Executive Function in Simultaneous and Sequential Bilingual Children

By

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Abstract

This study compared two types of cognitive control, inhibition and attentional monitoring, among monolingual English-speaking children (MON), simultaneous Spanish-English bilingual children (SIM), and sequential Spanish-English bilingual children (SEQ). Existing research suggests that bilinguals outperform monolinguals in cognitive control; however no extant research has systematically compared these advantages between bilinguals who differ on age of L2 acquisition. Children's inhibition was assessed using WCST and ANT, and ANT RT indexed attentional monitoring. No differences were found between the three language groups on measures of inhibition, but group differences in monitoring emerged. Children in the SIM group outperformed MON children in monitoring, while the SEQ group's performance was statistically indistinguishable from both the SIM and MON groups. These results provide preliminary evidence that age of second language acquisition may affect the advantage of bilinguals over monolinguals on cognitive tasks.

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Introduction

Over the past two decades, researchers have reported that bilingual individuals demonstrate cognitive advantages as compared to monolingual peers on both linguistic (Bialystok, 1988, 1997, 1999; Diaz, 1985) and non-linguistic measures (Bialystok, 1999; Bialystok, Craik, & Ryan, 2006; Carlson & Meltzoff, 2008; Costa, Hernandez, & Sebastian-Gallès, 2008). This reported 'bilingual advantage' has been documented across the lifespan in preverbal infants (Kovàcs & Mehler, 2009a, 2009b), preschool-age children (Bialystok, 1999; Bialystok & Martin, 2004; Bialystok & Shapero, 2005; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok 2008;), younger adults (Bialystok, Craik, & Ryan, 2006; Costa, Hernàndez, Costa-Faidell, & Sebastiàn-Gallès, 2009; Costa, Hernandez, & Sebastian-Gallès, 2008) and older adults (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006; Bialystok, Craik, Klein, & Viswanathan, 2004), and has been established among bilinguals speaking a variety of language pairs. Furthermore, the advantage of bilinguals over monolinguals has been demonstrated using multiple cognitive measures including the dimensional card-sort task (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008), the Attentional Network Task (Costa, Hernandez, & Sebastian-Gallès, 2008; Yang & Lust, 2004), the Simon task (Bialystok, Craik, Klein, & Viswanathan, 2004; Martin-Rhee & Bialystok 2008;), and a modified visual antisaccade task (Bialystok, Craik, & Ryan, 2006).

Although several researchers have reported finding a bilingual advantage for non-linguistic cognitive tasks, the precise type of cognition/attention that is improved in bilinguals is unclear. The advantage has been reported on a multiplicity of tasks that each involve recruitment of different cognitive skills. The majority of existing research in the field defines the bilingual advantage in terms of improved "cognitive inhibition" (Bialystok, 2001; Bialystok, 1999;

Bialystok et al., 2004; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Costa, Hernandez, & Sebastian-Gallès, 2008; Martin-Rhee & Bialystok 2008), but evidence also suggests that the bilingual advantage may include an improvement in monitoring skills, which leads to faster response times on a variety of tasks (Bialystok et al., 2004; Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006; Bialystok & DePape, 2009; Carlson & Meltzoff, 2008; Costa, Hernandez, & Sebastian-Gallès, 2008; Martin-Rhee and Bialystok, 2008). A review of studies providing support for a bilingual inhibitory control advantage and/or a bilingual advantage for attentional monitoring follows along with a discussion of the hypothesized sources of the bilingual advantage(s).

Support for a Bilingual Advantage in Cognitive Inhibitory Control

Cognitive inhibition is generally described as one of the executive functions, which is a category of cognitive skills that are defined by Miyake et al. (2000) as "general purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition" (p. 50). Specifically, inhibitory control is often used to refer to the ability to deliberately inhibit a prepotent response or tendency, such as the ability to ignore a misleading cue that encourages a dominant – but incorrect – response, in order to produce a correct response. Within the bilingual cognitive literature, an advantage for bilingual children over their monolingual peers on inhibition tasks has been reported using several different tasks and diverse bilingual language pairings, which suggests that the advantage is neither task- nor language-specific.

In a seminal study providing evidence of a non-linguistic bilingual cognitive advantage, Bialystok (1999) found that Chinese-English bilingual preschool children outperformed age-matched English monolingual children on the Dimensional Change Card-Sort task (DCCS; Frye, Zelazo & Palfai, 1995; Zelazo, Frye & Rapus, 1996), and, in fact, performed comparably to monolingual English-speaking children who were one year older. The DCCS is a measure of inhibitory control that requires children to sort cards that vary on two features (e.g., color and shape) into stacks based on one relevant dimension (e.g., color) in the pre-switch phase and then re-sort the same deck of cards using the other dimension (e.g., shape) during a post-switch phase. The standard version of the DCCS used in Bialystok (1999) requires inhibition during the post-switch phase because children must avoid responding to the perceptual dimension that was correct in the pre-switch phase, and instead sort by a new perceptual feature while the first sorting dimension remains salient. Bialystok reported that the preschool bilinguals made significantly fewer post-switch errors than age-matched monolingual children, which represents improved ability to inhibit the pre-switch sorting dimension. The younger bilingual children also made comparable numbers of post-switch errors to the older monolingual children in the study. This provides evidence to suggest that bilingual children not only outperform age-matched monolingual children on the DCCS, but they may also develop inhibitory control skills earlier than monolinguals.

The findings of the earlier Bialystok (1999) study have recently been extended by Carlson and Meltzoff (2008), who reported that the performance of Spanish-English bilingual kindergarteners in the United States on a composite score of conflict inhibition based on performance on six tasks (Visually Cued Recall, DCCS, C-TONI, Simon Says, ANT, KRISP) did not significantly differ from that of their English monolingual peers, or of monolingual English children attending an immersion (Japanese or Spanish) kindergarten. Although these results may seem contradictory to Bialystok's, the absence of a group differences on these measures actually suggests improved inhibition in bilinguals because the bilingual children were from families with significantly lower socioeconomic status (SES) and had lower verbal ability than the monolingual and immersion groups. Both lower SES and poor verbal ability are factors related to reduced executive function abilities in children (McClelland et al., 2007; Nobel, Norman, & Farah, 2005), and thus, one would expect the bilinguals to have performed significantly worse on these executive function measures than the monolingual and immersion group children with higher SES and verbal skills. Finding that bilinguals and monolinguals performed equally on measures of cognitive inhibition despite their comparative disadvantage (lower SES and verbal ability) led Carlson and Meltzoff (2008) to conclude that bilingual language status may protect children's executive function performance from the potentially negative effects of environmental factors.

When the differences in verbal ability and parental education were statistically controlled, the Spanish-English bilingual children significantly outperformed both the monolingual and second language-immersion groups on the composite conflict inhibition score, revealing a bilingual advantage similar to that reported by Bialystok (1999). The pattern of results found by Carlson and Meltzoff (2008) has especially important implications for bilingual research conducted in the United States, where individuals who speak a language other than English in the home have lower average income and education levels than monolingual English speakers (US Census Bureau).

The reported bilingual advantage in inhibitory control is not limited to the preschool-age children tested in Bialystok (1999) and Carlson and Meltzoff (2008). A comparison of bilingual and monolingual children's performance on the Simon task by Martin-Rhee and Bialystok (2008) resulted in the conclusion that both bilingual preschool-age (4- to 5-year-olds) and school-age (8-year-olds) children performed more efficiently on the task than age-matched monolingual peers. The Simon task is a computer-based test in which participants press a key on the left or right side of the keyboard to respond to the color of a target presented on the left or right side of the screen (e.g., participants press the left key if the target is green and the right key if the target is red). Trials may be congruent – when the correct key and target are spatially aligned – or incongruent – when the response key and the target are in opposite spatial positions. Individuals are generally faster to correctly respond to congruent trials than incongruent trials, and the reaction time (RT) difference between these trial types is the Simon effect.

In addition to finding evidence of a general bilingual advantage in inhibition among school-age children, Martin-Rhee and Bialystok (2008) also found that children speaking different language pairs (Spanish-English, French-English, and Chinese-English) all outperformed monolinguals, and did not significantly differ from one another, on the Simon task. These findings suggest that the bilingual advantage is a generalizable effect, and is not attributable to a particular language pairing.

The faster RT in the bilingual groups on incongruent trials was taken to suggest superiority in ignoring misleading spatial information and better focus on the relevant cue (color). However, it is important to note the bilingual advantage only existed on those trials that were presented immediately after the previous trial without pause; the bilingual advantage was absent in trial blocks that included a pause between each trial presentation, which presumably alleviated some level of processing demand. This finding was taken to imply that the bilingual advantage is best revealed under conditions when processing demand is high.

While Martin-Rhee and Bialystok (2008) provide evidence to extend the age range of the reported bilingual advantage in inhibitory control among preschool children to older, school-age children, recent research has extended the age range in the opposite direction, suggesting that even infants may demonstrate non-linguistic advantages due to bilingual exposure. Specifically, comparisons of preverbal infants raised in bilingual environments to infants in monolingual linguistic environments suggest linguistic and non-linguistic advantages for the bilingual-exposed infants (Kovàcs & Mehler, 2009a, 2009b). Seven-month-old bilingual-exposed infants outperformed monolingual-exposed peers in a switching task (Kovàcs & Mehler, 2009a). In a pre-switch phase, infants learned a pairing between an auditory stimulus (a speech-like nonword) or visual stimulus (a series of three shapes) and the location of a visual reinforcement. In the post-switch phase, the cuing stimulus changed and the visual reinforcement appeared on the opposite side of the screen. The variable of interest was the number of anticipatory looks to the correct post-switch location. Kovàcs and Mehler (2009a) found that bilingual-exposed infants made significantly more anticipatory looks to the correct post-switch side than monolingual infants on both auditory and visual stimulus trials, suggesting that the bilinguals were advantaged in cognitive switching (which requires inhibition of the previous look direction in order to reliably produce the correct post-switch look).

Young adult bilinguals and middle-age adult bilinguals have also been reported to outperform monolinguals on tasks of inhibitory control (Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006; Bialystok, et al., 2004; Costa et al., 2008), suggesting that bilingual advantages are not restricted to childhood. Using the Attentional Network Test (ANT; Fan, McCandliss, Sommer, & Posner, 2002) Costa, Hernandez, and Sebastian-Gallès (2008) found evidence of a bilingual advantage among young adult participants. The ANT is a computerized flanker task that requires participants to respond to the direction of a central arrow that may be presented in isolation (→), with congruent arrows (→→→→→) or with incongruent arrows (→→←→→). In addition to the classic flanker task, the ANT includes various cuing conditions (no cue, double cue, spatial cue, central cue) that precede each trial presentation. Costa, Hernandez, and Sebastian-Gallès (2008) reported that Catalan-Spanish bilingual participants outperformed Spanish monolinguals on two of the three attentional networks measured in the task (alerting and conflict). Using the ANT, alerting is measured based on a comparison of RTs to trials with cues preceding the presentation of the target arrow (double cue condition) and RTs to trials with no cues. Conflict is measured by comparing RTs to congruent trials versus RT to incongruent trials.

