EVALUATING LEXICAL ACCESS AND EXECUTIVE FUNCTION IN MONOLINGUALS, LATE BILINGUALS, AND EARLY BILINGUALS

By

SABRA D. PELHAM

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To my husband, Karl D. Welzenbach

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Sabra D. Pelham

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Previous research has documented both advantages and disadvantages in being an early bilingual, defined as someone who began learning their second language by school age and has used both of their languages since that time. Relative to monolinguals, early bilinguals manifest deficits in lexical access, namely reduced speed in producing words in either language. However, early bilinguals exhibit benefits in executive function, specifically better inhibitory control, interference suppression, and task switching. The present study investigated whether becoming bilingual *after* childhood is sufficient to produce the cognitive advantages and disadvantages typical of early bilinguals. One hundred and thirty-eight participants (54 monolingual English speakers, 54 late English-Spanish bilinguals, and 30 early Spanish-English bilinguals) completed two lexical access tasks and two executive function tasks. The lexical access tasks consisted of a timed picture naming task and a verbal fluency task, and the executive function tasks were a modified version of the Attentional Network Task and an auditory Simon task. Analyses were conducted on both response speed and accuracy, and the results showed that late bilinguals manifested the same general pattern of cognitive effects as early bilinguals across most tasks, although late bilinguals had more 'no response' errors than monolinguals in picture naming. In contrast, early bilinguals appeared to manifest a lexical access advantage relative to

monolinguals in terms of producing fewer invalid responses on verbal fluency. On balance, the overall pattern of results shows that becoming bilingual after childhood results in the lexical access deficits and executive function benefits heretofore only demonstrated in early bilinguals. Of two hypotheses previously proposed to account for bilingual lexical access deficits and executive function benefits, the Language Interference hypothesis can best account for the response speed results, while the Frequency Lag hypothesis cannot. However, neither of these hypotheses provides a straightforward explanation of the patterns of errors in the picture naming task or the overall results from the verbal fluency task.

CHAPTER 1
OVERVIEW

Unlike other animals, humans alone are endowed with the ability to communicate their thoughts to their fellow humans. The cognitive endowment that provides this remarkable ability is language, and psychologists, linguists, and cognitive neuroscientists have conducted considerable research trying to discern precisely how humans can learn, understand, and speak language. Past research has focused primarily on people who speak one language; however the reality for most humans is that they speak two or more languages (Grosjean, 1982; Tucker, 2003). This reality has prompted many scientists to turn their attention and research efforts to bilingualism, its effects on cognition, and the processes whereby bilingual and multilingual people control the languages they speak and understand. As a crucial step in understanding the mechanisms whereby language production and comprehension operate, research has focused on identifying the ways in which monolingual and bilingual people differ. Whereas previous research has documented differences between monolinguals and people who became bilingual in childhood on various cognitive measures, such as lexical access and executive functioning, the purpose of the present experiment was to determine the whether becoming bilingual after childhood is sufficient for these differences to emerge.

Previous studies have demonstrated that monolinguals and bilinguals perform differently on various verbal and nonverbal tasks. On verbal tasks such as picture naming and picture identification, monolinguals identify and name pictures more rapidly and more accurately than do bilinguals in either of their languages (Bialystok, Craik & Luk, 2008; Gollan & Fennema-Notestine, 2007; Gollan, Montoya, Fennema-Notestine & Morris, 2005; Ivanova & Costa, 2008). Similarly, on letter and semantic verbal fluency tasks, where individuals are given sixty seconds to name as many words beginning with a particular letter (letter fluency) or coming from a particular semantic category, e.g., animals (semantic fluency), monolinguals often produce more words than bilinguals regardless of whether bilinguals produce words in their first or second language (Gollan, Montoya & Werner, 2002; Rosselli et al., 2000). This monolingual advantage extends to everyday language use, where monolinguals experience fewer tip-of-the-tongue states (TOTs) than do bilinguals (Gollan, Bonanni, & Montoya, 2005). A TOT occurs when one is certain s/he knows a word or name but cannot retrieve it from memory. As is the case with everyday language use, bilinguals also experience more TOTs in experimental settings (Gollan & Acenas, 2004; Gollan et al., 2005; Gollan & Brown, 2006).

In contrast to these deficits in lexical retrieval, bilinguals demonstrate superior performance on nonverbal tasks of executive function compared to monolinguals. Among other things, executive function includes the ability to control attention such that one can respond quickly to a task, efficiently inhibit customary responses (referred to herein as inhibition), resist distracting information (referred to herein as interference suppression), and switch between task goals (referred to herein as switching) (Banich, 2009). In particular, on tasks that require participants to respond to one aspect of a stimulus while ignoring another salient but irrelevant aspect of the same stimulus, e.g., the Simon task (Simon & Ruddell, 1967) and Stroop task (Stroop, 1935), bilinguals have been shown to respond more quickly and accurately than monolinguals (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Luk, 2008; Carlson & Meltzoff, 2008, Costa, Hernández, Sebastián-Gallés, 2008). Though these tasks differ as described below, both require inhibition of a prepotent response, which requires engagement of executive function to inhibit that response.

In a Simon task, participants press a button with their left or right hand to indicate the direction in which an arrow is pointing. When a left-pointing arrow is presented on the left side of a computer screen (congruent condition), participants are faster to hit the button on the left side than if a left-pointing arrow is presented on the right side of a computer screen (incongruent position). This faster response in the congruent condition occurs because the prepotent response is to hit the button on the side that corresponds to the location on the screen where the arrow appears, and in the congruent condition, the prepotent response and the correct response match. In the incongruent condition, the prepotent response is the incorrect response and therefore must be inhibited. The time difference between incongruent and congruent responses is the Simon effect, and bilinguals have shorter Simon effects than monolinguals because they are slowed less in the incongruent condition.

