THE DEVELOPMENTAL ROLE OF ATTENTIONAL CONTROL IN LANGUAGE LEARNING

A Thesis

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Arts

By

Duc N. Tran

December, 2011

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ABSTRACT

Increasing research suggests that bilingual children have advanced (relative to monolingual children) development of attentional control. The present study includes 94 bilingual and 110 monolingual child participants from a variety of language and age groups (2.5 to 5 year-olds) to systematically investigate how early learning/exposure to more than one language is related to the developmental shift of attention and its possible implications in early language learning. Results from the present study support an initial bilingual advantage in the Attention Network Test (ANT; a nonlinguistic task measuring attentional shifting), with monolinguals demonstrating comparable performance over time. Furthermore, significant relationships were found among overall accuracy, response time, the efficiency of individual attentional networks of the ANT and the MacArthur Bates Communicative Development Inventories (MCDI; a standardized parental report used to assess children's lexical growth). Moreover, this was specifically the case for the selected lexical category of adjectives. The current study provides new insights into the early developmental trajectory of attention among monolingual and bilingual children and how effective attention may be relevant developmental component for early language learning.

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DEDICATION

I would like to dedicate this thesis to my family.

To Tâm Hồ, my best friend and soul mate… thank you for always lending me your ear (and occasional shoulder) and never allowing me to give up. I'm so grateful to have you in my life.

To Diana Shin, thank you for being my sunshine on rainy days. Thank you for being understanding and loving this lacking friend for the hours I spent toiling away in the lab instead of hanging out with you.

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To mom, wherever you are, I know you are always shining down on me. I love you.

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Introduction

Attentional control is essential for all learning. Selectively attending to relevant information enables quick learning, generalization to new situations, and successful decision-making; attending to irrelevant information, on the other hand, can lead to error and failure to learn. This particular area of research has been increasingly studied across a multitude of disciplines, ranging from behavioral (e.g., Grossberg, 1982; Rescorla & Wagner, 1972), cognitive, (e.g., Kruschke, 2001; Kruschke, Kappenman, & Hetrick, 2005; Brady & Chun, 2007), and to neuroscience (e.g., Desimone & Duncan, 1995; Preston & Gabrieli, 2008). Further, recent studies suggest that certain environmental factors foster and facilitate this fundamental and seemingly basic low-level cognitive function. For instance, children and adults who are exposed to learning and managing two languages have been found to hold certain cognitive advantages in attentional control (e.g., Bialystok, 1999; Costa, Hernández, & Sebastián-Gallés, 2008). Recently, this advantage (i.e., attentional control) has also been documented among infants as young as 7-months old (Kovacs & Mehler, 2009). Collectively, more and more research has reported Executive Attention (Posner & Fan, 2004) as a vital mechanism behind the cognitive advantages found in bilingual children (e.g., Bialystok, 1999; Yang, 2004; Yang & Lust, 2005; Martin-Rhee and Bialystok, 2008). As a result, the current field on attention has been predominately focused on emphasizing the effect of language learning on attention (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008; Yang, 2004) and that monolingual and bilingual children meet major language developmental milestones at similar times. However, these studies have often been snapshots of discrete developmental periods, thereby hindering our knowledge of the changes that are taking place in early development. For example, research advocating the bilingual cognitive advantages in attention has been typically studied at specific age groups (i.e., 4 year olds) and language types (i.e., Korean-English bilinguals vs. English monolinguals). As such, most developmental studies are narrowly focused on a particular age and language group, therefore impeding our understanding of how attention may emerge and how it is developed across a variety of ages and language learners.

Taken together, many researchers have demonstrated how one's language learning environment may influence cognitive advantages in attention. The new question, however, is how such cognitive flexibility may in turn influence the language-learning domain. As a general construct, attention is widely considered to be important for early word learning (Halberda, 2009; Hollich, Hirsh-Pasek, Tucker, & Golinkoff, 2000; Plunkett, 1997; Smith, 2000; Yoshida & Hanania, 2007); yet there are few studies demonstrating the direct link between development of attention and language learning (e.g., Yoshida, Tran, Benitez, & Kuwabara, 2011) and no study reporting the developmental trajectories regarding the relation. The current study addresses exactly this relation by asking two questions. First, (1) how is attention developed and changed in early childhood among different language learners? Finally, (2) if learning two languages promotes attentional control, what is the role of attentional control in learning words? That is, does attentional control facilitate the learning of new words in a global context (i.e., overall word knowledge) or, perhaps, in a local context (i.e., specific lexical category knowledge—noun , verbs, adjectives)? The current research is the first attempt to directly address these fundamental questions to test whether such advantages exist in children growing up bilingual, understanding the precise nature of attentional control in language learning, and its developmental trajectory across different language learners.

The current study will focus on attentional control and its emphasis on language learning as a means to better understand the cognitive consequences of bilingualism. Furthermore, implications and possible relationships between attentional control and language learning in bilinguals will be discussed.

Attentional Account on Bilingualism

Executive Function (EF) is a complex cognitive construct encompassing a set of processes that monitor and control thought and action for goal-directed responses (Welsh, Pennington, & Groisser, 1991; Zelazo, Carter, Reznick, & Frye, 1997). This cognitive construct is believed to play a major role in broadly explaining the bilingual cognitive benefits that have been found (e.g., Zelazo & Frye, 1997). Namely, studies suggest that bilingual children exercise an inhibitory control mechanism that monolinguals do not frequently exercise. This is evident in studies where bilinguals out-perform monolingual children in EF tasks, such as the Dimensional Change Card Sorting (DCCS) task, that require great exercise of inhibition, working memory, and attentional shifting (e.g., Bialystok, 1999; Carlson & Meltzoff, 2008). Recent studies, however, have reported mixed results in EF tasks when cultural values are accounted for (Oh & Lewis, 2008) and have shown that non-linguistic tasks measuring attentional shifting, such as the Attention Network Test (ANT), are a better measurement when assessing the cognitive advantages in bilingual children (Yang, 2004). Such studies have demonstrated that bilingual children, as young as the age of 4 years, outperform their monolingual peers on overall response time and accuracy across all conditions in the ANT task, even when they are not outperforming in other EF Tasks (Yang, 2004). EF tasks typically involve verbal instructions, and tasks are administered orally. Language related factors, such as comprehension, communication skills, and metalinguistic knowledge, might be responsible for influencing measures of executive function (Luo, Luk, & Bialystok, 2009). Due to the complexities and inconsistencies that accompany linguistic tests, the present study attempts to trace the possible positive consequences of bilingualism by considering the most non-linguistic task that requires no language knowledge—the ANT.