The conflict score on the ANT is a measure of inhibitory control because participants must inhibit responding to the direction of the incongruent flanker arrows in order to respond correctly to the trial. Thus, the conflict score is an index of the time cost in milliseconds required for a participant to ignore the incongruent flanker as compared to the RT necessary to correctly respond in the absence of conflicting information (congruent trials). A lower conflict score represents less time needed to ignore the conflicting information in incongruent trials (i.e. better inhibition). Costa, Hernandez, and Sebastian-Gallès (2008) found that Spanish-Catalan bilinguals had significantly lower conflict scores than Spanish monolinguals, which suggests that the bilingual adults show an improved ability to ignore misleading information as compared to monolingual adults. However, the bilinguals' conflict scores were only significantly lower than monolinguals' on the first and second trial blocks. The researchers suggest that the absence of a bilingual advantage on the third trial block may be the result of a practice effect among the monolinguals that allowed them to improve to the level manifest by the bilinguals. Incidentally, this finding supports Miyake et al.'s (2000) claim that the purest measures of executive function are measured in early trials before the effects of practice are realized.

Additional evidence of a bilingual advantage in inhibitory control among bilingual adults was provided by Bialystok et al. (2004) by employing the same Simon task used to support an inhibitory control advantage among bilingual children in Martin-Rhee and Bialystok (2008). Bialystok et al. (2004) reported that bilingual adults exhibited a smaller Simon effect (cost of responding to incongruent trials) than adult monolinguals, converging with the pattern found among children (Martin-Rhee & Bialystok, 2008).

Research supporting a bilingual inhibitory control advantage in both children and adults has further been extended across the lifespan to include evidence of such a bilingual advantage in tasks of executive function in aging populations. Older adults who were bilingual (Tamil-English) were reported to outperform monolingual (English) older adults on the Simon task (Bialystok et al., 2004) with older bilingual participants showing a reduced Simon effect as compared to monolingual peers. Thus, the pattern of performance of bilingual older adults compared to monolingual older adults on the Simon task mirror those reported in comparisons of bilingual and monolingual children (Martin-Rhee & Bialystok, 2008) and middle-age adults (Bialystok et al., 2004), suggesting a consistent bilingual advantage on the Simon task across the lifespan. However, Bialystok et al. (2004) found that the magnitude of the differences between language groups on the Simon task was larger among the older adults than the middle-aged adults, which suggests that the pattern of bilingual advantage is maintained across adulthood, but the degree of the advantage may be amplified with age.

Additional evidence of the increased magnitude of bilingual advantage among older adult bilinguals compared to young adult bilinguals is provided by the results of Bialystok, Craik, and Ryan (2006). The researchers reported that bilingual older adults outperformed monolingual older adults on a modified antisaccade task incorporating key press responses. In this task, a face was presented on the screen, which cued participants to match their response to the location of a target via key press (prosaccade) or to respond in the opposite direction of the target (antisaccade). Further, the gaze direction of the eyes on the face cue created congruent conditions when the eyes were gazing in the same direction as the target presentation (e.g., left eye-gaze and target presented on left), whereas an incongruent condition resulted when the eye gaze was to the opposite side of the screen than the target. Bilingual older adults with varying language pairs outperformed monolinguals on both response suppression and inhibitory control, indexed by smaller difference between RTs to antisaccade versus prosaccade trials and congruent versus incongruent trials, respectively. As was reported with the Simon task in Bialystok et al. (2004), the same pattern of results found among older adult bilinguals on the antisaccade task was also reported for bilingual young adults, but the magnitude of the bilingual advantage was increased for the older adults. The larger difference between bilingual and monolingual older adults compared to younger adults on both the Simon task and antisaccade task may stem from the fact that cognitive control declines in older adulthood, thus bilingualism is protecting older adult bilinguals from this cognitive decline, leading to large group differences (Bialystok, Craik & Ryan, 2006)

The aforementioned research has provided evidence in support of a bilingual advantage in inhibitory control, but due to a variety of cognitive tasks used, the precise type of attention that is improved among bilinguals is not clear. In order to delineate the specific type of attention enhanced in bilinguals, Bialystok and Martin (2004) altered the sorting features of the DCCS and found that the bilingual advantage for card sorting in children is only consistently elicited by tasks that require conceptual inhibition. The researchers also discovered that the advantage does not extend to tasks that require only response inhibition (i.e., inhibition of the familiar motor response of placing a card type in the same stack) nor is it produced in tasks that require representational control (i.e., sorting tasks in which the dimensions are semantic categories such as vehicle or animal that require some level of representational interpretation). In the series of studies conducted by Bialystok and Martin (2004), bilingual preschool children in all three studies made fewer post-switch errors than monolingual preschool children on card-sort tasks based on conceptual features (color-shape, and color-object). The researchers concluded that the bilingual advantage was consistently displayed in the conceptual inhibition version of the task that required attentional control to inhibit misleading information (pre-switch sorting dimension) suggesting that the improved performance in bilinguals is the product of increased inhibitory control to ignore misleading information, not response inhibition or representational control (Bialystok & Martin, 2004, Martin-Rhee & Bialystok, 2008).

In an attempt to further isolate the type of attentional control that is affected by bilingualism, Carlson and Meltzoff (2008) included measures of both cognitive (described above) and behavioral (Delay of Gratification, Statue, Gift Delay) inhibition in their comparison of bilingual, monolingual, and second language immersion groups. No differences were found among the three groups on the measures of behavioral inhibition despite the fact that bilingual children outperformed monolingual and immersion groups in overall cognitive inhibition scores. Taken together, this suggests that the bilingual advantage is specific to cognitive tasks that require inhibition of perceptually salient, misleading cue information, and not simply inhibition of a familiar motor movement.

Support for a Bilingual Advantage in Attentional Monitoring

As previously discussed above, the existing literature on cognitive advantages of bilingualism primarily focuses on the bilingual advantage in inhibitory control, but this line of research also reports bilingual advantages on cognitive tasks that do not necessarily reflect inhibition. One of the most commonly reported bilingual advantages aside from inhibitory control is faster RT on all trial types (not only incongruent trials that require inhibition) in a task. In a recent publication, Costa et al. (2009) assert that improved overall RT speed may be, in fact, a more robust bilingual advantage than the commonly reported conflict advantage. Costa and his colleagues reported that systematic manipulation of the types of stimuli that lead to a bilingual RT advantage revealed that bilinguals respond faster than monolinguals when a task requires high monitoring skills. A comparison between bilinguals and monolinguals on modified versions of the ANT that included low-monitoring demand (due to the fact that the majority of trials were of the same type; i.e., either congruent or incongruent) failed to produce a bilingual advantage for response time. However, when bilinguals and monolinguals were compared on high-monitoring versions of the ANT (these included equal or approximately equal numbers of trial types mixed together), bilinguals' response times to all trial types were significantly faster than monolinguals' response times. That is, the advantage is found on tasks that have a variety of trial types that are mixed within the same trial block, which creates the need for participants to monitor trial types.

Within the Costa, Hernandez, and Sebastian-Gallès (2008) study comparing ANT performance between Spanish monolingual and Catalan-Spanish bilingual young adults, described above, researchers also reported that bilingual participants were significantly faster to respond to all ANT trials regardless of whether they included incongruent flankers. This overall faster response lends support to the claim that bilinguals have improved monitoring (Costa et al., 2009). The standard version of the ANT task employed by Costa, Hernandez, and Sebastian-Gallès (2008) includes precisely the type of trial mixing that requires high monitoring as approximately equal numbers of congruent flanker trials, incongruent flanker trials, and neutral trials are all mixed within each trial block.

The proposed attentional monitoring advantage for bilingual adults is further supported and extended to include bilingual children by studies employing the Simon task and a modified antisaccade task. Young bilingual children were reported by Martin-Rhee and Bialystok (2008) to have faster RT to both congruent and incongruent Simon task trials than monolingual peers. The same pattern was also reported for middle-age and older adult bilinguals' performance on the Simon task compared to that of monolinguals (Bialystok & DePape, 2009; Bialystok et al., 2004). Bialystok, Craik, and Ryan (2006) found that older adults who were bilingual were faster to respond to all trial types in a modified antisaccade task (described above). Additional support that this RT difference results from improved monitoring comes from the fact that bilingual advantages were magnified when trial blocks included both prosaccade and antisaccade trials mixed together as compared to trial blocks that included either prosaccade or antisaccade trials only (Bialystok, Craik, & Ryan, 2006).

While monitoring advantages are usually reported as RT differences, evidence of a monitoring advantage among young adult and older adult bilinguals that is unrelated to RT was presented in Bialystok, Craik, and Ruocco (2006). Bilinguals from both age groups (young adults and older adults) outperformed age-matched monolinguals on a dual modality classification task that required simultaneous classification of items presented visually and auditorily. A monitoring advantage was supported by bilinguals outperforming monolinguals in trials that require visual classification of one category (letters versus numbers) while auditorily classifying a different category (musical instrument versus animal sound). These unrelated trial types required participants to switch between categories in the auditory and visual domain, which necessitated additional attentional monitoring. Bilinguals reportedly showed less cost of responding (ratio between number of correct visual and correct auditory responses) to the unrelated trial types, which lent support to the hypothesized monitoring advantage among bilinguals (Bialystok, Craik, & Ruocco, 2006).

Hypothesized Source of Bilingual Advantage

While numerous studies provide evidence supporting bilinguals' advantages over monolinguals on a variety of non-linguistic cognitive tasks, the underlying source of this advantage is unclear. Generally, researchers point to the differences in the process of lexical access between bilinguals and monolinguals as the underlying cause of the cognitive advantage among bilinguals (Bialystok, 1999; Bialystok, 2008; Carlson & Meltzoff, 2008; Costa, Hernandez, and Sebastian-Gallès, 2008). Researchers agree that the process of bilingual lexical access differs from that for monolinguals, but there is controversy surrounding how bilinguals access lexical items in their two languages and avoid accessing/producing words in the non-target language within a given discourse situation. Researchers disagree on whether bilinguals exert language-specific control over their languages, characterized by an absence of cross-language competition during selection (Costa, Albareda, & Santesteban, 2008; Costa, Miozzo, & Caramazza, 1999; La Heij, 2005) or whether languages compete during selection in bilinguals, resulting in a language non-specific selection mechanism (Green, 1998). However, both language-specific and non-specific models of bilingual lexical access posit that an additional control mechanism must be in place to allow bilinguals to separate their two languages. The disagreement stems from whether the mechanism exerts control over an entire language (language-specific) to preclude cross-language competition or if non-target access is prevented at the word level (language non-specific) where words from both languages are competing for access.

Claims for language-specific models of control are supported by evidence against cross-language competition during lexical selection. Costa, Miozzo, and Caramazza (1999) report that bilinguals' languages do not compete for access using a picture-word interference paradigm. In this paradigm, participants are required to name a picture in one language while the translation equivalent in their other language is printed on the picture. Here, the bilingual must produce a word from one language while the printed translation equivalent, which is semantically identical to the target, is presumably activating the word in the non-target language and creating cross-language competition. Bilingual participants were not slower to name the picture in the target language in trials including the printed non-target translation equivalent versus trials including an unrelated printed word from the non-target language, suggesting that competition for activation does not exist between the bilingual's two languages (Costa et al., 1999).

Conversely, a language non-specific mechanism is supported by evidence of cross-language competition from production time tasks that require bilinguals to switch between their two languages (Meuter & Allport, 1999). Here, bilinguals read numerals presented on a screen in one of their two languages based on the background screen color (e.g. yellow screen cues Spanish response and blue screen cues English response). Meuter and Allport (1999) found that bilinguals had different response latencies when switching between their dominant (L1) and nondominant (L2) languages. Specifically, naming latencies were shorter when the participants switched from their dominant language to their nondominant language than in the opposite direction from nondominant to dominant. Meuter and Allport interpret the longer latencies in the L2 to L1 switch direction as an indication that the dominant L1 is inhibited during L2 production to resolve cross-language lexical competition (i.e. to avoid producing L1 words). Although models of bilingual access differ in the posited level of lexical control, both models can be interpreted as leading to a bilingual advantage as the additional practice with a lexical access control mechanism (either language-specific or language non-specific) experienced by bilinguals is believed to improve non-linguistic cognitive control processes.