Similar comparisons between congruent and incongruent conditions occur in a Stroop task, where color words are presented to participants who are required to name the color in which the word is printed. In congruent conditions, color words are printed in a matching ink color (i.e., the word green is printed in green ink), and in the incongruent condition, color words are printed in a color that differs from the color spelled by the word (i.e., the word green is printed in red ink). On this task, the prepotent response is to read the word rather than to name the ink color. People are always slower to respond with the ink color in the incongruent condition where there is a mismatch between the prepotent response and the correct response than in the congruent condition where the prepotent and correct response match. The time difference between incongruent and congruent responses is the Stroop effect. Bialystok et al. (2008) found that bilinguals have significantly smaller Stroop effects than monolinguals because they are less slowed in the incongruent condition than monolinguals. The fact that bilinguals outperform monolinguals in both the Simon and Stroop tasks has led to the conclusion that bilinguals have enhanced executive function relative to monolinguals.

A related task, the Attentional Network task or ANT (Fan et al., 2002) has provided comparable results. However, this task differs from Simon and Stroop tasks, where the stimuli to which participants respond contain conflicting response possibilities and hence require inhibition of a prepotent response. Rather, correctly responding to stimuli on the ANT requires interference suppression, or ignoring distracting information, and suppressing interference from distracting stimuli engages a related but different aspect of executive function than response inhibition. Like the Simon task, on the ANT participants respond with a right or left button press to indicate the direction in which an arrow points. However, on the ANT, the target arrow is presented in the center of the computer screen, rather than on one side or the other of the screen. Consequently, the centrally-presented target arrow on the ANT does not elicit a prepotent response like the laterally presented arrows do on the Simon task. Instead, on the ANT, the centrally-presented target arrow is surrounded by arrows or horizontal lines, referred to as flankers, on both sides of it. When the flankers are arrows, they can point in the same direction as the central target arrow (congruent condition), or they can point in the opposite direction (incongruent condition). The presence of the flanking arrows provides a distraction from the central target arrow. However, when the flanking arrows point in the same direction as the target arrow, the distracting flankers indicate the same response as the target, so they do not interfere with the correct response. On the other hand, when the flankers point in the opposite direction of the target, they provide a distraction that interferes with the correct response. Consequently, in incongruent conditions interference must be suppressed so that participants can respond correctly to the target. Costa, Hernandez, and Sebastian-Galles (2008) conducted an experiment where monolinguals and bilinguals performed the ANT, and as with the Simon and Stroop tasks, bilinguals had smaller conflict effects than monolinguals, (i.e., incongruent minus congruent reaction times were smaller for bilinguals), which in this task suggests a bilingual advantage in suppression of interfering information.

While previous research has highlighted bilinguals' advantage as a reduced cost of responding to a target in the presence of some distracting stimuli (smaller conflict effects), bilinguals also respond more quickly overall than monolinguals on executive function tasks (Bialystok et al., 2004; Bialystok et al., 2008; Carlson & Melzoff, 2008; Costa et al., 2008), a finding that has not typically been described as a bilingual advantage. However, Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) have recently proposed that the bilingual advantage in executive function has two indices: 1) faster reaction times overall on executive function tasks, and 2) reduced conflict effect on tasks like the ANT, Stroop, and Simon tasks. They propose that the first advantage may stem from more effective task monitoring while the second stems from a combination of effective task monitoring and the ability to suppress interference from distracting but irrelevant stimuli. In their study, they manipulated the degree of monitoring required by changing the balance of incongruent to congruent trials. When the balance was 'low-monitoring', i.e., strongly weighted toward one type of trial or the other (i.e., 92% incongruent to 8% congruent or vice versa), bilinguals did not manifest any type of executive function advantage relative to monolinguals. In contrast, when incongruent and congruent trials were evenly balanced (50% for each), referred to as a high-monitoring condition, bilinguals demonstrated an overall reaction time advantage relative to monolinguals but no advantage in terms of a reduced conflict effect. When 75% of trials were congruent and 25% were incongruent, a condition which was also considered high-monitoring but which the researchers referred to as the 'less' monitor-demanding condition, bilinguals responded more quickly than monolinguals and also exhibited a reduced conflict effect. Costa et al. do not specify how the less monitor-demanding condition engages interference suppression to a greater degree than the high monitor-demanding condition, subsequently resulting in a reduced conflict effect of the bilingual group. Rather, they speculate that how bilinguals' executive function benefits manifest may depend on the interaction between task monitoring and interference suppression or it may only depend solely on task monitoring. Whatever the underlying attentional mechanism, these results indicate that bilingual advantages in executive function may manifest as faster overall reaction times, reduced conflict effects, or both. How these benefits manifest themselves appears to depend on the balance of incongruent and congruent trials in a way that has not yet been definitely determined.

Two general hypotheses have been proposed to account for the effects of bilingualism on lexical retrieval and executive function: (1) the Language Interference hypothesis (Bialystok et al., 2008), which was proposed to account for both the lexical retrieval and executive function effects associated with bilingualism, and (2) the Frequency Lag hypothesis (Gollan et al., 2002; Gollan & Acenas, 2004; Gollan et al., 2005), which provides an account for the lexical retrieval deficits. However, understanding these hypotheses requires a basic understanding of the process of lexical retrieval, which is described below.