The ANT is a non-linguistic paradigm that measures the efficiency of attentional networks involved in alerting, orienting, and executive control (Fan et al., 2002; Rueda et al., 2004). Referred to as Executive Attention by Posner and Fan (2004), this efficiency is critical in allowing humans to effectively exercise attentional resources that are involved in processing, organizing, and selectively attending to relevant information. Thus, this ability allows one to shift attention away from irrelevant information towards relevant information in the environment. Furthermore, advanced attentional networks in Executive Attention are suggested to be responsible for bilinguals to selectively attend to the currently used language (i.e., producing a word in the target language, while inhibiting the non-target language) thereby keeping the two linguistic systems separate (Green 1998; Gollan and Kroll 2001; Kroll, Bobb, Misra, & Guo, 2008). Therefore, this constant shifting of attention common in bilinguals' environments provides second language learners the experience and training required to effectively resolve competition in conflict tasks (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008).

Competitive Attentional Resolution in Word Learning

Conflict tasks that measure how effectively one can resolve competition have been frequently used in novel word learning paradigms. Accordingly, more and more research has emphasized the importance of attention (competitive processes) in language learning (Halberda, 2009; Horst, Scott, & Pollard, 2010; Smith, Colunga, & Yoshida, 2010; Yoshida & Hanania, 2011). A recent study by Yoshida, Tran, Benitez, & Kuwabara (2011) particularly looked into the role of competitive attentional resolution in adjective learning and found that attentional control is directly linked to novel word learning among monolingual and bilingual children. That is, children who had better attentional control processes demonstrated better performance in the novel word-learning paradigm. In this study, children were presented with an exemplar attached to a novel adjective label and were asked to pick between two target objects (one matched and one non-matched property) that shared the same novel adjective label. In this task, children have great difficulty mapping novel adjectives due to the strong tendency to map novel words to noun categories (Gentner, 1982; Markman, 1989; Mintz & Gleitman, 2002; Sandhofer & Smith, 2007; Gasser & Smith, 1998; Waxman, 1990). This could be the case provided that children generally have an easier time learning labels for shapes than non-shape properties due to saliency and recognition of objects (Rosh, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Biederman, 1987; Spelke, 1990; Johnson, 2001). Moreover, extensive research has suggested a purported and general tendency to extend novel labels to solid objects that share a common shape—shape-bias—in young children (e.g., Landau, Smith, & Jones, 1988; Baldwin, 1989, 1992; Soja, Carey, & Spelke, 1991; Smith, Jones, & Landau, 1992). This prepotency could emerge because across many different languages, children typically learn many nouns before they learn adjectives and thus build the expectation that an unknown word is likely to label an object rather than a property of an object (Gasser & Smith, 1998). Furthermore, this prepotent tendency appears to persist over time, even after children's vocabularies shift to include a variety of words that are not nouns. Indeed, even when the artificial word is not a noun, but an adjective or even a verb, there is a robust tendency for children as young as 2 years and as old as 4 years of age to treat the novel word as if it were the name of an object (Gentner, 1982; Markman, 1989; Mintz & Gleitman, 2002; Sandhofer & Smith, 2007; Gasser & Smith, 1998; Waxman, 1990; Imai, Haryu, & Okada, 2005; Kersten & Smith, 2002; Kersten, Smith, & Yoshida, 2006; Yoshida, in press).

Therefore, how effectively children can control their attention away from the object shape to the non-shape property is vital for effective adjective learning (Yoshida & Hanania, 2011). These findings suggest how effective attention and the involvement of competitive process is important for word learning. The present study further examines the relationship and implications of attentional control in early word learning among monolingual and bilingual children by observing multiple developmental time scales cross-sectionally. Specifically, if novel adjective learning is linked to effective attentional control, what are the basic characteristics behind monolingual and bilingual children's word learning? That is, is attentional control vital for only certain word learning (i.e., only for a specific lexical category—adjectives, nouns, verbs) or generally effective across all word learning (i.e., total productive vocabulary)? To understand the fundamental mechanisms that underlie word learning, it is important to understand the implications of attentional control for language learning and what language learning means for bilinguals.

Language Learning in Bilinguals

Bilingualism is generally perceived as the presence of two linguistic systems that modifies domain-general cognitive networks involved in the way that one processes information (Bialystok, 1988). Domain-general cognitive networks have been linked to control processing regions that are thought to be involved in working memory, selective attention, and performance monitoring (Chein & Schneider, 2005). In regards to language selection, controlling which language to use at a given moment and context is key to language production. Because bilinguals must selectively communicate in the target language while inhibiting the interferences of the nontarget language, this domain-general cognitive network appears to benefit competitive processes and the resolution of competition for bilinguals (Green 1998; Gollan and Kroll 2001; Abutalebi et al., 2008).

But what defines bilingualism? What makes one bilingual? Is it the ability to speak more than one language? The definition of bilingualism can add complexity to the current issues due to the diverse backgrounds that bilingual learners experience. Many factors come into play with the magnitude of bilingual advantages, including but not limited to, cultural backgrounds/immigration (Bialystok & Viswanathan, 2009), socioeconomic status (Calvo & Bialystok, 2009), and the relation between the languages learned (Bell, 1995). That is, how similar or different the languages learned (i.e., language/linguistic distance) may affect different cognitive processing (Croft, 2008). Executive control is a complex construct, but the groups that demonstrate this particular advantage are also a complex group to define. Consequently, given the complexities that accompany children growing up bilingual, it is imperative to control for such measures to purely assess whether or not such advantages exist across all children and all developmental periods.

The current study will focus on early childhood—the seemingly critical window to study how children are learning new words in early development—and how attention may be involved during this process. The study hypothesizes that bilinguals should show an advantage on attentional control, at least at the earlier stages of development. Furthermore, there should be an impact of attentional control on language learning—specifically, there should be a link between the ANT performances and productive vocabulary of specific lexical categories (i.e., adjectives, verbs) due to the complex nature and attentional resources that are required to learn such words.

To address these questions, performance on the ANT task of bilingual and monolingual children from a variety of cultural groups and ages will be compared to systematically investigate how early learning/exposure to more than one language is related to the developmental shift of attentional control and language learning in general. Language learning will be assessed using a measure of productive vocabulary— the MacArthur Bates Communicative Development Inventories (MCDI; Fenson et. al, 1993). Multiple versions of the MCDI are used to properly assess the diversity of the participant's language development. The current study includes children from two-and-ahalf to five years old to document changes in attentional control and productive vocabulary through the course of development.