Interestingly, bilingual cognitive advantages can be attenuated or even disappear when bilinguals are compared to monolinguals who have additional non-linguistic practice in tasks requiring increased cognitive control including individuals who regularly play video games (Bialystok, 2006) and music experts (Bialystok & DePape, 2009). A comparison of bilingual and monolingual university students with and without extensive practice playing computer video games on the Simon task (described above) revealed that video game experience led to faster RTs on all trial types (both congruent and incongruent trials with square or arrow stimuli) in both high and low switching conditions; recall that this is the form of advantage regularly reported for bilinguals over monolinguals (Bialystok, 2006). However, it is important to note that bilinguals maintained an advantage over video game players in the task that required the highest levels of inhibitory control (i.e., incongruent arrow stimuli in the high switching condition).

Bialystok and DePape (2009) compared the performance of bilinguals, monolinguals, and monolingual music experts (instrumentalists or vocalists) on the Simon task. The Simon task used had three variations. In the control task, participants responded to the direction (left or right) of a central arrow. None of the groups performed differently on this control task. The opposite condition of the Simon task required participants to provide a directional response that was opposite of that represented by a central arrow. The conflict condition required participants to indicate the direction of an arrow that appeared on either side of the screen, which created congruent and incongruent arrow direction and location conditions. Both the bilinguals and music experts had faster RTs than nonmusician monolinguals on the opposite and conflict versions (both congruent and incongruent trials) of the Simon task. The monolingual musicians and bilinguals did not perform significantly differently on any version of the Simon task, implying the presence of a general executive control advantage on visual tasks for musicians that is comparable to that of bilinguals.

Impact of Differences among Bilinguals on Bilingual Advantages

One of the fundamental problems facing bilingual researchers is defining who is bilingual. Although it seems fairly straightforward that bilinguals are individuals who speak two languages, it is not clear how proficient an individual must be in each language to be considered bilingual. This logically raises the question regarding how proficient a bilingual must be in his or her languages in order to display linguistic and/or non-linguistic advantages over monolinguals. Bialystok (1988) addressed this question and reported that children who were unbalanced bilinguals (i.e. significant strength in one language as compared to the other) produced a bilingual advantage on non-linguistic cognitive tasks, but not on metalinguistic tasks. However, these unbalanced children were native English-speaking children who had been exposed to a second language (French) in an immersion education setting for at least two years at the time of testing, which leaves the question of the minimum L2 exposure necessary to create bilingual advantages unanswered.

Carlson and Meltzoff (2008) expanded the literature with their inclusion of a group of children who were being educated in second-language immersion kindergarten. Inclusion of an immersion group as a comparison to both true monolinguals and fully bilingual children contributes to the yet unanswered question regarding the role of language proficiency in the bilingual advantage in executive control. Based on the results reported by Carlson and Meltzoff (2008), native English-speaking children in the immersion language group who had been exposed to a second language (Japanese or Spanish) in an educational setting for approximately six months performed indistinguishably from the true English monolingual group on the cognitive attentional control tasks. Taken together, the results of Bialystok (1988) and Carlson and Meltzoff (2008) suggest that young unbalanced bilinguals who are exposed to a second language through immersion education are capable of experiencing the bilingual advantage on non-linguistic cognitive tasks, but these advantages emerge at some point beyond six months of L2 exposure.

A comparison of monolingual, unbalanced bilingual, and balanced bilingual adults leads to similar conclusions as those described above for children. On a dual-modality classification task, bilingual adults significantly outperformed monolinguals in tasks requiring visual classification of letter versus number while simultaneously performing a related auditory classification task (letter versus number) and an unrelated auditory classification task (musical instrument versus animal), providing support of a bilingual advantage in controlling attention between the two modalities (Bialystok, Craik, & Ruocco, 2006). The unbalanced adult bilinguals' level of performance fell between that of the balanced bilinguals and the monolinguals, although the difference between this group and the other two groups was not statistically significant. These results support the hypothesis that the cognitive advantages of bilingualism are affected by language proficiency; balanced bilinguals outperformed unbalanced bilinguals, but even unbalanced bilingualism provides some cognitive advantages over monolinguals.

Proficiency, however, is not the only variable that characterizes differences between bilinguals. Another dimension that can be considered when categorizing bilinguals is the age at which a bilingual individual has acquired his/her two languages. In the case of simultaneous bilingualism, an individual is systematically exposed to two languages from birth, or at a very early stage in development. Genesee, Paradis, and Crago (2004), suggest that children who become bilingual before they are approximately three years of age can be considered simultaneous bilinguals. Conceptually, simultaneous bilinguals do not have a first language (L1) and a second language (L2) because both languages are acquired in tandem; instead, simultaneous bilinguals have two L1s. Conversely, sequential bilingualism arises when an individual first acquires an L1 and then adds an L2 later in development. Based on the rough guideline established by Genesee et al. (2004), individuals who are exposed to a second language after three years of age would be considered a sequential bilingual, because by this point in development, the L1 is fairly intact.

Role of Age of L2 Acquisition in Bilingual Advantages

Although it has been fairly well-established that bilingual individuals are advantaged in non-linguistic cognitive functions and comparisons between bilinguals have determined the level of L2 proficiency necessary for eliciting the advantage, a question that remains unanswered is whether the age of second language acquisition influences the cognitive effects of bilingualism. Generally speaking, studies of bilingual cognition involving young children include only simultaneous bilinguals (i.e. those who acquired two languages from infancy; Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008). The majority of evidence for a bilingual cognitive advantage stems from the study of preschool children who are proficient bilinguals. If children are fully bilingual by preschool age (3- to 5-year-olds), then it follows that these children were simultaneous bilinguals. Adult research on bilingual executive function has not specifically defined bilingual groups based on age of acquisition, but has instead only aimed to ensure that bilinguals were equally proficient in their two languages. Typically, the criterion for inclusion in adult bilingual groups is daily use of a second language since adolescence or early adulthood (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, & Ryan, 2006). Thus, both simultaneous bilinguals and sequential bilinguals are presumably pooled in this research. To our knowledge, no research has systematically compared two bilingual groups that differ only on age of acquisition to establish whether any differences exist between the groups' executive function performance.

Such a comparison between simultaneous bilinguals and sequential bilinguals may reveal that both types of bilingualism provide an inhibitory control advantage over monolinguals, but may also reveal that one type of bilingualism leads to greater levels of cognitive advantage than the other. If this were the case, we would expect to find bilinguals from both simultaneous and sequential groups outperforming monolinguals on executive function measures, but also one of the bilingual groups outperforming the other. Conversely, it may be the case that sequential and simultaneous bilingualism provide equivalent advantages in cognitive control, which would be evidenced by both bilingual groups outperforming monolinguals on a measure of executive function, but with simultaneous and sequential bilinguals performing indistinguishably from one another. Understanding the conditions of bilingualism that lead to the bilingual advantage in executive function is important because it will aid in further explaining the proposed bases for this advantage, which are currently under debate (Costa, Alberada, & Santesteban, 2008; Green, 1998; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007). That is, if it is discovered that differences in age of acquisition lead to differential impact on cognitive function, this can contribute to explanations of how the proposed linguistic control mechanisms employed in bilingual lexical access develop and influence general cognitive processes.

The current study is a comparison of three groups of school-age children that differ in their language backgrounds. A group of monolingual children who have only been exposed to English is compared to two groups of bilingual children. The sequential bilinguals are children whose first language is Spanish and are reported by their parents to have first spoken English after three years of age, and the simultaneous bilingual group includes children who are reported by parents to have spoken both Spanish and English by three years of age. These three groups of children were compared on two tests of cognitive control, the Wisconsin Card Sorting Test (WCST; Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss,1993) and the Attention Network Test (ANT) modified for children (Fan, McCandliss, Sommer, Raz & Posner, 2002; Rueda et al., 2004) to explore whether the bilingual advantage could be replicated in this population, as well as to provide a novel comparison of cognitive function between bilingual children who differ on age of second language acquisition.

Specific Predictions and Hypotheses for the Current Study

Based on conclusions from existing research comparing monolingual and bilingual children on cognitive control tasks (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008) and adult research comparing bilingual and monolingual performance on the ANT (Costa, Hernandez, & Sebastian-Gallès, 2008), the following results are expected in the present study based on the ANT scores. A main effect of flanker type is anticipated due to faster RT to congruent flanker trials versus incongruent flanker trials (conflict effect). Additionally, a significant language group by flanker type interaction is expected with the simultaneous bilingual group outperforming (i.e. smaller conflict effects) the monolingual group on the conflict sub score of the ANT. Performance of the sequential bilingual group is less clear because this language category is rarely studied in children; however, it is hypothesized that the simultaneous bilinguals will outperform both other language groups on the ANT conflict score, while the sequential bilinguals will outperform the monolingual group on in terms of the conflict score. Although Costa, Hernandez, and Sebastian-Gallès (2008) report additional bilingual advantages for overall RT, the alerting effect, and switching effect on the ANT, no specific hypotheses are made regarding performance on these measures.

The hypothesized results on the WSCT are somewhat less straightforward than those of the ANT because this task has not been previously used to compare bilingual and monolingual cognitive function. However, overall improved performance represented by a higher percentage of correct responses is anticipated in the bilingual groups as compared to the monolingual group. Based on the assumption that the bilingual advantage is due to improved cognitive control, it is anticipated that the bilingual groups will have lower percentages of perseverative errors (i.e. errors resulting from lack of inhibition) than the monolingual group. Because this task is more exploratory in bilingual research than the ANT, no specific predictions are made in comparing the two bilingual groups to one another on the WCST.

Method

Participants

The study included 83 school-age children ranging in age from 5;8 to 14;11. All children were recruited through word-of-mouth in a working-class, rural area in Northwest Georgia. Participants were divided into three language groups based on parent report of language use: 23 English monolinguals (MON, mean age = 116.4 months, SD=28.13), 21 simultaneous Spanish-English bilinguals (SIM, mean age = 111.95 months, SD=29.10), and 36 sequential Spanish-English bilingual (SEQ, mean age = 117.5 months, SD=27.82). An additional monolingual child was tested but removed from the final sample due to parent report of auditory processing disorder. Two additional simultaneous Spanish-English bilingual children were tested but excluded from analyses due to scoring below standardized limits on the TVIP. According to parent reports, children in the MON group spoke English daily with all communication partners. Participants included in the SIM group were reported to speak both Spanish and English daily and reportedly began speaking both languages before 4 years of age. The SEQ group was composed of children whose parents reported that they spoke both Spanish and English daily and began speaking Spanish before the age of 4 and began speaking English when they were 4 years of age or older. At the time of testing, all participants were enrolled in monolingual English education programs.

Tasks and Procedures

Each child was tested in his or her home, or in a quiet area in a public location (e.g. church, public library, etc.), depending on parent preference. Each participant completed all the tasks in a single testing session. Sessions lasted approximately 60 minutes for MON children and approximately 90 minutes for SEQ and SIM children, due to the additional language testing necessary for these groups. After parental consent and participant assent were obtained, participants completed the following tasks in the order listed below.

Child Language and Family Background Interview

Parents completed a child language questionnaire (see Appendix), which was used to establish daily language use and age of acquisition for children's language(s) to categorize children as monolingual, sequential bilingual, or simultaneous bilingual. Also, parents answered a short list of demographic questions used to record the languages spoken by parents, the number of siblings of a participant, and the socioeconomic status of the family.