Monolingual and bilingual lexical access are assumed to operate in essentially the same way, beginning with accessing semantic representations, followed by lexical selection, then phonological encoding, and finally articulation. At the first stage in word production, speakers select the concept they wish to name. All the concepts are part of the semantic store, and research indicates that the semantic store does not differ between monolinguals and bilinguals (De Groot & Nas, 1991; Francis, 1999; Gollan et al., 2005; Kroll & De Groot, 1997; Tokowicz, 2000). All concepts or semantic representations are connected to other semantic representations with which they share conceptual features. For example, in the semantic store, the concept ‘dog’ shares connections with concepts like ‘puppy’, ‘animal’, ‘furry’, ‘bark’, ‘pet’, ‘cat’, etc. Concept selection results in activation of a particular semantic representation or node, and activation flows from the selected node to the next level in the process of word production, lexical selection. It is important to note that activation not only spreads downward to lexical nodes but also laterally to all the semantic nodes in the semantic store with which the selected concept shares connections. It is at the level of lexical selection that speakers identify the specific word they wish to articulate. However, as a consequence of the spread of activation to other concepts in the semantic store, those activated semantic nodes also send activation to lexical nodes, where the words representing those concepts also receive activation. Many researchers agree that this spread of activation to other concepts in the semantic store and subsequent activation of lexical nodes, where the words representing those concepts also receive activation, results in competition between activated words for lexical selection (Costa & Caramazza, 1999; Green, 1998; Levelt, Roelofs, & Meyer, 1999; Starreveld & La Heij, 1996, but see Finkbeiner, Gollan & Carramazza, 2006), which is resolved when the item with the strongest activation is selected for production. Once the correct word is selected, it sends activation to the level of phonological encoding. It is at the level of phonological encoding that the individual speech sounds that make up the word are activated. After successful activation of the sounds that make up the word, articulation proceeds.[1] See Figure 1-1 for clarification of this process.

The difference between monolinguals and bilinguals in the process of lexical access arises at the level of lexical selection. For virtually every concept in the semantic store, bilinguals have

[1] While this general path from concept to articulation is essentially unchallenged, there is still considerable debate about precisely how lexical access, for both monolinguals and bilinguals, proceeds through these levels and whether activation is strictly serial (Levelt, 1989) or parallel (Morsella & Miozzo, 2002) as well as whether activation can feedback from lower to higher levels (Dell, Juliano, & Govindjee 1993). These unresolved issues are noted here but are not relevant for the purposes of the present investigation.

two words, one in each of their languages, that exactly match that concept whereas monolinguals have only one word for each concept. Some researchers have suggested that bilinguals' having multiple words for any given concept results in competition between words in a bilingual's languages (Green, 1998; Kroll, Bobb, & Wodniecka), requiring suppression of interference from and/or inhibition of the non-use language (i.e., the language that a bilingual is not using at any given time), whereas others have proposed that bilingual lexical access is language specific, meaning that only words from the language in use receive activation or are considered for selection (Costa & Caramazza, 1999; Costa, Albared & Santestaban, 2008; La Heij, 2005). Regardless of one's perspective on whether or not bilingual lexical access is language specific, it is widely agreed that, "bilingual lexical access must involve some kind of attentional control." (Costa et al., 2008, p. 60) and that the management of two language systems, which provide two words for virtually every semantic concept, may impact lexical access as well as other aspects of cognition. This assumption leads back to consideration of the hypotheses proposed to account for the various cognitive effects associated with bilingualism, specifically the Language Interference hypothesis.

The Language Interference hypothesis maintains that whenever bilinguals produce words in one of their languages, words from their other language that have the same meaning are activated. This dual activation of words in a bilingual's languages results in constant interference from words in the non-use language. Hence, whenever bilinguals engage in a verbal task, they must utilize some mechanism whereby they successfully employ the desired language while ignoring the other language. To accomplish this multi-tasking, bilinguals are thought to engage executive functions related to controlling attention and inhibiting/suppressing interference. According to the Language Interference hypothesis, a bilingual advantage in executive function arises as a natural result of bilinguals’ constant engagement of executive function in managing their two languages. However, lexical deficits arise as a result of the fact that both of a bilingual’s languages are constantly active whenever s/he engages in any verbal task, and even efficient engagement of executive function cannot fully overcome the effects of the competition that results from having both languages active. Evidence for this hypothesis comes from a number of sources, all of which show that when a bilingual speaks one of his/her languages, the other language is activated and the non-use language impacts word production in the language in use (Colomé, 2001; Costa et al., 1999; Gollan & Kroll, 2001; Hermans, Bongaerts, De Bot & Schreuder, 1998; Knupsky & Amrhein, 2007; Rodriguez-Fornells et al., 2005).

The Language Interference hypothesis provides a viable mechanism whereby the both lexical access disadvantages and executive function advantages associated with bilingualism may arise. There is an alternative hypothesis, the Frequency Lag hypothesis, that suggests frequency of usage may be responsible for the lexical access deficits associated with bilingualism, rather than bilinguals’ need to manage their two languages. According to the Frequency Lag hypothesis, bilinguals experience deficits in lexical retrieval relative to monolinguals because bilinguals access words in each of their languages less frequently than monolinguals access the words in their one language. This reduced frequency of use results in weaker links between semantic concepts and the words that represent those concepts, and these weaker links result in lexical retrieval deficits. Evidence for this hypothesis includes the finding that monolinguals and bilinguals both produce low-frequency words more slowly than high-frequency words, and this difference is exacerbated for bilinguals (Gollan, Montoya, Cera, & Sandoval, 2008). Additionally, while bilinguals experience more tip-of-the-tongue (TOT) states than monolinguals, they do not have more TOTs for proper names, which are the same across languages and so are accessed with equal frequency by monolinguals and bilinguals (Gollan, Bonanni, & Montoya, 2005). This hypothesis is appealing in its simplicity such that no special mechanism particular to bilinguals is posited to account for bilinguals' lexical retrieval deficits. Rather, frequency of use of words affects the strength of the links between lexical nodes and their phonological forms in the same way for both monolinguals and bilinguals. However, this hypothesis provides no explanation of the executive function benefits conferred by early bilingualism because the frequency with which one accesses words is unrelated to and has no obvious theoretical or practical bearing controlling attention, the critical aspect of executive function thought to be enhanced in bilinguals.

