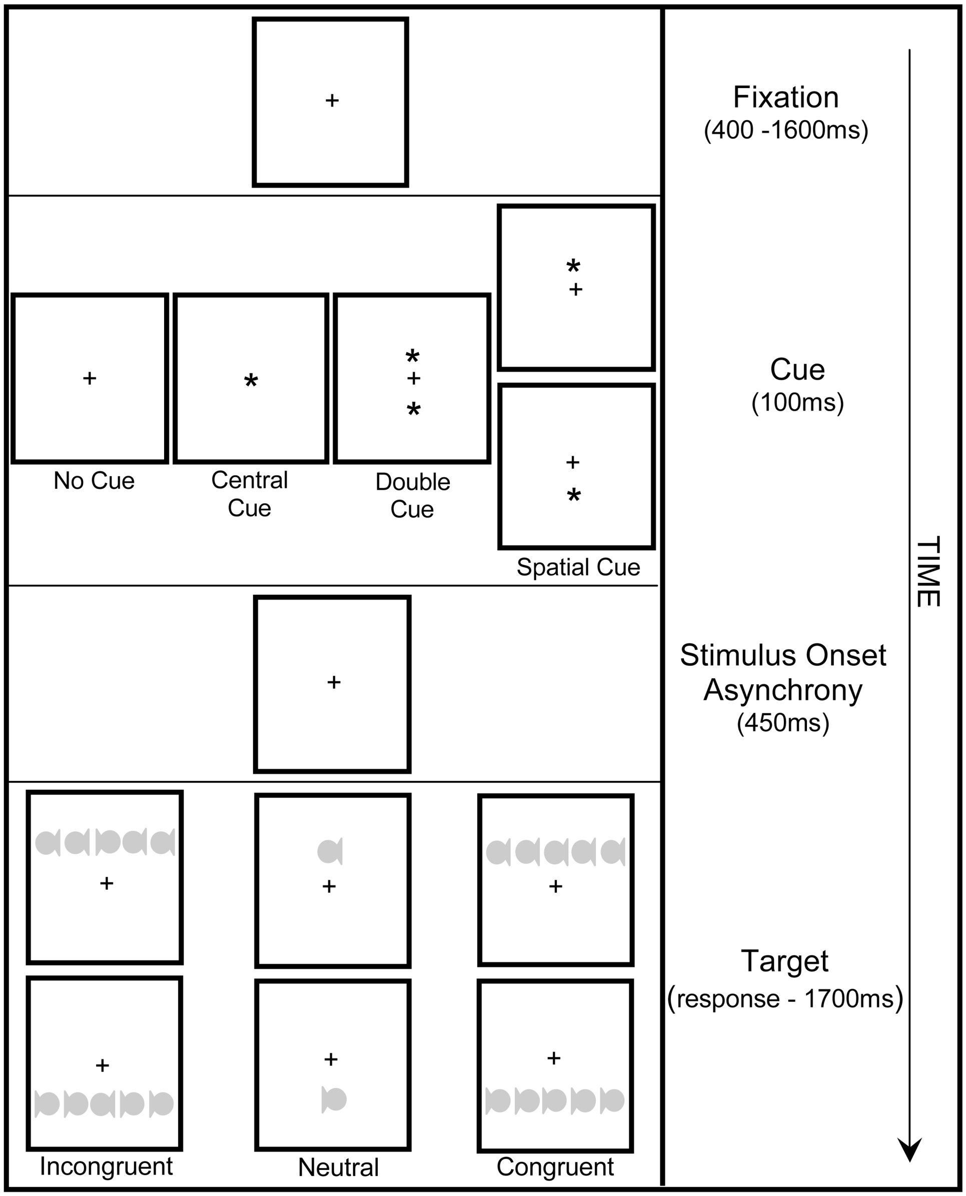

Figure 1.
ANT schematic. This figure illustrates the presentation order of an ANT trial and the possible cue and flanker conditions.

Table 1

Means and standard deviations for demographic and language measures

	MON (*n* = 22)	L-BIL (*n* = 36)	E-BIL (*n* = 21)
Age	117.7 (28.0)	118.6 (27.8)	109.6 (29.1)
Age of English Acquisition	—	*59.4 (10.0)	24.7 (10.3)
Raw PPVT-III	*128.1 (26.1)	103.4 (38.5)	103.7 (31.0)
Standardized PPVT-III	*104.2 (11.8)	85.3 (18.4)	90.3 (13.1)
Raw TVIP	—	70.0 (23.7)	60.3 (28.9)
Standardized TVIP	—	94.2 (20.6)	87.8 (23.6)
Parent education[a*]	*4.6 (1.2)	1.7 (0.68)	2.1 (1.0)
Digit span[b]	8.0 (1.7)	7.3 (1.8)	7.2 (1.9)

Note. Age at testing and English acquisition are reported in months; PPVT = Peabody Picture Vocabulary Test; TVIP = Test de Vocabulario en Imagenes Peabody.

[a] The statistic reported for parent education is the mean value.1 = no high school, 2 = some high school, 3 = high school degree/GED, 4 = some college, 5= technical degree/associate's degree, 6 = college degree, 7 = master's degree or higher

[b] Possible scores range from 0 to 18.

[*] $p < .05$

Table 2

Means and standard deviations of RTs (correct trials only) and proportion correct trials for each trial type on the ANT by Language Group

	RT			Accuracy		
Trial Type	**MON**	**L-BIL**	**E-BIL**	**MON**	**L-BIL**	**E-BIL**
Incongruent Flanker	940 (138)	940 (158)	896 (173)	.94 (.06)	.94 (.08)	.92 (.08)
Congruent Flanker	866 (124)	870 (143)	828 (173)	.96 (.06)	.95 (.07)	.95 (.07)
Neutral Flanker	838 (138)	831 (135)	779 (162)	.96 (.04)	.96 (.05)	.94 (.10)
No Cue	923 (141)	929 (152)	885 (170)	.95 (.05)	.94 (.08)	.93 (.10)
Double Cue	847 (116)	871 (145)	815 (166)	.95 (.04)	.97 (.05)	.95 (.05)
Central Cue	880 (125)	873 (138)	834 (170)	.95 (.05)	.96 (.07)	.94 (.06)
Spatial Cue	852 (122)	849 (146)	802 (177)	.96 (.06)	.95 (.06)	.93 (.12)