The experimenter asked each child the appropriate questions on the child language interview. Each child was asked to report the languages that he/she could speak, read, and write. Additionally, children identified which language they used most with a list of various communication partners (e.g. parents, teachers, friend, etc.) and any additional language(s) used with these partners. Finally, children who reported speaking/reading/writing multiple languages were asked about language preferences in each of these modalities. This interview was used to supplement the language usage patterns reported by parents in the child language questionnaire to verify parent report that bilingual children used both languages daily.

Forward Digit Span Task

For the digit-span task, children were read series of digit lists of increasing length and asked to repeat the digit list back to the experimenter in the same presentation order. Participants were tested on two digit lists of each length until they made errors on two consecutive lists of the same length. One point was awarded for each list that was successfully repeated, and a score of zero was given for each list that was incorrect. Points from all lists attempted were summed for the final score (possible scores range from zero to sixteen points).

Peabody Picture Vocabulary Test-III (PPVT-III)

Every study participant completed the PPVT-III (Dunn & Dunn, 1997), a standardized test of English receptive vocabulary. On the PPVT-III, participants were shown a test plate composed of four different pictures while a digital audio recording of a target word was presented auditorily via headphones. Children indicated the picture on the test plate that they thought was the best representation of the target word. A basal score was established (set of 12 test items with one or no errors) and testing continued with increasingly difficult target words until the child reached ceiling criterion (8 or more errors in a set of 12 test items). Children's raw scores were converted to age- normed standard scores using PPVT-III standardized tables.

Attention Network Test (ANT)

All children completed the ANT adapted for children (Rueda et al., 2004). The task was administered via E-Prime software on a Dell Latitude laptop computer. Children completed a practice trial session followed by three experimental trial sessions, for a total test time of approximately 20 minutes. During the practice session of 24 trials, the experimenter explained the rules (e.g. "use the buttons to tell me which way the middle fish is going") and received experimenter feedback (e.g. "great job!") as well as visual and auditory feedback from the program. Following the practice session, participants completed three experimental sessions (each 48 trials) that were approximately 5 minutes in duration. Participants did not have an opportunity to stop testing during the five minute sessions, but were given opportunities to rest between experimental sessions.

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 after which a cue was presented for 150ms or the target was presented. Cues were varied such that children were either presented with no cue before the target presentation (no cue condition), a central asterisk cue replaced the fixation cross (central cue condition), two asterisks presented above and below the central fixation point (double cue condition) or a single asterisk appearing above or below the central fixation point indicating where the target would appear (spatial cue condition). Following the cue presentation and an additional 450ms of central fixation, the target fish was presented in isolation (neutral condition) or with flankers (congruent and incongruent conditions) 1^{o} above or below the central fixation cross until a response was made or 1700ms had elapsed. Children responded to the direction of the target fish using mouse buttons on the laptop keyboard on which yellow arrow buttons corresponding to spatial position (left-pointing arrow on left button and right-pointing arrow on right button) were affixed.

The ANT yields scores on three attentional constructs: alerting, orienting, and conflict resolution. The alerting effect is calculated by subtracting the mean RT (ms) to trials in the central cue condition from the mean RT to double cue trials and is an indication of one's ability to utilize cueing to prepare for trial response, as indexed by faster responding following cue trials versus no cue trials. The orienting effect is calculated by subtracting the mean RT to spatial cue trials from the mean RT to central cue trials. An individual's orienting score is a measure of ability to use spatial information included in a cue to predict the spatial location of the trial, which is indicated by faster responses to spatial cue trials that provide information regarding the location of the forthcoming trial as compared to central cue trials that contain no information about the trial's location. Finally, the conflict score is calculated by subtracting mean RT on congruent flanker trials from mean RT on incongruent flanker trials. Roughly speaking, the conflict score is a quantification of the cost of ignoring the misleading information provided by the incongruent flankers. A higher conflict score results from a larger difference between RT to congruent and incongruent trials and indicates a larger cost of ignoring the incongruent flankers, while a lower conflict score reflects a smaller RT cost.

Wisconsin Card Sorting Test (WCST)

The computerized version of the Wisconsin Card Sorting Test Computer Version 4 (Berg, 1948; Heaton et al., 1993), a widely used test of higher-order cognitive ability, sometimes characterized as executive function, was administered to all children on the same Dell Latitude laptop computer used for the ANT. The testing instructions given to participants deviated slightly from those described in Heaton (1993), in that the experimenter used a set of example cards to point out to the children the three dimensions (color, shape, or number) that could be used to sort the cards, and also described the fact that the correct sorting rule would periodically change (i.e. ‘the computer sometimes changes its mind about which rule you should use’). These changes in task administration were made because the specific variable of interest in the current study is perseverative errors, which can only be committed if a child has successfully sorted 10 consecutive cards using one rule, resulting in a change in correct sorting rule.

Somsen, van der Molen, Jennings, and van Beek (2000) identified two separate processes required for successful completion of the WCST: rule search (i.e. discovery of the correct sorting dimension) and rule application (i.e. consistent application of the correctly identified sorting dimension). Thus, the error of interest here, perseverative error, is an error in the rule application process, not rule search. Describing the nature of the task was intended to allow children to more fully understand how to find the correct sorting rule and move to the next rule, which in turn created more opportunity for perseverative errors during the rule application process. All children were given a description of the task, but younger children were usually given a more explicit explanation of the sorting dimensions by the experimenter, whereas older children were led to discover and describe the sorting rules to the experimenter using the practice cards before completing the computerized task.

Following task instruction, participants completed the computerized WCST, which requires participants to correctly sort 10 consecutive cards in 6 categories (color, number, or shape, each used twice) or sort 128 cards. Children received auditory and visual positive ('right') and negative ('wrong') feedback from the computer during sorting. The experimenter provided encouragement throughout the task (e.g. 'great job') and gave additional feedback during the rule search process (e.g. 'what rule makes those two cards match?' 'What else could you try?'). Because the focus of this project was rule application as opposed to rule search, no experimenter feedback was given during the rule application process.

The WCST yields both raw and standardized scores of the total number of cards sorted in the task (0-128), the number and percentage of cards correctly sorted, the number and percentage of incorrectly sorted cards (errors), the number and percentage of perseverative responses, the number and percentage of perseverative errors, the number and percentage of nonperseverative errors, the number and percentage of conceptual level responses, the number of trials administered before completing the first sorting rule (10 consecutive correct sorts), the number of rules completed (0-6), failure to maintain set, and learning to learn. Because administration of the task was slightly altered from the standard procedures, standardized scores are neither reported nor used for any analyses.

Test de Vocabulario en Imagenes Peabody (TVIP)

Bilingual participants were tested on the TVIP (Dunn et al., 1986), which is a standardized test of Spanish receptive vocabulary. Testing was completed identically 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 incorrectly responded to six of eight consecutive test items. Each child's raw score was converted to a standard score using standardized tables.

Results

Preliminary Measures

A summary of the means and standard deviations on all measures for each language group is provided in Table 1. A comparison of the mean age for the three language groups (SEQ, SIM, MON) revealed that the mean age of the groups was not significantly different, $F(2,77)= .267$, $p = .766$. Additionally, box and whisker plots (Figure 1) indicate that age distribution is comparable among the three groups. The MON group differs significantly from the SEQ $t(57) = 4.17$, $p < .001$ and SIM groups $t(42) = 3.94$, $p < .001$ in their English verbal ability, which is indexed by standardized PPVT-III scores. The PPVT-III scores of the SEQ and SIM groups are not, however, significantly different, $t(55)= .80$, $p = .428$. The SEQ and SIM also had equivalent TVIP scores, $t(55) = .75$, $p = .459$, which indicates that the two bilingual groups did not differ on verbal ability in either of their languages.

As expected, the two bilingual groups did differ significantly in their length of bilingual experience; SIM children having a significantly longer mean bilingual experience (87.24 months) than SEQ children (58.08 months), t (55) = 3.88, p < .001. The three groups did not significantly vary on forward digit span scores, $F(2,76) = 1.27$, $p = .287$, suggesting that any group differences on WCST or ANT are not the result of working/short-term memory differences among the three groups.

A series of t-tests comparing the three language groups on family demographic variables revealed differences between the three groups. The three language groups were significantly different in terms of SES. The MON group had significantly higher parent education (i.e. averaged reported maternal and paternal education levels) than both the SIM and SEQ children, $t(40) = 7.28$, $p < .001$, $t(52) = 11.76$, $p < .001$, respectively. The SEQ and SIM groups also differed significantly in terms of parent education, $t(48) = 2.06$, $p = .044$, with the SIM group having higher average parent education than the SEQ group. Finally, MON children had significantly higher family income than both the SIM group, $t(38) = 8.42$, $p < .001$, and SEQ group, $t(51) = 12.38$, $p < .001$, and the SIM children had significantly higher family income levels than children in the SEQ group, $t(51) = 2.08$, $p = .042$.

Wisconsin Card Sorting Test

In order to test the hypothesis that bilingual children (n=55) and monolingual children (n=23) would perform differently on the WCST, the percentage of correct responses for children in the two groups was compared using a t-test, which revealed that the two groups did not differ significantly in their percentage of correct responses, $t(76) = .75$, $p = .454$. Due to the wide range in participant age (68 to 179 months) and the significant differences in verbal ability (PPVT-III) and SES (indexed by average parent education levels), these variables were included as covariates (see also Carlson & Meltzoff, 2008) in a second comparison of bilingual and monolingual correct percentages on the WCST. Including average parent education as a covariate resulted in a reduced sample size due to removal of three children (2 SIM and 1 SEQ) with missing values for maternal education and paternal education and four children (4 SEQ) with missing values for paternal education. An ANCOVA including the aforementioned covariates indicated that the two groups of children did not have significantly different percentages of correct responses on the WCST, $F(4,66) = 1.32$, $p = .255$ (see Figure 2).

Further analyses were conducted to compare the performance of all three language groups on the WCST. An ANOVA was performed in order to compare the percentage of correct responses on the WCST between the three language groups (MON, SEQ, SIM) indicating that there is not a significant effect of language group membership on the percentage of correct WCST responses, $F(2,75) = 2.20$, $p = .118$. An ANCOVA including age, verbal ability, and SES as covariates was then used to compare WCST percentage of correct responses between children in the three language groups. The ANCOVA again revealed no significant effect of language group, $F(5,65) = 1.83$, $p = .169$, which is represented in Figure 3.

A t-test comparing the percentage of perseverative errors between the bilingual (n=22) and monolingual (n=53) groups was performed to test for hypothesized differences. Three children (1 MON and 2 SEQ) were removed from analyses of perseverative errors because they completed only one WCST category and therefore could not have been considered to commit preservative errors. The t-test revealed no differences between the two language groups in the percentage of perseverative errors committed on the WCST, $t(76) = .92$, $p = .356$ and inclusion of covariates (age, PPVT-III, parent education) in an ANCOVA comparing percentage of perseverative errors between bilinguals and monolinguals (Figure 4) did not lead to different conclusions, as the groups remained statistically indistinguishable , $F(4,66) = .729$, $p = .396$.

A one-way (3: Language Group) ANOVA was used to compare the percentage of perseverative errors on the WCST among the three groups. The results of the ANOVA indicated no significant main effect of language group membership, $F(2,75) = 1.71$, $p = 0.188$. A subsequent ANCOVA including child age, PPVT-III, and average parental education level was used to compare WCST percentage of perseverative errors between children in the three language groups; the ANCOVA results (Figure 5) converged with those from the ANOVA, revealing no significant main effect of language group on percentage of perseverative errors, $F(5,65) = 1.37$, $p = 0.260$.