The age at which one becomes fluently bilingual and the degree to which age affects the advantages and disadvantages of bilingualism may prove useful in testing the two hypotheses. To date, virtually all the research on the advantages and disadvantages of bilingualism has been limited to early, balanced bilinguals (see Bialystok, Craik, & Ruocco, 2006; Linck, Hoshino, & Kroll, 2008; and Luk, De Sa, & Bialystok, 2011, for exceptions), i.e., bilinguals who have been bilingual since early childhood and have spoken both of their languages on a daily basis since acquiring those languages. One exception is Linck et al. (2008), who found executive function benefits for late bilinguals relative to monolinguals on a Simon task. The focus of this paper was comparisons of late immersed bilinguals, late non-immersed bilinguals, and monolinguals using data collected for other studies. However, the previous studies did not include data from early bilinguals, so the authors could not assess whether or not late and early bilinguals differed. Furthermore, only one study has investigated lexical retrieval deficits and executive function benefits in the same study with the same group of bilingual participants (Bialystok et al., 2008), but this study only measured accuracy of lexical retrieval, not response times. Assessment of the speed with which people access the picture names can speak more definitively to the issue of lexical access because the speed with which one can produce a picture's name reflects the efficiency of activation in word production. It also more closely parallels the measures used in the executive function tasks, which are typically speed-based.

The fact that previous research has only been conducted with early bilinguals leaves open the question of whether or not other types of bilinguals manifest these same cognitive effects. Previous research has shown that, among other things, bilingual lexical processing differs according to bilinguals' age of second language acquisition, history of first and second language use, and degree of first and second language proficiency and dominance (Kroll & de Groot, 1997; Marian, Blumenfeld, & Kaushanskaya, 2007). Therefore, it seems reasonable that more general cognitive processing might differ according to these factors as well. Given that, the question that arises is how long one must be bilingual for the cognitive effects associated with bilingualism to arise. It is possible that the effects associated with bilingualism result from developmental changes that occur when people learn two languages as children. If so, then people who become fluent in a second language at a later age may never manifest either lexical retrieval or executive function effects. On the other hand, it is possible that the cognitive effects associated with bilingualism arise from practice in using two languages. If so, then there should be a point at which bilinguals have attained sufficient practice in using their languages for the cognitive effects to emerge. However, there is no research to indicate how much practice might be sufficient to affect cognitive changes, a research question that will be explored in the present study.

The purpose of the present study was to determine if young adults who are fluent bilinguals but acquired their L2 in their teenage years, herein referred to as late bilinguals, manifest executive function benefits or lexical retrieval deficits in either of their languages. To investigate this question, both monolinguals and early bilinguals will serve as comparison groups. A monolingual comparison group is necessary to determine if the late bilinguals differ from monolinguals in terms of lexical access and executive function. The early bilingual comparison group is necessary to determine if becoming fluently bilingual after childhood is sufficient to cause the same degree of executive function benefits and lexical access deficits typical of early bilinguals. This study will be the first to compare the performance of early versus late bilinguals on lexical retrieval deficits and executive function benefits using multiple dependent measures.