Method

Participants

A total of 110 monolingual and 94 bilingual children with ages ranging from 2.5- to 5 years old participated in the present study. For detailed descriptions of the total number of participants for each language and age group, refer to Table 1. Participants were recruited from the USA (Houston, TX), Argentina, and Vietnam. All bilingual children spoke no more than 2 languages and were all from the USA. Language background was determined by a demographic questionnaire.

Stimulus Materials

Vocabulary Assessment (MCDI)

To assess the children's vocabulary, we asked the parents of the children to complete the MacArthur–Bates Communicative Development Inventories (MCDI; Fenson et al., 1993), a parent checklist of productive vocabulary. There were 8 sections of the MCDI checklist used in the study, classified into three lexical categories; noun, verb, and adjective. The nouns were words contained on 6 sections of the CDI—Animals, Vehicle, Toys, Food and Drink, Small Household Items, and Furniture and Rooms. Verbs were the Action Words on the CDI, andAdjectives refer to the category of Descriptive Words on the CDI. For English monolingual children, the American English version was used. For bilingual learners, the same English measure was used along with a parent checklist for the second language. Parents fluent in the assessed language/s were asked to complete the MCDI. For Spanish bilinguals, we used the Spanish version of the MCDI (Jackson-Maldonado, Bates, & Thal, 2003), and for Chinese- and Vietnamese-speaking bilingual children, we developed language-specific versions of the MCDI by translating the American English and Japanese versions (Ogura & Watamaki, 1997; see also Ogura, Yamashita, Murase, & Dale, 1993). For all other languages, we used translations of the English MCDI. Adult native speakers of the non-English language (i.e., Chinese, Vietnamese, etc.), who were also fluent in English, translated and modified all the documents. Monolingual children's total vocabulary was measured as their parent reports in their productive vocabulary in English; bilingual children's total vocabulary was measured as their parent reports in both languages. For productive vocabulary scores, we computed the number of words (i.e., total, noun, verbs, adjectives) in the dominant language, total language/s (combined languages for bilinguals), and conceptual knowledge. To fairly assess and compare bilinguals' language knowledge, conceptual knowledge was computed on the basis of the total number of concepts known in both languages minus the number of words that overlap in the two languages. For example, if a Vietnamese-English bilingual child has produced the word "*dog*" in English and the word "*chó*" (dog) in Vietnamese, the total conceptual score for the word *dog* would be one (instead of two). The conceptual knowledge score discounts any overlapping words that may exist between two languages to correctly assess the number of concepts that a child knows and, therefore, may be a more meaningful way when making bilingual to monolingual group comparisons (Bedore et al., 2005).

Socio-Economic Status (SES)

Parents were also asked to fill out the John D. and Catherine T. MacArthur Foundation Research Network on Socioeconomic Status and Health questionnaire (retrieved from the MacArthur Network on SES & Health website: www.macses.ucsf.edu) to control for the influences of Socio-Economic Status (SES) in bilingual and monolingual participants. Specifically, parents were asked to fill out self-rating scales on the basis of their combined household income, highest education, and how they rate themselves in the community and nation (see Appendix 1).

Attention Network Test (ANT)

The Attention Network Test (ANT) is a non-linguistic paradigm that measures the three attentional networks (alerting, orienting, and executive control) in terms of accuracy and response time (Fan et al., 2002; Rueda et al., 2004). The alerting network is responsible for achieving and maintaining sensitivity to incoming information (Wang & Fan, 2007). The efficiency of the alerting network is examined by changes in Response Time (RT) resulting from a warning signal (i.e., difference of RT for No Cue and Double Cue trials). The orienting network is responsible for selectively attending to relevant information from an array of distracting information (Wang & Fan, 2007). Orienting visual attention has also been defined as disengaging, shifting, and reengaging one's attention (Posner, Walker, Friedrich, & Rafal, 1984). The efficiency of the orienting network is examined by the changes in RT from cues indicating where the target will occur (i.e., difference of RT for Central Cue and Spatial Cue trials). Finally, the executive control network is responsible for inhibition, conflict resolution, planning, and cognitive flexibility (Wang & Fan, 2007). Behaviorally, it is responsible for monitoring and resolving conflicts in planning, decision-making, error detection, and overcoming habitual actions (Wang & Fan, 2007). The efficiency of the executive control network is examined by the changes in RT from congruent to incongruent trials (i.e., difference of RT for Incongruent and Congruent trials). See Figure 1 for more details.

The ANT used in the present study is the original "child version" downloaded from Dr. Jin Fan's webpage (http://www.sacklerinstitute.org/users/jin.fan/). Children were asked to watch a computer screen where one or five fish were lined up horizontally. The task was to point to the mouth of the "hungry fish," which was defined always as the fish in the middle. The direction of where the hungry fish faced changed throughout the task. Children were required to shift their attention effectively to detect the direction of the hungry fish's mouth. A touch-screen laptop was used to measure for selection and response time.

Procedure

All children participated in the ANT in their dominant language. The dominant language was determined by parental reports on child's language exposure—number of hours in a day, how many days in a week, with whom, and since what age—for each language. The ANT trials were administered in a quiet, controlled room (both at the laboratory and at daycare centers) by trained research assistants fluent in the child's dominant language. Parents were asked to fill out the SES and MCDI forms. Additionally, parents of bilingual children were asked to fill out two MCDI forms—one in English and the other in their second language. Parents were asked to go through the list and specify all the words in which they had heard their child use.

Tasks

Attention Network Test (ANT)

The ANT trials were administered using E-Prime software on a 15" touch-screen laptop computer. The children sat at a comfortable distance and used their index finger to touch the fish displayed on the screen.

Practice Trials. There were a total of 10 practice/familiarization trials. During the practice trials, children were instructed to feed the hungry fish as fast as they can by touching its mouth with their index finger. The target (i.e., hungry fish) is either a single fish (neutral condition) or the middle fish in a row of five fish (see Figure 1). The fish could appear above, on, or below the fixation point. The row of five fish could face left or right, and the stimuli could be in a congruent or incongruent direction. The congruent trial will have all five fish facing the same direction (→→→→→ or ←←←←←) and the incongruent trial will display the middle fish facing the opposite direction from the others (→→←→→ or ←←→←←). Children were told that sometimes the fish would appear alone, and other times it would swim together with other fish. In all cases, they were instructed to concentrate on the middle fish—the hungry fish. They were also asked to keep their eyes on the centered fixation point (+) that is displayed throughout the task. Once they were familiarized with the task, testing trials were administered.