Attention Network Test

The number of errors (incorrect responses and failure to respond within 1700 ms) committed by children in each language group was compared in a one-way ANOVA. This revealed that the three groups did not differ significantly in the number of ANT errors they committed, $F(2,75) = .024$, $p = .976$.

All RTs to respond to ANT trials were log transformed and RTs on error trials were removed before the following analyses were performed. A series of ANCOVAs were performed with age, PPVT-III (verbal ability), and average parent education (SES) entered as covariates; these were conducted to compare the three separate attention networks assessed the ANT (Alerting, Orienting, and Conflict) between the three language groups. First, a 2 (Flanker Type) × 3 (Trial Block) × 3 (Language Group) ANCOVA was conducted in order to determine whether conflict effects (RT to congruent versus incongruent flanker trials) differed significantly across the three trial blocks. The results of the ANCOVA indicated no significant main effect of Trial Block, $F(2,64) = 1.04$, $p = .355$, and no significant interaction between Trial Block and Flanker Type $F(2,64) = .35$, $p = .709$. A 2 (Cue Type) × 3 (Trial Block) × 3 (Language Group) ANCOVA was used to determine whether alerting effects (RT to no cue versus double cue trials) were significantly different between trial blocks. Again, results indicated no significant main effect of trial block $F(2,65) = .68$, $p = .508$, and no significant two-way interaction between trial block and flanker type *F*(2,64) =.20 , *p* = .818. Finally, we conducted a 2 (Cue Type) × 3 (Trial Block) × 3(Language Group) ANCOVA to establish whether orienting effects (RT to central cue versus spatial cue trials) differed across trial block. This revealed no significant main effect of Trial Block *F*(2,64) = .26, *p* = .771 and no significant two way interaction between Trial Block and Cue Location *F*(2,64) = .048, *p* = .948.

As no statistically significant main effect of trial block nor significant two-way interactions between network and trial block were found for any of the ANT network subscores, the following ANCOVA comparisons including the covariates described above were made using RTs averaged across all three trial blocks. A 2 (Flanker Type) × 3 (Language Group) ANCOVA (Figure 6) was conducted to compare conflict between the three language groups. The ANCOVA revealed a marginally significant main effect of Flanker Type, *F*(1,66) = 3.95, *p* = .051, due to longer RT to incongruent flanker trials than to congruent flanker trials. The ANCOVA did not, however, provide evidence of a language group difference in conflict as there was no significant interaction between language group and flanker type, *F*(2,66) = .05, *p* = .948.

This ANCOVA did, however, reveal a significant between-subjects main effect of Language Group, *F*(2,66) = 3.19, *p* = .048, η^2=.088 . A significant between-subjects main effect of language group was found on all analyses used to compare the language groups on each ANT subscore (described below) and is attributable to a difference in overall RT among the SIM, SEQ, and MON groups. This main effect is driven by bilinguals' faster RTs on all trial types, relative to monolinguals. A subsequent ANCOVA (covariates were age, PPVT-III, and average parent education) comparing overall RT to all trial types among the three groups revealed a significant Language Group effect, *F*(2,66) = 3.292, *p* = .043, η^2=.091; pairwise comparisons revealed that the language difference was driven by a significant difference in RT between the

MON and SIM groups, p = .022 (see Figure 7). The performance of the SEQ group falls between that of the MON and SIM groups but is not significantly different from either, p = .205 and p = .132, respectively.

A 2 (Cue Type) × 3 (Language Group) ANCOVA (Figure 8) compared alerting between the three language groups. The analyses revealed no significant main effect of Cue Type, $F(1,66) = 2.39$, p = .127, which indicates that RT to no-cue trials was not significantly longer than RT to double-cue trials; thus, there is no significant alerting effect. The ANCOVA revealed no significant interaction between Cue Type and Language Group, $F(2,66) = 1.39$, p = .257, suggesting that the three language groups did not significantly differ in their magnitude of the alerting effect. Again, as with the conflict analyses, there was a significant between-subjects main effect of Language Group, $F(2,66) = 3.15$, p = .049, η^2=.087, representing RT differences between the groups.

Finally, a 2 (Cue Type) by 3 (Language Group) ANCOVA, represented in Figure 9, was employed to compare orienting between the three language groups. The analyses indicated that the main effect of Cue Type was not significant, $F(1,66) = 1.29$, p = .261, which indicates that RT to central cue trials was not significantly different than RT to spatial cue trials; there was no significant orienting effect. Additionally, although the interaction between Cue Type and Language Group approached significance, $F(2,66) = 2.703$, p = .059, the three language groups did not significantly differ in their magnitude of the orienting effect. As reported above for both conflict and alerting, the ANCOVA revealed a between-subjects main effect for Language Group, $F(2,66) = 3.342$, p = .041, η^2=.092, driven by between-group RT differences. Based on the marginally significant interaction between language group and cue location, pairwise comparisons were used to compare ANT orienting performance between the different language groups. These pairwise comparisons revealed significantly faster ANT RTs on spatial cue trials versus central cue trials (i.e. ANT orienting effect) for the MON, $p = .001$, and SIM, $p = .006$, groups but no significant orienting effect for the SEQ group, $p = .530$, which accounts for the marginally significant language group by cue location interaction.

Discussion

A comparison of monolingual children, sequential bilingual children, and simultaneous bilingual children on two measures of cognitive functioning, WCST and ANT, provides mixed evidence of a bilingual cognitive advantage, and preliminary evidence that age of second language acquisition affects the magnitude of bilingual advantages on cognitive tasks. After statistically controlling for age and group differences in verbal ability and SES, none of the three language groups differed significantly on the total percentage of correct responses or percentage of preservative errors on the WCST, two variables that index inhibitory control. On a third measure of inhibitory control, the ANT conflict effect, the three groups also showed no significant differences in performance. Additionally, there were no significant group differences on the ANT alerting effect or orienting effect, and all groups made comparable numbers of ANT errors, further suggesting that the three language groups performed equivalently on the task. However, a significant difference in average ANT RT, which is suggestive of differential attentional monitoring abilities, did emerge in comparisons of performance among the three language groups. .

Inhibitory Control

Taken together, the results of the WCST and ANT conflict score do not support a bilingual advantage in inhibitory control among this sample, nor do they indicate that bilinguals who differ on age of second language acquisition differ in inhibitory control function. Thus, none of the hypothesized inhibitory control differences between the three language groups were realized in the results. While the results suggest that no inhibitory control differences exist among the three language groups, it is unclear why the widely reported difference between bilingual and monolingual inhibition was not found in this sample of children. One plausible explanation is that the inhibitory control advantage is not as robust in school-age children as preschool children, perhaps due to improvement in executive function after 5 years of age (Diamond, 2002). That is, the school-age children may be past the formative stage of executive function development, leading to fewer individual differences between children and therefore, more difficulty establishing group differences. Furthermore, this particular sample of bilingual children is unlike those who have been previously cited as demonstrating a cognitive advantage because they are from families of lower SES, and from a rural community instead of a metropolitan city or university community.

Finally, societal differences in the status and support of bilingualism create difficulty in comparing results across studies. The children in the current study were tested in the United States where bilingualism, especially among immigrant populations like those tested here, generally receives less institutional support (e.g. English-only legislation and education; Bialystok & Hakuta, 1994; Genesee et al., 2004; Goldstein, 2004) than in other countries where researchers have reported bilingual advantages in inhibitory control (e.g. Spain and Canada). Although the impact of social support of bilingualism on the resulting cognitive advantages of bilingual experience is unclear, these cross-cultural differences might contribute to the disparity between the current results and those reported by other researchers.

It is interesting to note that children from all language groups performed statistically equivalently on inhibition tasks before covariates (age, verbal ability, SES) were included in analyses, despite the fact that monolingual children had significantly higher family income levels compared to both bilingual groups. The equivalent performance of the socioeconomically disadvantaged bilingual children to the monolingual children is unexpected due to the fact that children from lower SES families generally perform worse on measures of executive function than children from higher SES families (Nobel, Norman, & Farah, 2005). Carlson and Meltzoff (2008) also found that low SES bilinguals performed equally to higher SES monolinguals, which led to the conclusion that the additional cognitive control required of bilinguals may serve to protect low SES bilingual children from expected deficits in executive function related to low SES. The results of the current study thus lend support to the notion that low SES bilingual children’s executive functions may be protected from the potentially negative effects of suboptimal environmental conditions by their bilingual experience. Future studies comparing low SES monolingual children to low SES bilingual children will serve as a more stringent test of the theory that bilingualism protects executive function.

Attentional Monitoring

Despite the lack of group differences in inhibitory control, an effect of language group emerged in all ANT subscore comparisons, reflecting a difference in RT between the language groups and suggesting that language experience influences attentional monitoring. Specifically, the monolingual children had significantly longer ANT RTs than children from the simultaneous bilingual language group. The sequential bilingual children’s average RT fell between that of monolinguals and simultaneous bilinguals, but was not significantly different from either group.

Because the ANT is a flanker task that mixes congruent and incongruent trials within a single trial block, this task requires high monitoring skills in order to respond accurately to intermixed trial types. The observed RT difference suggests that simultaneous bilingual children are better equipped at handling the cognitive task demands of the ANT than their monolingual peers. It is also important to note that simultaneous bilinguals and monolinguals did not differ significantly in the number of errors committed on the ANT, suggesting that there is no time/accuracy tradeoff for the faster simultaneous bilingual children. The overall RT difference between the simultaneous bilingual and monolingual children thus supports the assertion that bilinguals have improved monitoring skills compared to monolinguals (Costa et al. 2009). Further, the fact that a monitoring difference was discovered in the absence of any evidence of group differences in inhibitory control bolsters the claim made by Costa et al. that bilingual monitoring advantage may be a more robust effect than the frequently reported bilingual advantage in inhibitory control. Regardless of the ultimate veracity of this claim, the present results suggest that, even in the absence of evidence supporting a bilingual advantage in one type of cognitive control (inhibition), a bilingual advantage for another type of control (monitoring) may emerge.

Comparison of Bilingual Groups

The results of the current study comparing simultaneous and sequential bilingual children do not provide definitive evidence that the two groups of bilingual children, who differ on age of second language acquisition, perform differently on either of the types of cognitive control tested. However, the finding that the average RT for the sequential bilingual children is significantly different from neither the monolinguals nor the simultaneous bilinguals suggests an important difference between the two types of bilinguals tested in this study in terms of their relationship to monolinguals. Specifically, these results suggest that only those children who acquired two languages by the age of three (i.e., simultaneous bilinguals) have a significant monitoring advantage over monolinguals, while sequential bilinguals were not advantaged compared to monolinguals. The sequential bilinguals' average RT was faster than that of the monolinguals and slower than that of the simultaneous bilinguals (though these differences were not significant). This pattern of performance suggests that the monitoring advantage may not be strictly limited to simultaneous bilingual children, but may instead differ in magnitude between simultaneous and sequential bilinguals, such that both groups have somewhat improved attentional monitoring skills compared to monolinguals, but the simultaneous bilinguals also outperform sequential bilinguals.

However, lack of unambiguous statistical evidence makes these conclusions necessarily speculative at this point, and future studies specifically comparing simultaneous and sequential bilingual children on tasks that measure attentional monitoring are needed to establish whether simultaneous and sequential bilinguals differ in their monitoring abilities. Additionally, any suggested differences between the two bilingual groups in this sample must be interpreted with caution due to the fact that the simultaneous and sequential bilingual children differ both in age of second language acquisition and the length of bilingual experience at time of testing. Thus, any differences between the two groups may be attributed to either of these factors. Future comparisons of cognitive control between groups of bilingual individuals who differ only on age of acquisition or length of bilingual experience will be necessary to disentangle these two variables.