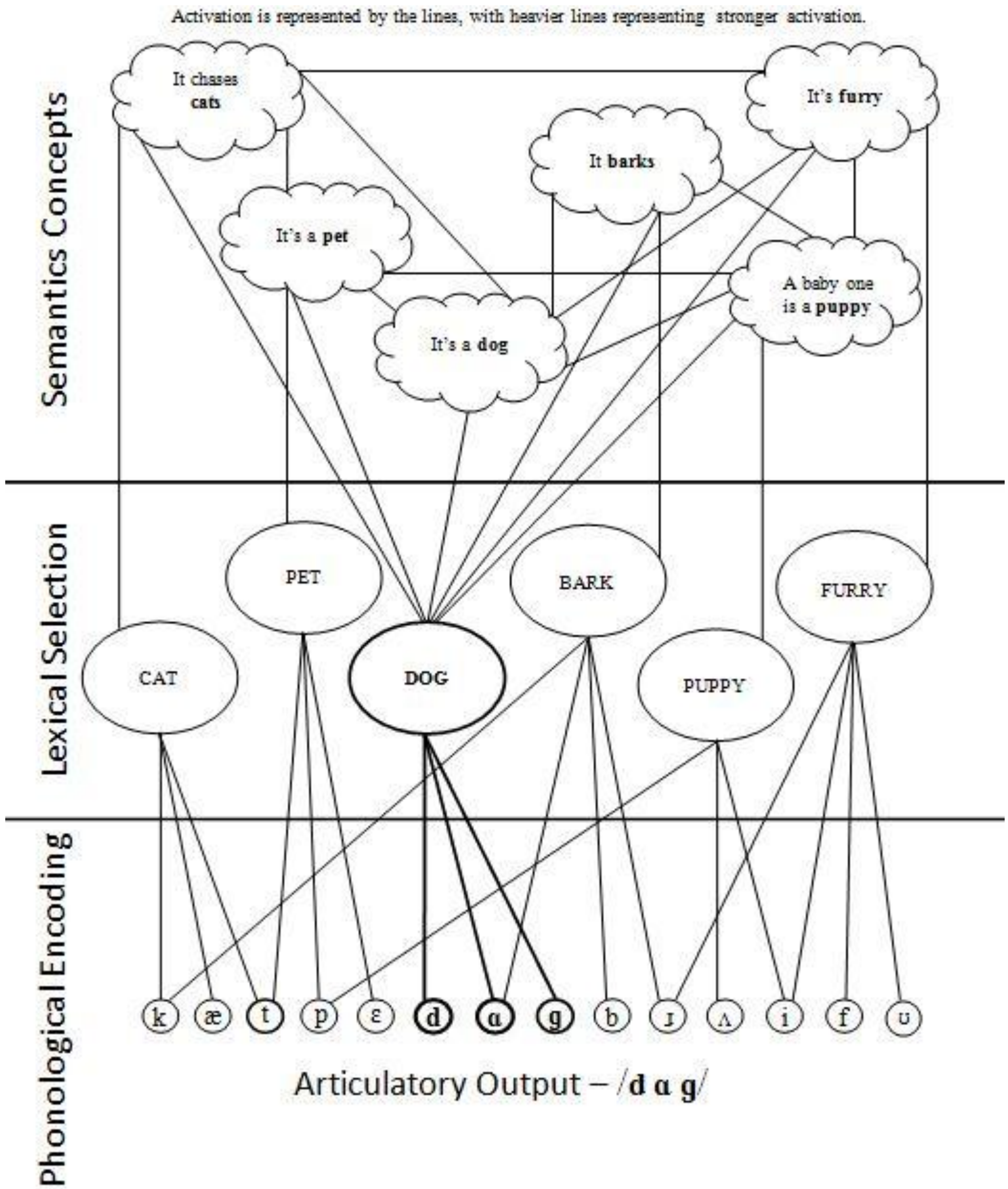

Figure 1-1. Lexical access from concept selection to phonological encoding

CHAPTER 2
HYPOTHESES

The hypotheses in this section were designed to address two specific research questions. The first research question investigates whether people who become bilingual after childhood manifest the same cognitive effects of bilingualism as early bilinguals. To evaluate this question, three groups of participants completed several lexical retrieval and executive function tasks. The lexical retrieval tasks consisted of a timed picture naming task and verbal fluency tasks, and the executive function tasks were an auditory Simon task and the ANT. Details of these tasks are provided in the methods section that follows the hypotheses. The three groups were monolingual English speakers, late English-Spanish or Spanish-English bilinguals, and early Spanish-English or English-Spanish bilinguals. No study to date has investigated both lexical retrieval and executive function effects in participants who differ in the age at which they became fluently bilingual. By comparing *late bilinguals* to *monolinguals* on executive function tasks and on lexical access tasks in their dominant language, we assessed whether becoming bilingual after childhood is sufficient to produce executive function benefits and/or lexical access deficits. By comparing *late bilinguals* to *early bilinguals* on executive function tasks, we determined whether becoming bilingual after childhood is sufficient to produce the same degree of executive function benefits as early bilingualism. We also compared these two bilingual groups on lexical access tasks when producing responses in the dominant language, non-dominant language, or a condition where either language was acceptable. This manipulation allowed us to determine whether bilinguals' lexical access differed when production tasks were constrained to one language as opposed having the option to use either language to respond.

The second research question explored the extent to which the Frequency Lag hypothesis and the Language Interference hypothesis can account for the cognitive effects associated with bilingualism. Executive function tasks can be used to test the Language Interference hypothesis by determining with which group the late bilinguals align on these tasks. Lexical access tasks can test both the Frequency Lag and the Language Interference hypotheses, with late bilinguals helping to elucidate whether language interference or frequency of access is responsible for the lexical access deficits typical of early bilinguals.

Hypothesis 1

On lexical access tasks where responses are in English for monolinguals and in the dominant language for early and late bilinguals, early bilinguals were predicted to show greater lexical access deficits than late bilinguals, who in turn will have no lexical access deficits (i.e., equivalent lexical access) relative to monolinguals.

If this hypothesis is supported, it would be consistent with the Frequency Lag hypothesis, where monolingual speakers of English and late English-Spanish or Spanish-English bilinguals have accessed the words in their dominant language with approximately the same frequency and consequently are equivalent on tasks of lexical access. Early bilinguals, on the other hand, have accessed words in their dominant language much less frequently than either the monolinguals or the late bilinguals, causing them to manifest lexical retrieval deficits compared to the monolinguals and late bilinguals. In contrast, these findings would not support the Language Interference hypothesis because if lexical access deficits arise from the effort of managing two languages, then late bilinguals should show lexical access deficits in their dominant language despite the fact that they have accessed words in that language with approximately the same frequency as the monolingual group.

Hypothesis 2:

On lexical access tasks where responses were given in either language, bilinguals' performance was predicted to either not differ from, or be better than, their performance on those tasks when their responses were in the dominant language.

While bilinguals' performance on lexical access was also assessed in the non-dominant language, the comparison between the dominant language and either language conditions is the critical comparison for this hypothesis because the results of this comparison have the potential to shed light on whether the Frequency Lag or Language Interference hypothesis provides a better explanation for bilingual lexical access disadvantages. If this hypothesis is supported, it would be consistent with the Frequency Lag hypothesis in that if higher frequency words are produced faster than lower frequency words, then higher frequency words should come to mind first irrespective of language, and these should be produced as fast as or faster than when participants are constrained to the dominant language only. On the other hand, this result would be inconsistent with the Language Interference hypothesis because allowing participants to choose in which language could result in greater language interference than if participants were constrained to using only their dominant language. When given the option of responding in either language, words from both languages may be more active than if participants were constrained to using only their dominant language. If words for the same concept from both languages are equally activated (or more equally activated than when participants are constrained to the dominant language only), then choosing which word to produce should take longer, causing bilinguals to respond more slowly and with fewer exemplars in the either language response condition than in the dominant language response condition.

Hypothesis 4:

On executive function tasks, early bilinguals were predicted to have smaller conflict effects than late bilinguals, who in turn will have smaller conflict effects than monolinguals.

If this hypothesis is supported, it will suggest that the executive function benefits associated with bilingualism result from practice in using two languages and therefore do not arise from developmental changes in executive function that occur in childhood when one grows up being bilingual. Furthermore, it will demonstrate that the degree of executive function benefits associated with bilingualism is somehow related to the *amount* of practice bilinguals have in using their two languages, where the combination of learning a second language later in life and having used that language less than early bilinguals results in insufficient practice to obtain maximal executive function benefits. If late bilinguals have the same degree of executive function benefits as early bilinguals, it will suggest that being fluently bilingual confers executive function benefits whether one becomes bilingual as a child or as a young adult. If late bilinguals have executive function benefits relative to monolingual that are either less than or equivalent to those of early bilinguals, both of these results would be consistent with the Language Interference hypothesis, under which the effort of managing interference between two languages results in executive function benefits. However, if late bilinguals have no executive function benefits relative to monolinguals, that result would not be consistent with the Language Interference hypothesis.