Testing Trials. A total of 48 trials were presented in 2 blocks (i.e., 24 trials each block) with a 60 second break in-between the blocks. The procedure is identical to the practice trials, except the experimenter will no longer provide feedback. Instead, participants were presented with trials that were accompanied by automated sound feedback: "Woohoo!" for correct responses and a buzzer sound for incorrect responses. For the study design, see Figure 2. Completion time was approximately 10 to 15 min. The dependent measures, accuracy (proportion correct) and Response Time (RT), were recorded for later analysis. Example of the instruction and question asked are as follows:

"This (middle) fish is the hungry fish. In order to feed it, you need to touch its mouth."

"Can you feed the hungry fish?"

Results

All bilingual and monolingual participants came from similar SES background (see Table 2) and had no overall differences in productive vocabulary when conceptual knowledge was accounted (see Table 3).

Attention Network Test

Overall accuracy and response time. The overall proportion accuracy on the ANT trials indicate that bilingual children performed significantly better than monolingual children at age 2.5, $t(33)=-3.748$, $p<.001$, while response time (RT) was approaching significance, $t(33)=1.448$, $p<.10$, across all conditions (see Figure 3 and 4). Performance accuracy was well above chance for bilingual 2.5-year-olds, $t(12)=6.263$, p=.000, while monolingual children was not, $t(20)=-.290$, p=.775, indicating that the advantages in attentional control was demonstrated in bilingual children as young as 2.5-years-old.

There were no significant differences found on overall proportion accuracy and RT among monolingual and bilingual children at age 3-, 3.5-, 4, and 4.5. Furthermore, the developmental trajectory (as illustrated by the linear lines in Figure 3 and 4) of overall accuracy and RT on the ANT indicates that bilingual children are more accurate and faster earlier in development, and that such performance is steadily changed across time. Meanwhile, although monolingual children demonstrated poorer performance during the initial stages of development, they displayed a sharper increase in accuracy and faster decline in RT across time.

Efficiency of attentional networks. A series of t-tests were conducted and revealed that at age 2.5 and 3, bilinguals were marginally faster than monolinguals in RT in the executive control condition, $t(31)=.494$, $p=.070$, $t(61)=-2.897$, $p=.005$, respectively (see Figure 5b). Further, at age 3, bilinguals were more efficient in the orienting condition, $t(61)=-.720$, $p=.073$ (see Figure 6), than the monolinguals of the same age. At age 3.5, there were no significant differences in performance level among the language groups (see Figure 5-7). At age 4, monolinguals were marginally more accurate in the executive control condition, $t(30)=1.888$, $p=.069$, than the bilinguals (see Figure 5a). Finally, at age 4.5, monolinguals were faster in RT in the alerting condition, $t(35)=-2.1888$, $p=.035$, than the bilinguals of the same age (see Figure 7).

Vocabulary Production

A series of t-tests were performed to document the differences in vocabulary knowledge among the two language groups. As expected, significant differences were found when the total vocabulary knowledge (combined languages for bilinguals) and dominant language were compared among monolingual and bilinguals. This comes to no surprise given the inflated nature of bilinguals' vocabulary when raw scores on both language measures were computed for total vocabulary knowledge and underestimations when only the dominant language is assessed. However, when conceptual knowledge was assessed, there were no significant differences other than the lexical category of verb concepts for the 2.5-year-olds. See Table 3.

Correlational analyses. To document whether attention and vocabulary knowledge may be related, correlational analysis between performances on the ANT and vocabulary knowledge were performed. Given the nature of the MCDI (i.e., standardize norms), correlational analyses were conducted only on 2.5- and 3-year-old children. Results reveal that children's success in overall accuracy on the ANT was significantly correlated with the total number of words produced ($r(74)=.251$, $p=.031$)—specifically, on the lexical category of adjectives in total (combined) knowledge ($r(74)=.262$, $p=.024$) and conceptual knowledge ($r(73)=.284$, $p=.015$). Scores on overall RT on the ANT was also significantly correlated with the MCDI, specifically for the number of verbs in the dominant language ($r(86)=.277$, $p=.036$). There were no significant correlations among scores on overall accuracy on the ANT with the MCDI for the total dominant language ($r(86)=.424$, $p=.087$), dominant nouns ($r(86)=.537$, $p=.067$), dominant verbs ($r(86)=.546$, $p=.066$), total conceptual knowledge ($r(73)=.213$, $p=.071$), noun concepts ($r(73)=.177$, $p=.135$), or verb concepts ($r(73)=.179$, $p=.129$). This was also the case for overall RT on the ANT.

Regression analyses. More critically for the present study, multiple regressions between the performances on the ANT and vocabulary knowledge (conceptual, dominant, and total) were performed. For conceptual and dominant knowledge, overall accuracy and RT (independent variables) and the total number of adjectives known (dependent variable) were included in the models. Although model fit was poor (R^2=.096) for conceptual knowledge, overall accuracy on the ANT trials significantly predicted the total number of adjective concepts known ($F(2, 72)=3.737$, $p<.05$). Further, there were no significant relationships between overall accuracy and total conceptual knowledge ($F(2,72)=1.810$, $p=.171$) or noun concepts ($F(2,72)=1.430$, $p=.246$). Finally, although model fit was poor (R^2=.07) for dominant knowledge, overall accuracy and RT on the ANT trials significantly predicted the total number of adjectives known in the dominant language ($F(2, 85)=3.103$, $p<.05$). There were no significant relationships between overall accuracy and RT on total dominant knowledge ($F(2,85)=1.962$, $p=.147$), dominant nouns, ($F(2,85)=1.165$, $p=.317$), or dominant verbs ($F(2,85)=2.474$, $p=.090$). Scores on the efficiency of attentional networks (alerting, orienting, and executive control) did not significantly predict vocabulary knowledge.

General Discussion

The current study finds significance of assessing attention and language learning at different ages to provide comprehensive work on the changes that are undergoing in early development, particularly as they advance their language learning.