Finally, these conclusions may be limited to the sample examined in this study. First of all, the children in the simultaneous and sequential language groups did not differ drastically in their age of second language acquisition, as the mean age for the simultaneous children was 24.7 months versus 59.4 months for the sequential children. While the difference between these ages is statistically significant, the difference may not be large enough to lead to significant differences in cognitive function. That is, a cognitive difference in simultaneous and sequential bilinguals might exist, but may only be evident when the difference in age of second language acquisition is more extreme (e.g. infancy versus early adulthood). Secondly, as with all conclusions drawn from this study, the pattern of results may be restricted to children who are raised in a working-class, rural community.

Conclusion

Although no evidence was found in this sample for the frequently reported bilingual advantage in inhibitory control, support was found for a bilingual advantage in attentional monitoring, which Costa et al. (2009) suggest is the more robust of the two effects. Furthermore, the present results provide initial (though limited) evidence that researchers examining executive functions of bilinguals should consider age of second language acquisition of their bilingual participants when interpreting results. Although the simultaneous and sequential bilingual children in the current study were not significantly different from one another in terms of inhibition or monitoring abilities, the relationship between these two groups to monolinguals was different. That is, in the case of monitoring abilities, the simultaneous bilinguals, but not the sequential bilinguals, outperformed monolinguals. The pattern of results suggests that the relationship between simultaneous bilingual performance and monolingual performance on cognitive measures is not equal to the relationship between sequential bilinguals' and monolinguals' performance. Additionally, although results are not conclusive, the difference in attentional monitoring between the two bilingual groups is suggestive of greater cognitive advantages in simultaneous bilinguals than sequential bilinguals. Thus, future research should take into account variables that may differ among bilinguals including age of second language acquisition, length of bilingual experience, and proficiency when interpreting the cognitive advantages of bilingualism.

References

Berg, E. A. (1948). A simple objective technique for measuring flexibility in thinking. Journal of *General Psychology, 39,* 15-22.

Bialystok, E. (1988). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24*, 560-567.

Bialystok, E. (1997). Effects of bilingualism and biliteracy on children's emerging concepts of print. *Developmental Psychology, 33*, 429-440.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70*, 636-644.

Bialystok, E. (2006). Effect of bilingualism and computer video game experience on the Simon task. *Canadian Journal of Experimental Psychology, 1*, 68-79.

Bialystok, E., Craik, F. I. M., & Freedman, M. (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neurospychologia, 45*, 459-464.

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19,* 290-303.

Bialystok, E., Craik, F. I. M., & Ruocco, A. C. (2006). Dual-modality monitoring in a classification task: The effects of bilingualism and ageing. *The Quarterly Journal of Experimental Psychology, 59*, 1968-1983.

Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1341-1354.

Bialystok, E. & DePape, A. (2009). Musical expertise, bilingualism, and executive functioning. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 565-574.

Bialystok, E. & Hakuta, K. (1994). In other words: The science and psychology of second-language acquisition. New York: BasicBooks.

Bialystok, E. & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 7,* 325-339.

Bialystok, E. & Shapero, D. (2005). Ambiguous benefits: The effect of bilingualism on reversing ambiguous figures. *Developmental Science, 8,* 595-604.

Carlson, S. M. & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*, 282-298.

Costa, A., Albareda, B., & Santesteban, M. (2008). Assessing the presence of lexical competition across languages: Evidence from the Stroop task. *Bilingualism: Language and Cognition, 11,* 121-131.

Costa, A., Hernàndez, M., Costa-Faidella, J., & Sebastiàn-Gallès, N (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition, 113,* 135-149.

Costa, A., Hernandez, M., & Sebastian-Gallès, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition, 106*, 59-86.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in the bilinguals' two lexicons compete for selection? *Journal of Memory and Language, 41,* 365-397.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss & R. T. Knight (Eds.), *Principles of Frontal Lobe Function* (pp. 466-503). New York: Oxford University Press.

Diaz, R. M. (1985). Bilingual cognitive development: Addressing three gaps in current research. *Child Development, 56,* 1376-1388.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test—Third Edition (PPVT III)*. Circle Pines, MN: AGS Publishing.

Dunn, L. M., Padilla, E. R., Lugo, D. E., & Dunn, L. M. (1986). *Test de Vocabulario en Imagenes Peabody (TVIP).* Circle Pines, MN: AGS Publishing.

Fan, J., McCandliss, B.D., Sommer, T., Raz, A., & Posner, M.I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive*

Frye, D., Zelazo, P.D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10,* 483–527.

Genesee, F., Paradis, J., & Crago, M. B. (2004). Dual language development and disorders: A handbook on bilingualism and second language learning. Baltimore, MD: Brookes.

Goldstein, B. A. (2004). Bilingual language development and disorders in Spanish-English speakers. Baltimore, MD: Brookes.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1,* 67-81.

Heaton, R.K., Chelune, G.K., Talley, J.L., Kay, G.G., & Curtiss, G.(1993). *Wisconsin Card Sorting Test manual: Revised and expanded*. Odessa, FL: Psychological Assessment Resources Inc.

Kovàcs, A. M. & Mehler, J. (2009a). Cognitive gains in 7-month-old bilingual infants. PNAS Proceedings of the National Academy of Sciences of the United States of America, 106, 6556-6560.

Kovàcs, A. M. & Mehler, J. (2009b). Flexible learning of multiple speech structures in bilingual infants. *Science, 325*, 611-612.

La Heij, W. (2005). Selection processes in monolingual and bilingual lexical access. In Kroll & De Groot (eds.), *Handbook of Bilingualism*, 289–307.

Mahon, B. Z., Costa, A., Peterson, R., Varga, K. A., & Caramazza, A. (2007). Lexical selection is not competition: A reinterpretation of semantic effects of semantic interference and facilitation in the picture-word interference paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 503-535.

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11 (1),* 81-93.

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. Developmental Psychology, 43, 947-959.

Meuter, R. F. I. & Allport, A. (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language, 40*, 25–40.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex ‘frontal lobe’ tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100.

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8,* 74-87.

Rueda, M.R., Fan, J., McCandliss, B.D., Halparin, J.D., Gruber, D.B., Lercari, L.P., & Posner, M.I. (2004). Development of attentional networks in childhood. *Neuropsychologia, 42,* 1029-1040.

Somsen, R. J. M., van der Molen, M. W., Jennings, J. R., & van Beek, B. (2000). Wisconsin Card Sorting in adolescents: Analysis of performance, response times and heart rate. *Acta Psychologica*, *104*, 227-257.

U.S. Census Bureau (2008). *Characteristic of People by Language Spoken at Home* [data table]. Retrieved January 13, 2010 from http://factfinder.census.gov/servelt/STTable?_bm=y&-geo_id=01000US&gr_name=ACS_2008_3YR_G00_S1603&-ds_name=ACS_2008_3YR_G00.

Yang, S. & Lust, B. (November, 2004). Effects of bilingualism on the Attentional Network Test: Its significance and implications. Poster presented at the Boston University Conference on Language Development. Boston, MA.

Zelazo, P.D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, *11*, 37–63.

Appendix

1. Which of the following languages can your child speak? Please check all that apply.
____ENGLISH ____SPANISH ____OTHER please specify ____________

2. Please list the approximate age when your child began speaking each of the languages you checked in #1.
ENGLISH age:__________ SPANISH age:__________ OTHER age:__________

3. Which of the following languages can your child read?
____ENGLISH ____SPANISH ____OTHER please specify ____________

4. Which of the following languages can your child write?
____ENGLISH ____SPANISH ____OTHER please specify ____________

Relationship to Child	Language **Most Often** Spoken with Child Check only one.	Other Languages Spoken to the Child. Check all that apply.	How often does the child speak to this person? Check only one.
MOTHER	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
FATHER	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
BROTHERS/ SISTERS	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
GRANDPARENTS	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
AUNTS/UNCLES	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
COUSINS	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
FRIENDS	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH
TEACHERS/ AT SCHOOL	______ENGLISH ______SPANISH ______OTHER	______ENGLISH ______SPANISH ______OTHER	_____DAILY _____ONCE A WEEK _____ONCE A MONTH _____LESS THAN ONCE A MONTH

Please indicate how often your child uses each of the languages in an average day by drawing an X on each line below.

ENGLISH: |-----------------------------|-----------------------------|------------------------------|---------------------------------|
NEVER (0%) HALF OF THE TIME (50%) ALWAYS (100%)

SPANISH: |-----------------------------|-----------------------------|------------------------------|---------------------------------|
NEVER (0%) HALF OF THE TIME (50%) ALWAYS (100%)

OTHER: |-----------------------------|-----------------------------|------------------------------|---------------------------------|
NEVER (0%) HALF OF THE TIME (50%) ALWAYS (100%)

Table 1. Descriptive statistics of performance divided by language group.

	MONOLINGUAL				SEQUENTIAL BILINGUAL				SIMULTANEOUS BILINGUAL			
	Min.	Max.	Mean	Std. Deviation	Min.	Max.	Mean	Std. Deviation	Min.	Max.	Mean	Std. Deviation
Age (months)	76.00	167.00	116.39	28.13	78.00	173.00	117.53	27.82	68.00	179.00	111.95	29.10
Forward Digit Span	5.00	13.00	8.00	1.62	3.00	11.00	7.31	1.77	4.00	12.00	7.24	1.97
PPVT-III	84.00	127.00	104.17	11.76	47.00	128.00	85.83	18.80	69.00	118.00	89.76	12.08
TVIP					59.00	137.00	93.47	20.04	50.00	126.00	88.43	24.16
Mom Education	2.00	7.00	5.30	1.18	1.00	4.00	1.72	.74	1.00	6.00	2.55	1.70
Dad Education	3.00	7.00	4.26	1.39	1.00	4.00	1.53	.72	1.00	2.00	1.7500	.44
Income	3.00	6.00	4.30	.86	1.00	4.00	1.64	.74	1.00	4.00	2.0500	.83
Overall ANT RT(ms)	617.66	1043.73	875.64	122.34	572.72	1177.78	873.00	139.43	510.24	1173.26	845.64	171.43
ANT Error	.00	22.00	6.82	6.31	.00	36.00	6.53	8.78	.00	35.00	7.00	8.26
Incongruent Flanker RT	649.17	1154.57	939.23	137.72	643.19	1268.55	933.18	156.14	563.58	1179.62	904.88	176.31
Congruent Flanker RT	606.52	1051.08	866.57	124.33	535.73	1163.16	861.22	140.55	488.58	1226.05	841.74	179.48
No Cue RT	645.88	1123.20	923.55	140.97	588.06	1288.61	920.30	151.17	579.06	1235.89	899.37	174.11
Double Cue RT	632.64	1038.24	846.21	116.59	604.03	1158.73	864.97	142.51	479.78	1107.29	824.55	170.23
Central Cue RT	628.92	1076.58	880.71	125.70	544.81	1121.59	865.45	136.32	525.44	1163.96	844.87	173.76
Spatial Cue RT	551.78	1027.30	852.57	122.15	553.97	1165.36	841.99	144.51	456.69	1215.33	814.11	182.28
WCST % Correct	.52	.89	.79	.08	.53	.90	.76	.08	.36	.88	.78	.11
WCST % Perseverative Error	.05	.22	.10	.04	.04	.21	.10	.04	.05	.15	.09	.02

Figure 1. Box and whisker plot of age distributions within each language group.