CHAPTER 3
METHOD

Participants

Fifty-four monolingual English speakers (61% female, 81.5% Caucasian), 30 late bilinguals fluent in English and Spanish (53% female, 46.6% Caucasian, 56.4% Hispanic), and 56 early bilinguals also fluent in both English and Spanish (77% female, 100% Hispanic) were recruited from graduate and undergraduate courses at the University of Florida as well as via newspaper advertisements in the university newspaper. Participants enrolled in courses with a research requirement received partial course credit for participation, while participants who were not in a class for which they had a research requirement were paid $10 per hour for their participation. Monolinguals' and bilinguals' demographic characteristics as well as performance on several cognitive tests are presented in Table 3-1. The groups differed significantly in terms of age, $F(2, 137) = 18.33$, $MSE = 5.48$, $p < .01$, where late bilinguals were older than early bilinguals ($p < .001$), who were older than monolinguals ($p = .03$). The groups also differed in years of formal education, $F(2, 137) = 12.91$, $MSE = 5.41$, $p < .01$, with monolinguals having fewer years of formal education than both bilingual groups ($ps < .001$), who did not differ ($p = .21$). The groups also differed marginally on their backward digit spans, $F(2, 137) = 2.44$, $MSE = 4.55$, $p = .09$, with late bilinguals having longer backward digit spans than monolinguals ($p = .03$); no other group differences were significant ($ps > .19$). The groups did not differ on their forward digit spans, self-reported college grade point averages, or self-reported health ratings, $Fs < 1$.

Participants were prescreened for their monolingual or bilingual status, either through a pre-screening questionnaire on the university's psychology participant website or via e-mail through questions about how many languages they spoke and the age at which they began learning and subsequently became fluent in those languages. If they fit the prescreen criteria, they then completed the Language Experience And Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld & Kaushanskaya, 2007). This questionnaire assessed participants' age of acquisition, age of fluency, proficiency in speaking and understanding, and daily usage of all the languages that they had ever learned or studied. On the basis of their responses on the LEAP-Q, participants were categorized as monolinguals, late bilinguals, or early bilinguals. To be classified as monolingual, participants were required to report English as their first and dominant language and indicate a proficiency level of 3 or below on a 10-point scale (0 = *none*, 1 = *very low*, 2 = *low*, 3 = *fair*, 4 = *slightly less than adequate*, 5 = *adequate*, 6 = *slightly more than adequate*, 7 = *good*, 8 = *very good*, 9 = *excellent*, and 10 = *perfect*) in any languages other than English that they had studied. Participants in the monolingual group reported proficiency in speaking and understanding their L2 well below this threshold (speaking proficiency, $M = 1.17$, $SD = .63$; proficiency understanding L2, $M = 1.23$, $SD = .78$). In addition, the majority of these participants had never spent any time in a place where their L2 was spoken, had only studied another language while in school, and were not currently speaking this language.

To be categorized as bilingual, participants' proficiency in both English and Spanish was first assessed via oral production. Bilinguals’ proficiency in English was demonstrated by completing the majority of the experiment in English, which required reading and understanding task instructions as well as giving at least a third of their responses on verbal tasks in English. To evaluate both receptive comprehension of and spontaneous speech in Spanish, participants were interviewed by native Spanish-speaking research assistants. The interview consisted of a brief script of questions (see Appendix A for English translations) as well as a separate demographic questionnaire, both of which were given orally in Spanish. Participants who could not carry on a fluent conversation in Spanish were subsequently not allowed to participate in the experiment (approximately 14 would-be bilingual participants,10 late bilinguals and 4 early bilinguals, were rejected for this reason and were not included in the numbers of participants described above on). This screening process resulted in all but four of the bilingual participants having a minimum self-reported proficiency on the LEAP-Q of 7 or above in speaking and understanding Spanish and English; the four participants who rated their proficiency in in one of their languages below a 7 were nonetheless categorized as fluently bilingual because of their performance on the conversational interviews.

Bilingual participants were categorized as late or early bilinguals based on the age at which they began to learn and subsequently became fluent in their L2. To be categorized as a late bilingual, participants had to become fluent in their L2 no earlier than 13 years of age. We did not have a strict criteria for the age at which late bilinguals began acquiring their L2, as many of the participants indicated that they began acquiring Spanish in kindergarten when they were taught how to count in Spanish. Despite the early age of acquisition that these participants reported, they all indicated that they never actually began studying the language seriously until middle school or later. To be categorized as an early bilingual, participants had to begin acquiring their L2 by school age, and they had to become fluent in their L2 no later than nine years of age.

Independent-samples *t*-tests were conducted on several aspects of late and early bilinguals' language history, which are shown in Table 3-2. As intended, the two bilingual groups did differ significantly on their age of L2 acquisition, $t(84) = 11.36$, $p < .01$, the age at which they became fluent in their L2, $t(84) = 20.72$, $p < .01$, and the number of years they had been fluently bilingual, $t(84) = 16.04$, $p < .01$. On average, late bilinguals began acquiring L2 7.8 years later than early bilinguals, became fluent in their L2 12.3 years later than early bilinguals, and had been fluently bilingual for 10 years less than early bilinguals. With respect to the other self-report ratings in Table 3-2, late bilinguals consistently reported higher ratings in L1 than early bilinguals, who reported higher ratings in L2 than late bilinguals. This pattern occurred for the percent of exposure to their L1, $t(83) = 2.86$, $p = .005$, percent of exposure to their L2, $t(83) = 3.14$, $p = .002$, percent of time speaking their L1, $t(83) = 3.94$, $p < .001$, percent of time speaking their L2, $t(83) = 4.53$, $p < .001$, proficiency in speaking their L1, $t(84) = 5.11$, $p < .001$, proficiency in speaking their L2, $t(84) = 6.40$, $p < .001$, proficiency in understanding their L1, $t(83) = 2.12$, $p = .04$, and proficiency in understanding their L2, $t(83) = 5.78$, $p < .01$.