Results on the ANT support a general bilingual advantage among participants from a wide spectrum of cultures and language backgrounds. Specifically, cross-sectional results from the present study suggest that bilingual children display an earlier advantage in attentional control (overall accuracy and RT), but that the trajectory is steady over time. Although monolingual children do not demonstrate comparable advantages in attentional control at 2.5-years-old, they develop a sharper increase in accuracy and a distinct decline (i.e., faster) in response times on the ANT trials over time (see Figure 3-4). Further analysis on individual attentional networks, as indicated in Figures 5-7, reveals the difference of proportion accuracy and response time as a means for documenting the efficiency of the 3 attentional networks—alerting, orienting, and executive control. Smaller differences between the cues and flanker types indicate the efficiency of the respective attentional network. Scores on the efficiency of alerting and orienting network demonstrate that monolingual and bilingual children have similar attentional patterns across the developmental periods (see Figure 6-7). However, more critically for the present hypothesis, scores on the efficiency of executive control reveals that bilinguals are more efficient and consistent (i.e., differences close to zero) across the developmental periods (see Figure 5b). This indicates that the attentional advantages in inhibition, conflict resolution, planning, and cognitive flexibility among bilinguals are robust at least in the early stages of development and thus supports the first hypothesis. Therefore, the cross-sectional data on overall accuracy, RT, and scores of individual attentional networks demonstrate that bilingual children have an advantage over their monolingual peers in attentional control in early childhood, but that monolingual children catch up over time and are rightfully performing better in some cases (see Figure 7b). This is an important contribution to our understanding of cognitive developmental differences between monolingual and bilingual children.

Results on the MCDI, namely the significant relationship between overall ANT scores and specific lexical category of adjectives, lends support to the role of attention in early language learning. Recent developmental work on non-nominal learning (i.e., adjectives, verbs) suggests that attentional processes, specifically competition and selective attention, may be involved in early word learning (Yoshida, Tran, Benitez, & Kuwabara, 2011). Different lexical categories, particularly adjectives and verbs, that are referenced as perceptually less salient (e.g., Sandhofer & Smith, 2007; Gentner, 2006) may require more attentional control for acquisition. As predicted, there were significant correlations between adjectives and verbs with overall accuracy and RT on the ANT, but no significant relationships were found in regards to total vocabulary (i.e., nouns, verbs, and adjectives combined), dominant, total, or conceptual nouns known. This finding suggest that given the attentional resources that are required to learn more complex lexical categories such as adjectives and verbs, noun learning may not require and does not place as strict of a demand on attentional control for acquisition.

The present study is an important first step for understanding how the attentional control advantage in bilingualism is related to language learning, and how it develops in young childhood. The present attempt also provides a clear demonstration of the magnitude of the potential differences on the role of attention and learning for different word categories. The questions examined by the study are not only relevant for understanding how bilingualism affects cognitive development, but, it also offers a new window into the potentially different processes involved in different types of word learning. Programmatic developmental work on attention and word learning is clearly important, and the recognition of such linkages advances our understanding of the nature of language learning (via their relation to the development of attention), the fundamental mechanism involved in children’s cognitive development, and the cognitive significance of bilingualism.

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TABLE AND FIGURE CAPTIONS

Table 1. Age and total number of participants for each language groups. M refers to monolingual participants. B refers to bilingual participants.

Table 2. Mean scores for the key Socioeconomic Status (SES) measures used from the MacArthur Network on SES & Health. M refers to monolingual participants. B refers to bilingual participants.

Table 3. Mean productive vocabulary of languages based on the MacArthur–Bates Communicative Development Inventories (MCDI) for Conceptual, Dominant, and Total Knowledge.

Figure 1. A set of stimuli used in the ANT for three types of trials, including the neutral, congruent, and incongruent flankers.

Figure 2. The Attention Network Test (ANT) task design, including the feedback responses (correct and incorrect) and types of cues presented. Figure retrieved from Rueda et al., 2004.

Figure 3. Overall accuracy (proportion correct) across all conditions in the ANT.

Figure 4. Overall response time (in ms) across all conditions in the ANT.

Figure 5a and 5b. Efficiency of the Executive Control network in accuracy (5a) and response time (5b). Efficiency is measured based on the difference between incongruent and congruent flanker trials.

Figure 6. Efficiency of the Orienting network in response time (in ms). Efficiency is measured based on the difference between the RT for the central cue and spatial cue trials.

Figure 7. Efficiency of the Alerting network in response time (in ms). Efficiency is measured based on the difference between the RT for the no cue and double cue trials.

TABLES

Table 1. Age and total number of participants for each language groups.

Age Groups	N		Age (in months)		SD	
	M	**B**	**M**	**B**	**M**	**B**
2.5	21	13	34.62	34.37	1.51	2.29
3	25	23	39.67	38.94	1.36	1.62
3.5	24	27	44.70	43.80	1.68	1.32
4	19	16	50.24	49.34	2.49	1.49
4.5	21	15	61.57	60.02	3.76	4.63

Table 2. Mean scores for the Socioeconomic Status (SES) measures.

Age Groups (in years)	**Rank in the community** (scale 1-10)		**Rank in the nation** (scale 1-10)		**Highest education** (scale 1-20)		**Income** (scale 1-9)	
	M	**B**	**M**	**B**	**M**	**B**	**M**	**B**
2.5	6.18	4.50	5.86	4.50	14.38	13.4	7.38*	5.60
3	5.74	6.47	5.71	6.47	14.33	14.13	7.67	6.78
3.5	5.59	5.71	5.41	5.89	14.68	14.82	7.14	6.45
4	4.71	6	4.86	7*	14.67	16.43	7.17	7.33
4.5	6.50	6	6	4.25	17.50	16.73	8.5*	6

*significantly different at p<.05

Table 3. Mean productive vocabulary of languages for Conceptual, Dominant, and Total Knowledge.

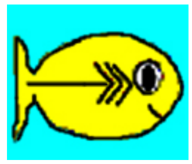
	Number of nouns		**Number of verbs**		**Number of adjectives**		**Total number of words**	
Age Groups (in years)	**2.5**	**3**	**2.5**	**3**	**2.5**	**3**	**2.5**	**3**
Monolingual	173.68	196.77	84.47	91	45.63	50.82	303.79	338.59
Bilingual (Conceptual)	136.71	207.88	50.14*	101	32	59.94	219.29	366.59
(Dominant)	145.58	167.19*	63.92	83.66	39.33	48.67	247.33	299.19*
(Total)	231	264.5*	90.57	123.44*	56.14	70.61*	377.71	454.83*

*significantly different at p<.05

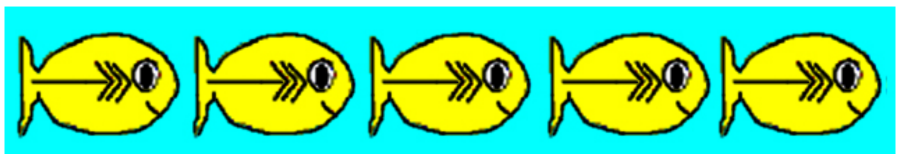
FIGURES

Figure 1. A set of stimuli used in the Attention Network Test (ANT).