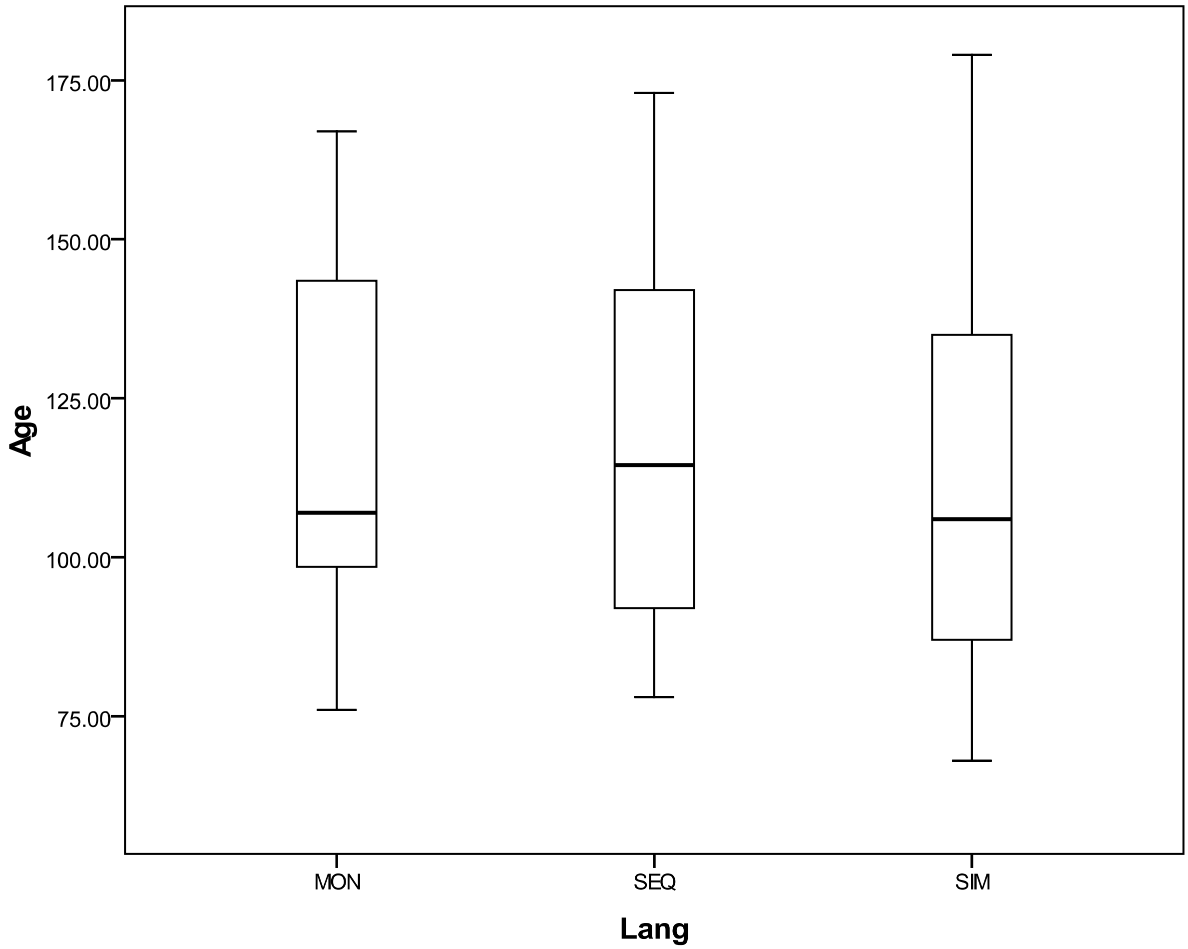

Figure 2. ANCOVA comparing WCST percentage of correct responses between monolinguals and bilinguals. Covariates included were child age, PPVT-III, and parent education.

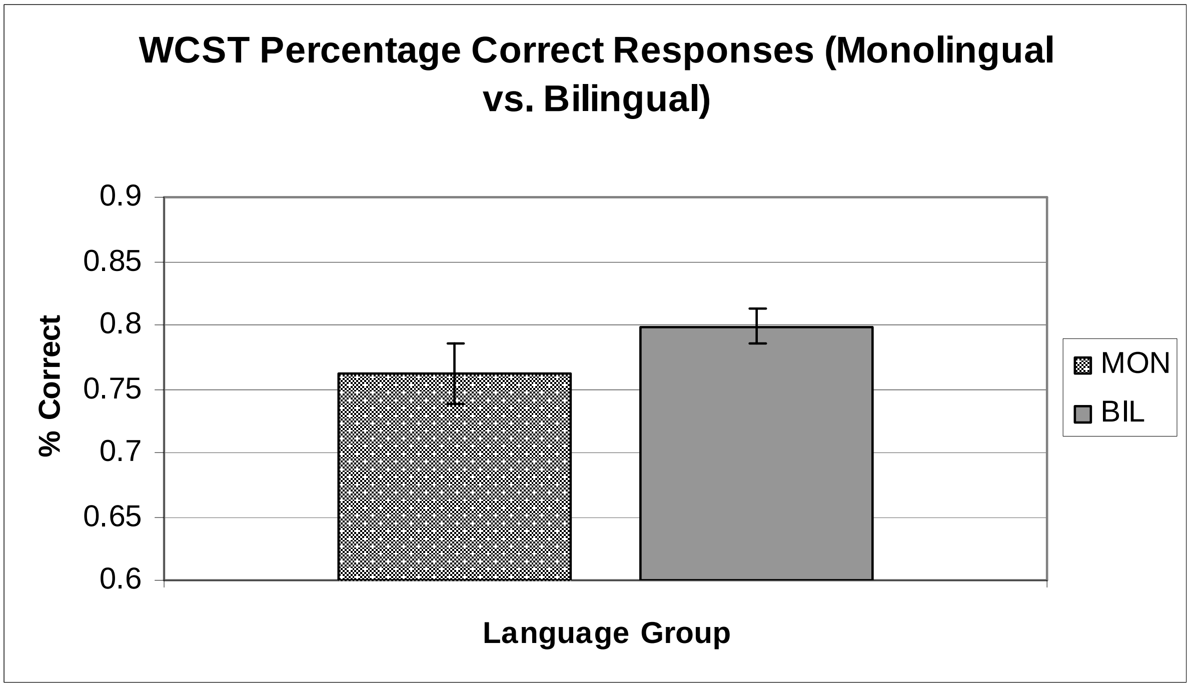

Figure 3. ANCOVA comparing WCST percentage of correct responses across three language groups. Covariates included were child age, PPVT-III, and parent education.

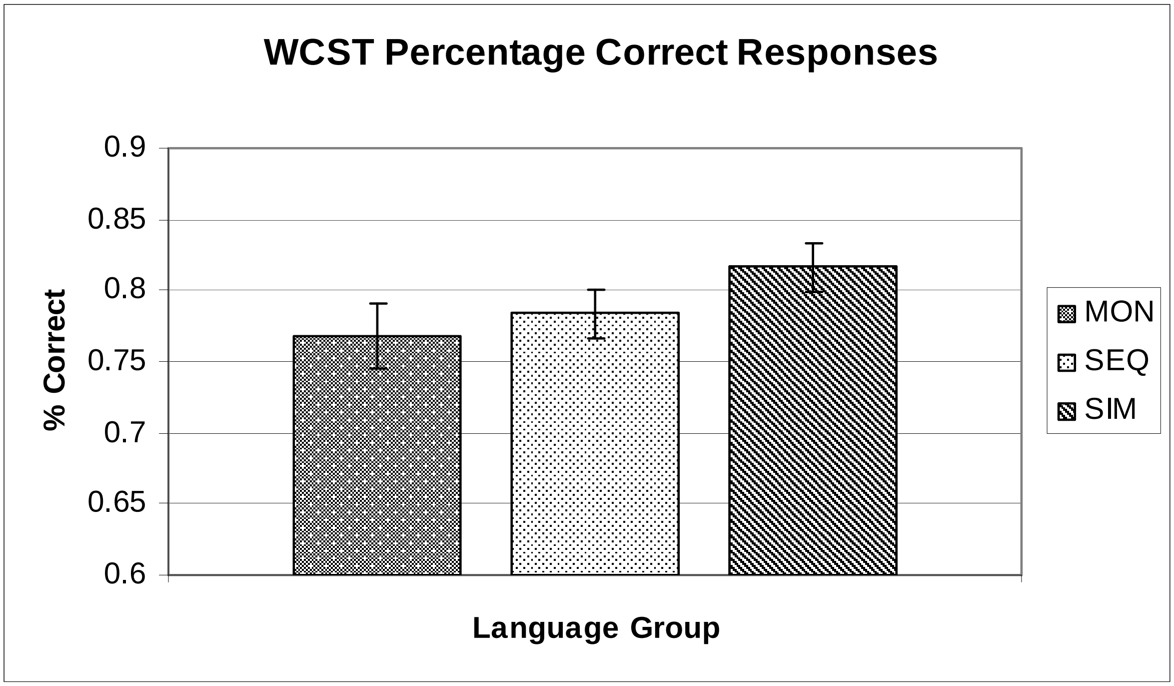

Figure 4. ANCOVA comparing WCST percentage of perseverative errors between monolinguals and bilinguals. Covariates included were child age, PPVT-III, and parent education.

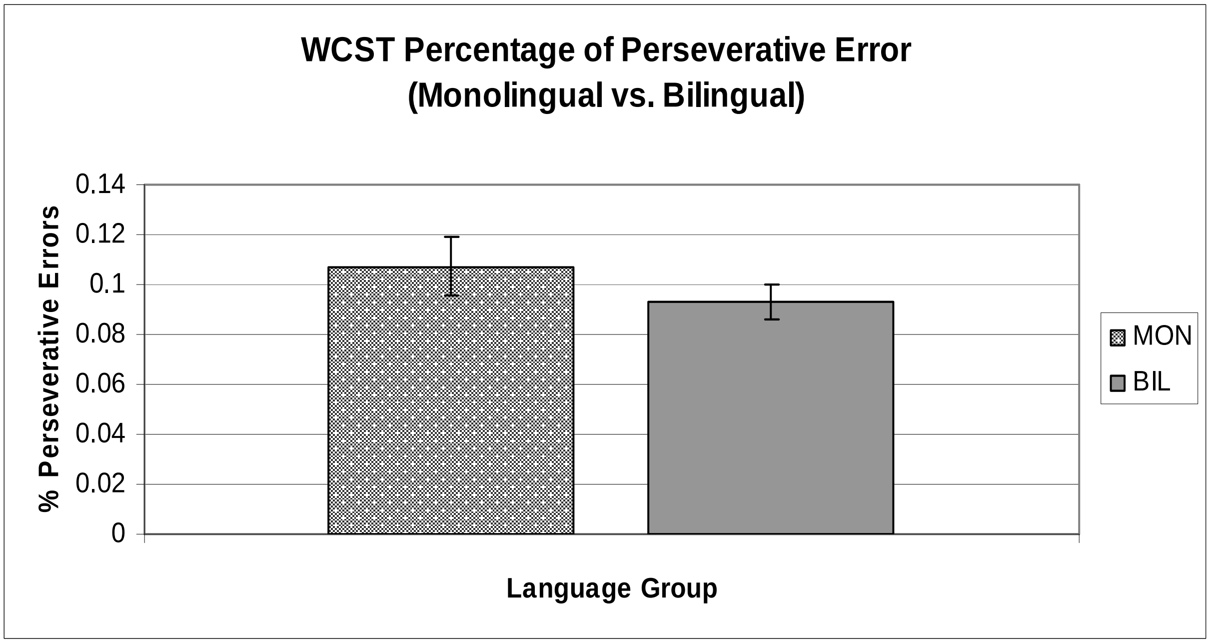

Figure 5. ANCOVA comparing WCST percentage of perseverative errors across three language groups. Covariates included were child age, PPVT-III, and parent education.