However, L1 and L2 may not be the most appropriate comparisons for late and early bilinguals because the majority of the early bilinguals (41 of 56) reported reversed dominance, i.e. their dominant language was their L2, which was English for all the reversed dominance early bilinguals. For the remaining 15 early bilinguals, English was the first and dominant language for 10 of them, while Spanish was the first and dominant language for the remaining 5 early bilinguals. In contrast, all but one of the late bilinguals stated that their dominant language was their L1, which was English for 15 of the participants and Spanish for 14 of them. The one reversed dominance late bilingual's L1 was Spanish but her dominant language was English. Hence, comparing late and early bilinguals on ratings in their dominant and non-dominant languages (Table 3-3) is necessary to overcome this confound. T-tests revealed that the groups differed in their self-rated proficiency in speaking their non-dominant language, $t(84) = 2.24$, $p = .03$, and in their proficiency in understanding their non-dominant language, $t(83) = 4.03$, $p < .001$, both of which result from early bilinguals reporting greater proficiency than late bilinguals. The groups also differed marginally in their percent of exposure to their dominant language,

$t(83) = 1.93$, $p = .06$, with early bilinguals reporting more exposure than late bilinguals; conversely, late bilinguals reported slightly more exposure than early bilinguals to their non-dominant language, $t(83) = 1.64$, $p = .10$. The groups were equivalent on percent of time speaking their dominant language, $t(83) = 1.18$, $p = .24$, percent of time speaking in their non-dominant language, $t < 1$, proficiency speaking their dominant language, $t < 1$, and proficiency understanding their dominant language, $t < 1$.

The foregoing results indicate that if the bilingual groups were compared in their L1 and L2, any effects in the L1/L2 comparisons would likely result from late bilinguals being compared in their dominant language (L1) to early bilinguals in their non-dominant language (L1). As can be seen in Table 3-2, the bilingual groups differed significantly on every measure when comparing the groups in L1 and L2. However, when comparing them in their dominant language (Table 3-3), they only differed marginally in their percent of daily exposure, and in their non-dominant language they only differed in their self-rated proficiencies in speaking and understanding. In past research, it was not necessary to differentiate L1 and L2 from dominant and non-dominant language, especially if bilinguals were being compared in both of their languages to monolinguals who had only one language[1]. However, in this study, where bilingual groups were compared to one another in both of their languages, it was critical that they be compared in the languages where they were most evenly matched, and for this group of participants, the demographics demonstrate that the most balanced comparisons result from comparing dominant and non-dominant language performance. Hence, all analyses will use bilinguals' dominant and non-dominant languages for comparison instead of their L1 and L2.

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[1] However, some past studies only compared monolinguals to bilinguals' when they were using only one of their languages without ascertaining whether or not that language was their dominant language (e.g. Bialystok et al., 2008a; Portocarrero, Burright & Donovick, 2007). In such studies, any group difference may have resulted from the monolinguals being compared when using their only (dominant) language to bilinguals when using their non-dominant, which may have been their non-dominant language.

Materials and Procedure

Lexical Access

Previous research comparing lexical access in monolinguals and bilinguals has employed picture naming and verbal fluency tasks, and lexical access in the present study was evaluated using these tasks. Task order was counterbalanced across participants. All of the tasks were presented via computer programs written in Visual Basic® 5.0.

Picture naming

For the picture naming task, 231 black and white line drawings were selected from the Snodgrass and Vanderwart (1980) picture set. All 231 pictures used in the present study were normed for Spanish on the dimensions of name agreement, image agreement, familiarity, and visual complexity (Sanfeliu & Fernadez, 1996), and word frequency data in Spanish and English (Cuetos, Ellis & Alvarez, 1996) were available for 211 of our pictures. These 211 pictures were divided into three blocks that were matched on mean English word frequency and Spanish word frequency, and a one-way ANOVA using set as a factor conducted on word frequency (separately for English and Spanish) revealed no main effect (Fs < 1), indicating that the pictures in each blocks were equivalent on word frequency. The remaining 20 pictures for which no frequency data were available were divided between the 3 blocks. This picture set also contained 39 cognates, and the number of cognates was similar across the frequency-balanced blocks, with one block containing 14 cognates, one containing 13 cognates, and the other containing 12 cognates. Each block of 77 pictures began with two practice pictures followed by 75 experimental pictures.

Monolingual participants named all the pictures in English, while bilingual participants named pictures in three consecutive blocks: one third of the pictures were named in English, one third in Spanish, and one third in either language, and in this last condition, participants were instructed to respond with picture names and exemplars in whichever language came to mind first.. Order of blocks was counterbalanced across participants and order of instructed language to use was also counterbalanced across the bilingual groups. Each picture appeared one at a time for 3 seconds, and participants were instructed to name each picture aloud as quickly as they could. Participants self-advanced to the next picture after naming a picture by pressing the enter key. If they did not name a picture in the allotted 3 seconds, the picture disappeared, and the next trial will began. For each picture, the program recorded an audio wavefile from the time a picture appeared on the screen until the participant pressed the enter key after saying the picture's name or until the trial ended. Voice onset times were extracted from each audio file using a separate Visual Basic program written for this purpose.

Verbal fluency

Participants completed both semantic and letter verbal fluency tasks. In the semantic fluency task, participants named items in three semantic categories: animals, occupations, and fruits and vegetables. In the letter fluency task, letter categories consisted of words that start with P, E, and M. These letters were selected because both English and Spanish had approximately equal numbers of words beginning with each of these letters as determined by comparing numbers of dictionary entries for each letter in each of the two languages. In each task, participants were given 60 seconds to verbally provide as many exemplars as they were able for each category or letter, and their responses were recorded, after which the recorded responses were reviewed and the number of correct exemplars and errors were tallied. Monolingual participants completed all semantic and letter fluency tasks in English. Bilingual participants completed one semantic and one letter fluency task in English, one of each in Spanish, and one each in either language. The order of presentation of semantic and letter categories and response language conditions were counterbalanced across participants.

Executive Function

Participants completed two different tasks, the ANT and an auditory Simon task, that engage executive function.