Neutral



Congruent



Incongruent

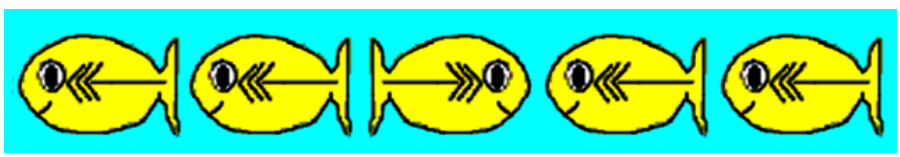


Figure 2. The ANT task design. Figure retrieved from Rueda et al., 2004.

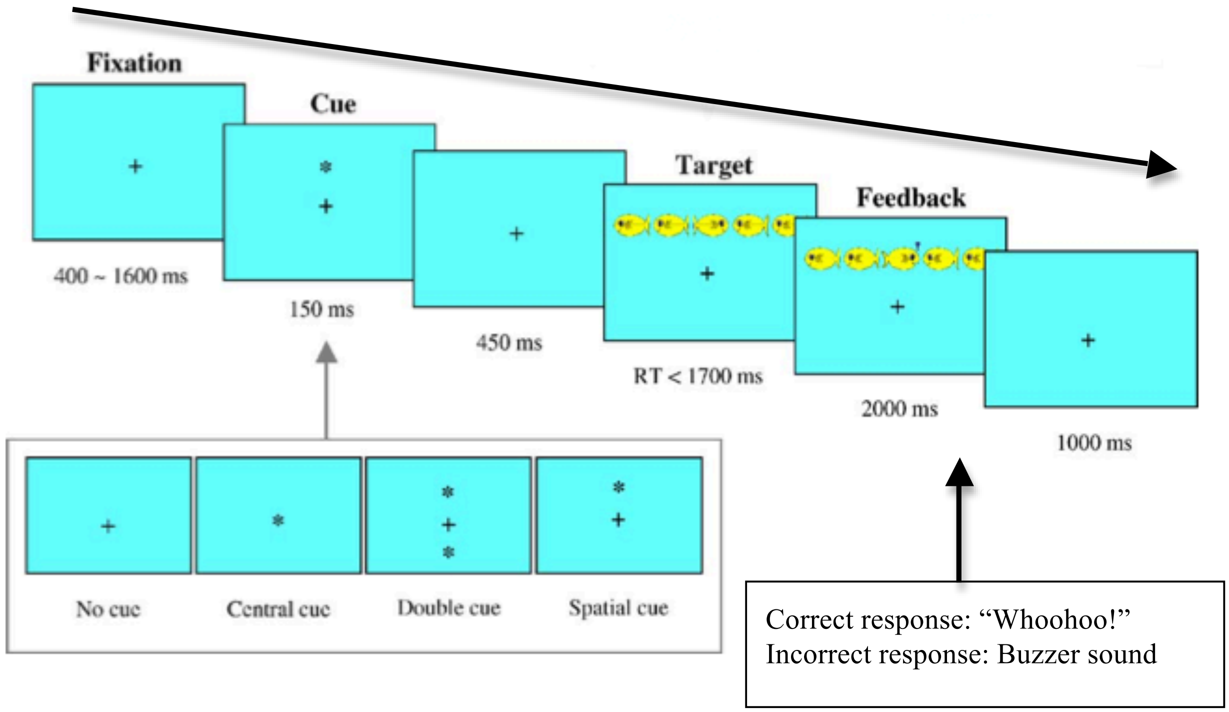
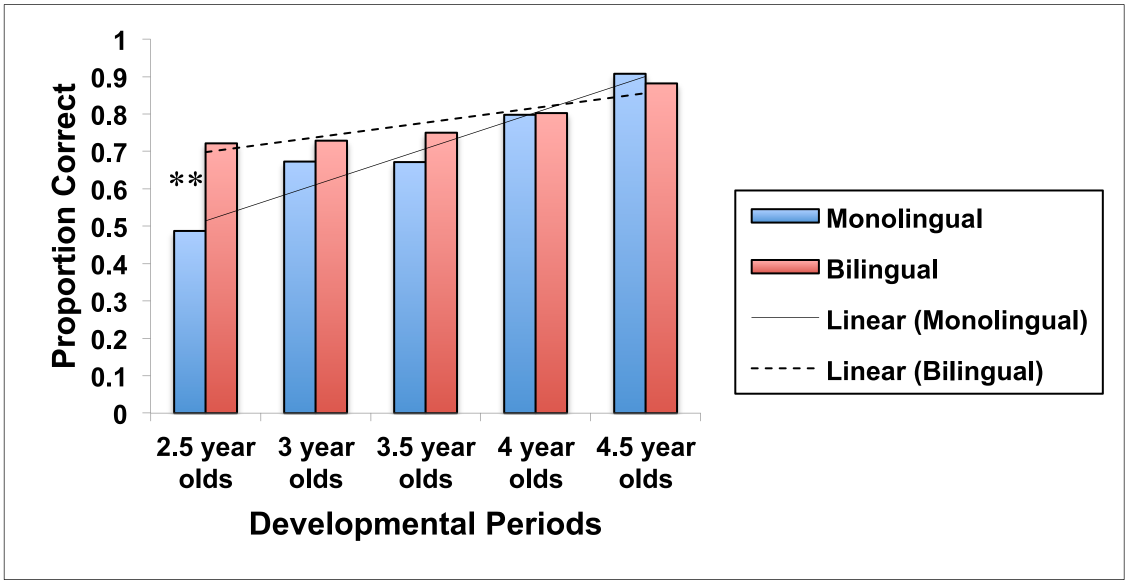
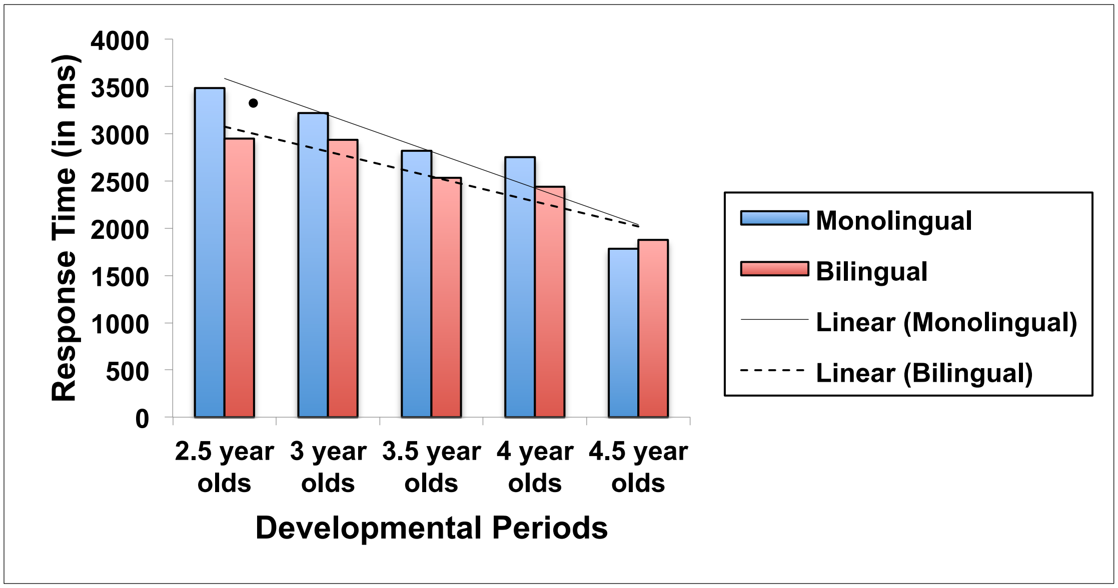