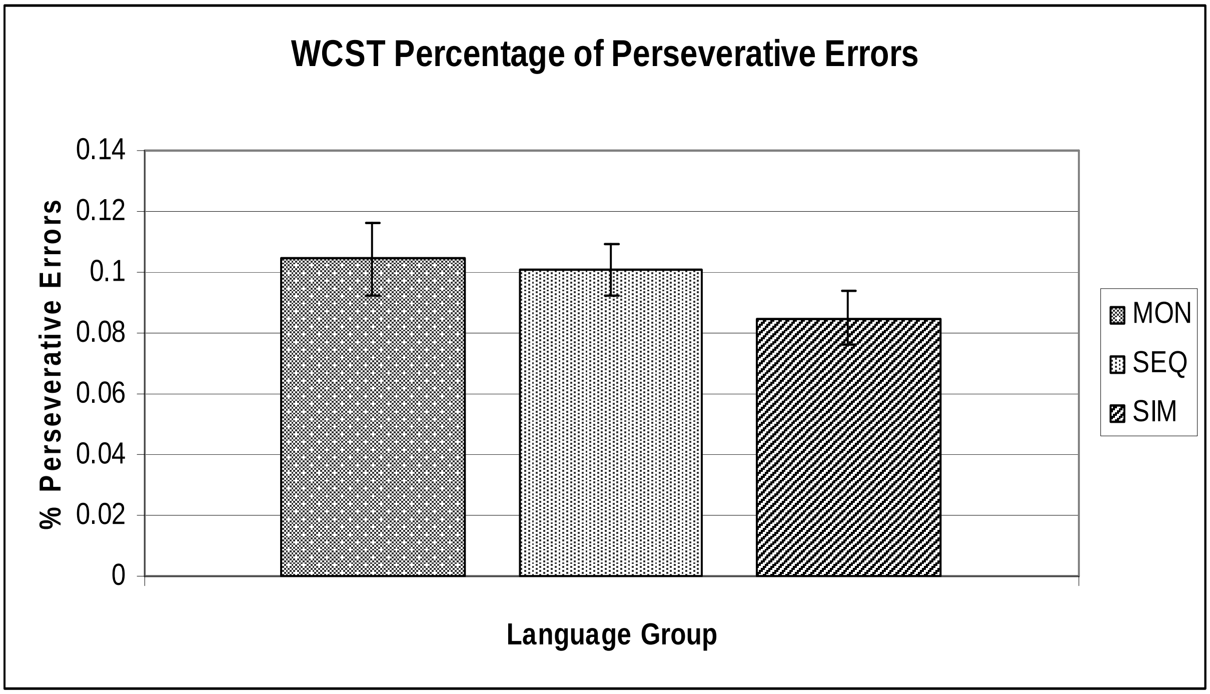

Figure 6. ANCOVA comparing ANT Conflict performance (difference in RT between incongruent and congruent trials) across three language groups. Covariates included were child age, PPVT-III, and parent education.

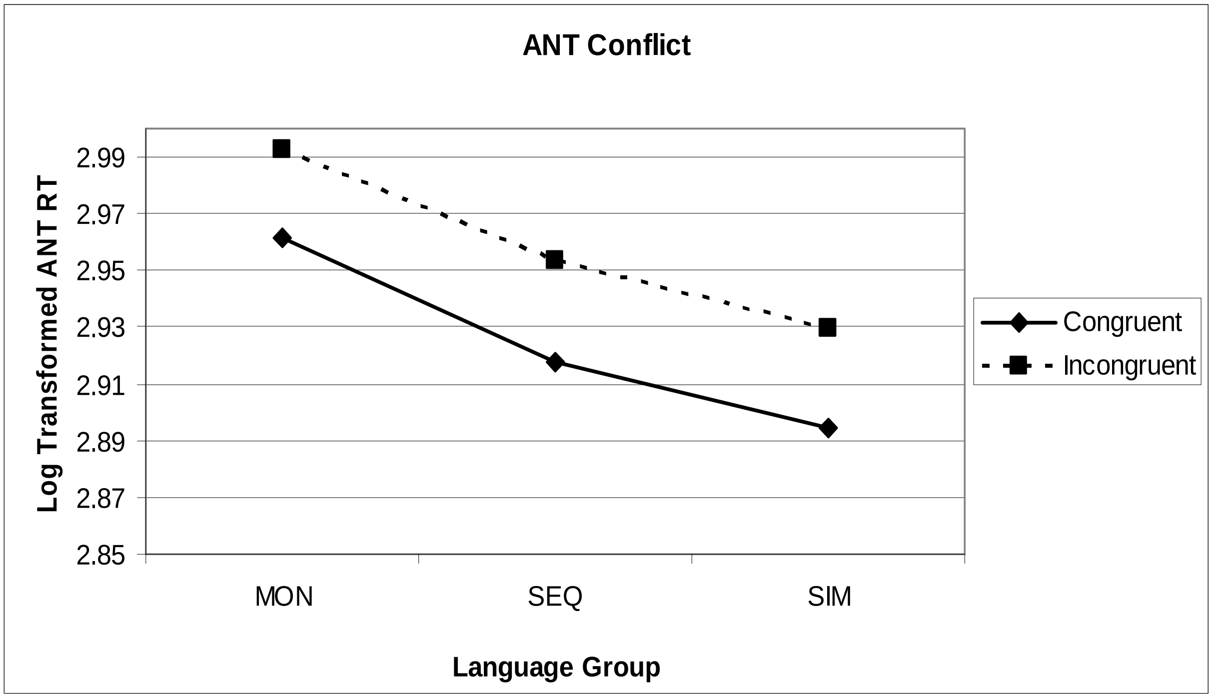

Figure 7. ANCOVA comparing log transformed ANT RT averaged across all trial types and trial blocks among the three language groups. Covariates included were child age, PPVT-III, and parent education.

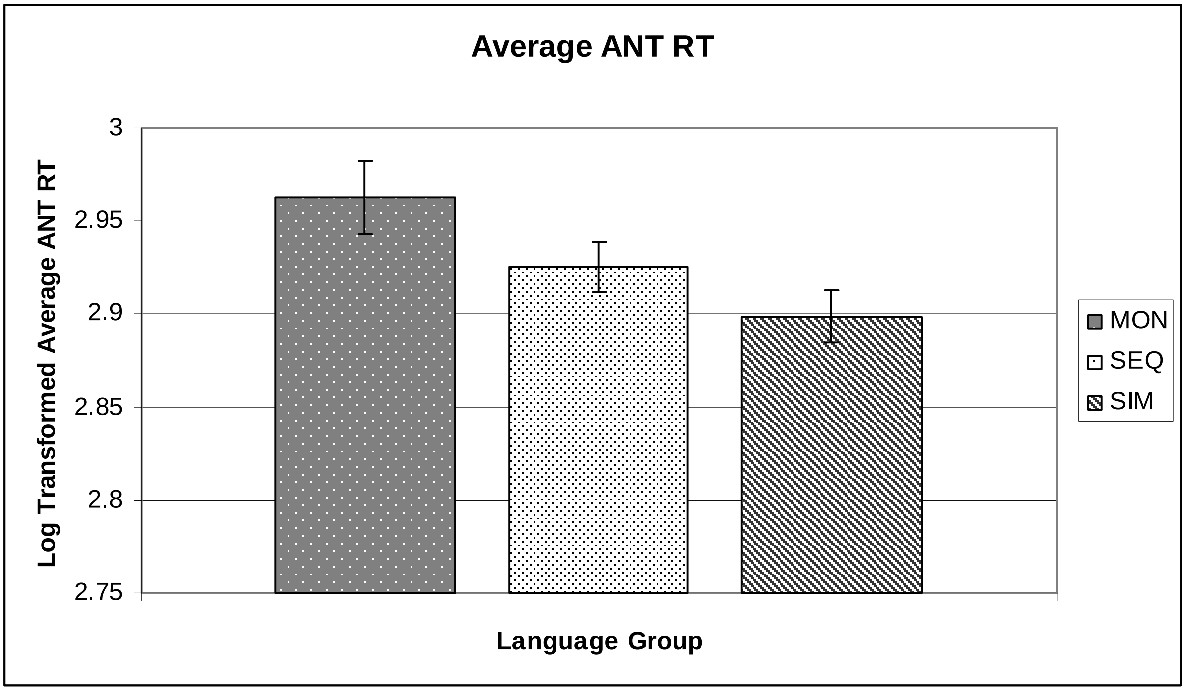

Figure 8. ANCOVA comparing ANT Alerting performance (difference in RT between no cue and double cue trials) across three language groups. Covariates included were child age, PPVT-III, and parent education.

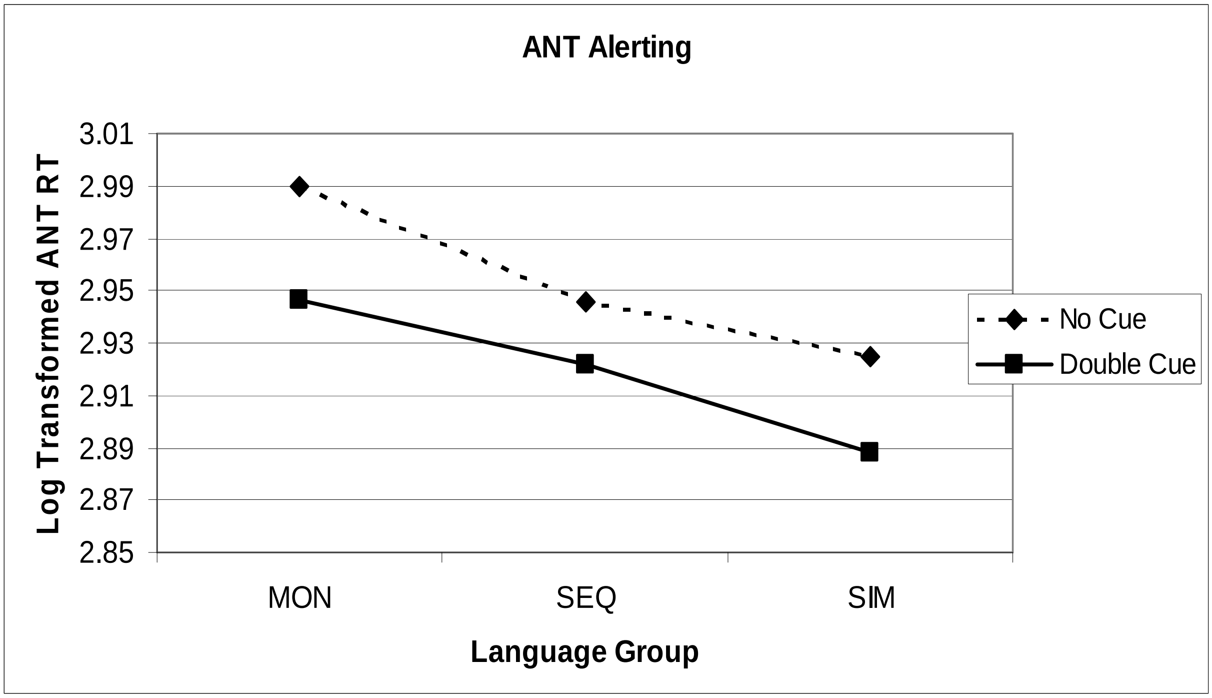

Figure 9. ANCOVA comparing ANT Orienting performance (difference in RT between central cue and spatial cue trials) across three language groups. Covariates included were child age, PPVT-III, and parent education.