Figure 3. Overall accuracy (proportion correct) in the ANT.



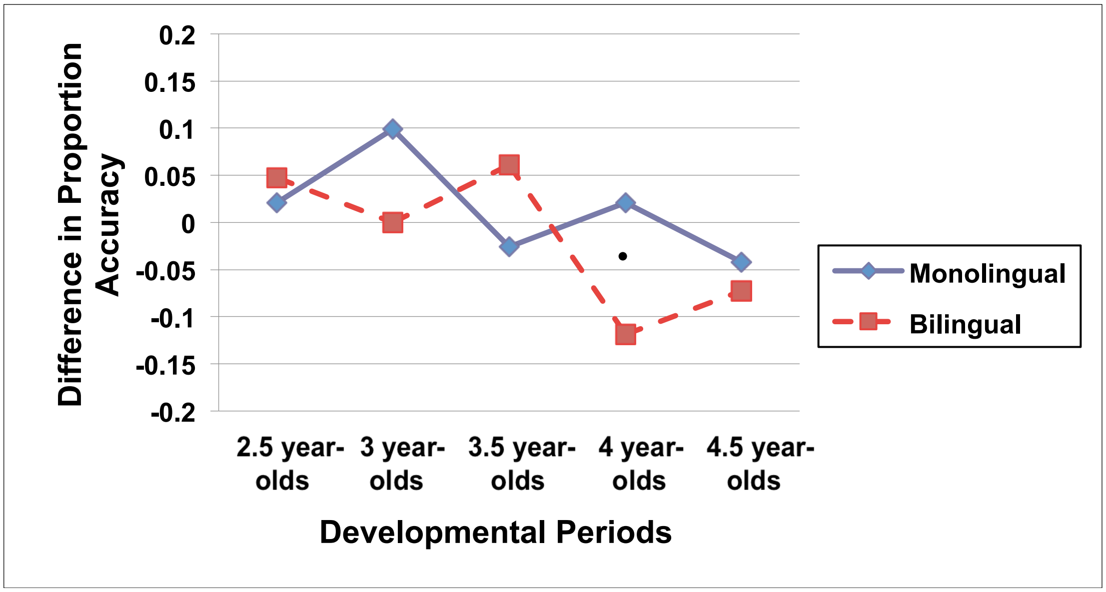
**significant at p<.01

Figure 4. Overall response time (in ms) in the ANT.

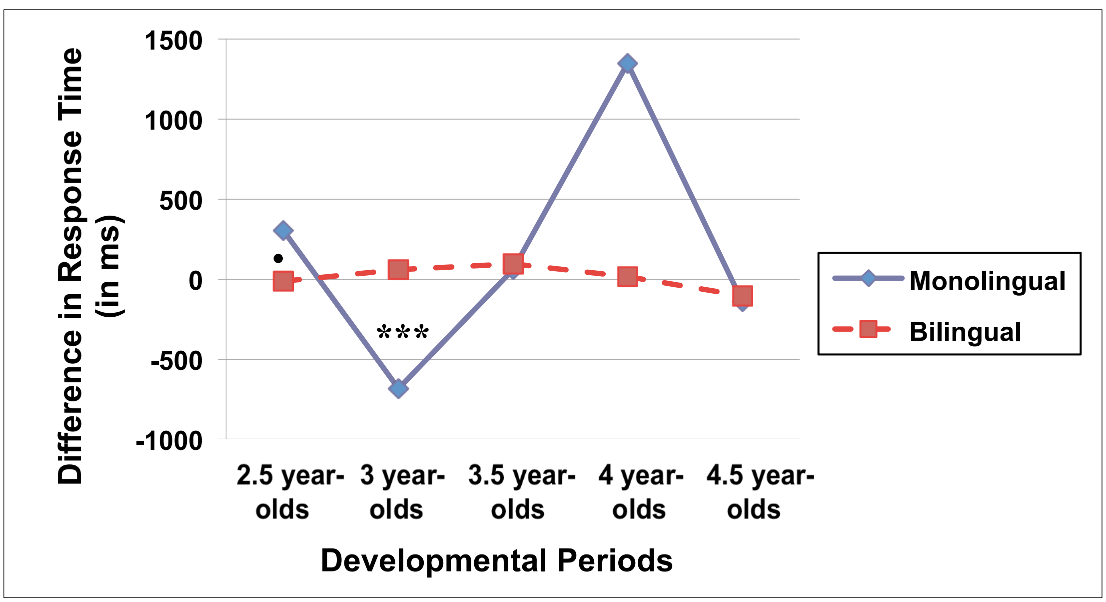


•significant at p<.10

Figure 5a and 5b. Efficiency of the Executive Control network in accuracy (5a) and response time (5b).

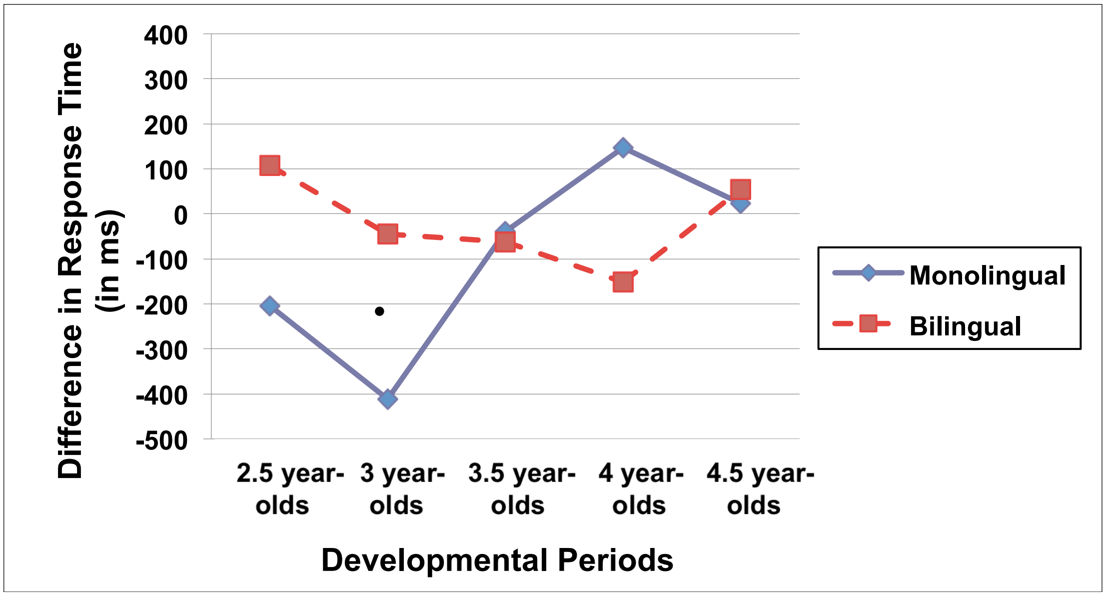


•significant at p<.10



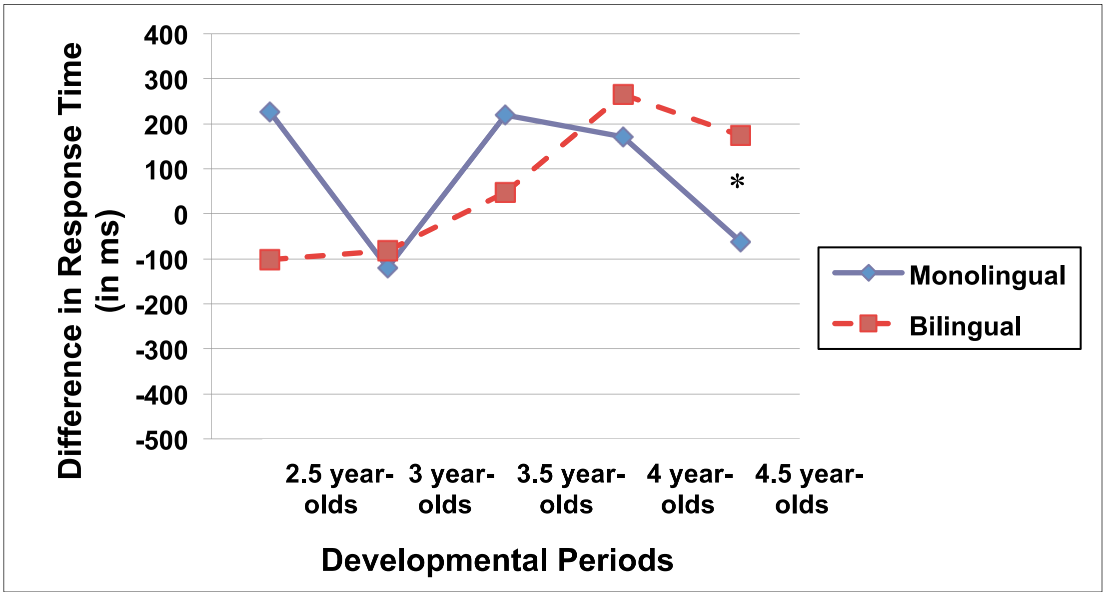
***significant at p<.001
•significant at p<.10

Figure 6. Efficiency of the Orienting network in response time (in ms).



•significant at p<.10

Figure 7. Efficiency of the Alerting network in response time (in ms).



*significant at p<.05

APPENDICES

Appendix A: Socioeconomic Status (SES) Questionnaire

Appendix A1: Self-Rate in the Community

Think of this ladder as representing where people stand in their communities.

People define community in different ways; please define it in whatever way is most meaningful to you. At the **top** of the ladder are the people who have the highest standing in their community. At the **bottom** are the people who have the lowest standing in their community.

Where would you place yourself on this ladder?

Please place a large **"X"** on the rung where you think you stand at this time in your life, relative to other people in your community.

Appendix A2: Self-Rate in the Nation

Think of this ladder as representing where people stand in the United States.

At the **top** of the ladder are the people who are the best off – those who have the most money, the most education and the most respected jobs. At the **bottom** are the people who are the worst off – who have the least money, least education, and the least respected jobs or no job. The higher up you are on this ladder, the closer you are to the people at the very top; the lower you are, the closer you are to the people at the very bottom.

Where would you place yourself on this ladder?

Please place a large **"X"** on the rung where you think you stand at this time in your life, relative to other people in the United States.

Appendix A3: Highest Education Level

What is the highest grade (or year) of regular school you have completed? (Check one.)

Elementary School	High School	College	Graduate School
01____	09____	13_____	17_____
02____	10____	14_____	18_____
03____	11____	15_____	19_____
04____	12____	16_____	20+____
05____			
06____			
07____			
08____			

Appendix A4: Total Household Income

Which of these categories best describes your total combined family income for the past 12 months? This should include income (before taxes) from all sources, wages, rent from properties, social security, disability and/or veteran's benefits, unemployment benefits, workman's compensation, help from relatives (including child payments and alimony), and so on.

_____Less than $5,000

_____$5,000 through $11,999

_____$12,000 through $15,999

_____$16,000 through $24,999

_____$25,000 through $34,999

_____$35,000 through $49,999

_____$50,000 through $74,999

_____$75,000 through $99,999

_____$100,000 and greater

_____Don't know

_____No response