Attentional network task (ANT)

The ANT was designed to tap into different aspects of the attentional network, specifically alerting, orienting, and executive attention. As already noted, Costa et al. (2007) used the ANT in their comparison of monolinguals and bilinguals and found that bilinguals had smaller conflict effects than monolinguals, i.e., the difference between reaction times to incongruent trials minus reaction times to congruent trials was smaller for bilinguals than monolinguals, indicating that bilinguals in the study had better executive function than the monolinguals. While some executive function tasks have failed to reveal differences between young adult monolinguals and bilinguals, e.g. the visual Simon task (Bialystok, Craik, Grady et al., 2005) and a modified antisaccade task (Bialystok, Craik, & Ryan, 2006), the ANT was used successfully by Costa et al. to reveal such differences.

Participants sat in front of a computer screen with a computer keyboard in front of them, and stimuli appeared on the computer screen one at a time. The task for participants was to press a keyboard button on the side of the keyboard that corresponded to the direction in which a centrally presented arrow was pointing (see Figure 3-1 modified from Fan et al. 2002). The target arrow appeared in the middle of the computer and could appear in one of two conditions: 1) a right pointing arrow, or 2) a left pointing arrow. The flankers that surrounded the arrow could appear in one of three conditions: 1) two short horizontal lines appeared on both sides of the target arrow; 2) two left-pointing arrows appeared on each side of the target arrow; or 3) two right-pointing arrows appeared on both sides of the target arrow. There was a central fixation point on the computer screen in the form of a plus sign, and on each trial the target arrow and flankers appeared above or below the central fixation point. In the original implementation of the ANT and in the Costa et al. (2008) experiment, appearance of the target and flankers on each trial occurred following one of four cue conditions, where the cue was one or two asterisks. This manipulation measured alerting and orienting, and the cue conditions were as follows: 1) no cue; 2) a single central alerting cue, where a single asterisk replaced the fixation point; 3) a double alerting cue, where one asterisk appeared above the fixation point and another appeared below the fixation point; and 4) a single orienting cue where an asterisk appeared either above or below the fixation point in the location where the target arrow and flankers subsequently appeared on the trial that followed.

To simplify the ANT in the present study, the cue conditions were reduced to only two: 1) no cue and 2) the double alerting cue. This change was made for several reasons. First, fewer cue conditions reduced the total different target presentations by half, allowing for twice as many trials in each condition and increasing the power of the experiment to reveal differences between the groups without lengthening the experiment. Second, the single central alerting cue condition and the single orienting cue conditions were selected for removal because in the Costa et al. study, these manipulations did not result in differential benefits between the monolinguals and bilinguals. In contrast, the no cue and double cue conditions were included because the bilinguals did show a relative advantage in the double cue condition.

Participants' accuracy and response times were recorded from the onset of the target stimulus to the time when participants responded. Following Fan et al. (2002), participants completed a practice block of 24 trials with feedback, and then they completed 3 blocks of 96 trials with no feedback (two target directions x three flanker conditions x two target and flanker locations x two cue conditions x four repetitions). Hence, in each block, participants completed four trials in each condition in random order. One third of the trials were congruent, one third were incongruent, and one third were neutral.

Each trial lasted 4000 ms. Once a trial began, there was a variable delay ranging from 400 to 1600 ms, where only the fixation was visible on the screen. After the fixation disappeared, there was a 100 ms delay during which a cue appeared if the trial called for a cue, followed by a 400 ms delay after which the target and flankers appeared. The target and flankers remained on the screen for 1700 ms or until the participant responded. The trial then continued with only the fixation point on the screen until 3500 ms had passed, after which the next trial began. The time course for each trial resulted in variable inter-trial intervals and unpredictable timing of the appearance of the target on each trial.

Simon task

The Simon task has been used extensively by Bialystok and colleagues to evaluate executive function in monolingual and bilingual participants, and this task provides a good behavioral measure of participants' ability to inhibit a prepotent response and therefore demonstrate control of executive function. Whereas researchers have typically used a visual Simon task, minimal practice with a visual Simon task has been shown to improve performance on the task, and these practice effects are manifest from five minutes to as long as a week after the initial practice session (Vu, Proctor & Urcuioli, 2003). The relevance of practice effects in comparing monolinguals and bilinguals is that practice may reduce potential differences between monolinguals and bilinguals, which may already be relatively small and therefore difficult to detect without a large number of participants. However, Vu et al. found that practice did not improve performance on an auditory Simon task. Therefore, the present study used an auditory Simon task in hopes of detecting group differences.

For the auditory Simon task, participants sat in front of a computer keyboard, and they heard either a high or a low tone. When they heard a tone, their task was to press a key on either the right or the left side of the keyboard, according to the instructions they were given prior to beginning the task. One of the tones corresponded to a keystroke on the right side of the keyboard, and the other of which corresponded to a keystroke on the left side of the keyboard. For half the participants, a high tone was paired with a keystroke on the right side of the keyboard, and a low tone was paired with a keystroke on the left side of the keyboard. For the other half of the participants, the pairings were reversed. Participants listened to the tones with headphones, and during the experimental blocks, tones were delivered in one of three conditions: in stereo to both the left and right ear, to the left ear only, or to the right ear only. Thus, tones could be neutral, congruent, or incongruent. They were neutral if delivered in both ears and so not biasing a prepotent right or left keystroke; they were congruent if presented on the right and indicating a right keystroke or presented on the left and indicating a left keystroke, and they were incongruent if presented on the right but indicating a left keystroke or presented on the left but indicating a right keystroke. Participants' accuracy and reaction times were measured from the onset of the tone presentation until a keystroke response. Prior to the beginning the experimental blocks, participants completed a training block consisting of 24 practice trials during which participants learned to associate the high and low tones with the appropriate left or right keystroke. During the practice block, tones were delivered in stereo, and throughout both the practice and experimental blocks the word “incorrect" appeared on the computer screen when participants responded incorrectly. Following Vu et al. (2003), after completion of the training block, subjects completed 3 experimental blocks each consisting of 72 trials (two tones (high vs. low) x three positions (right vs. left vs. stereo delivery) x 12 repetitions).

Each trial lasted 3000 ms. Once a trial began, there was a variable delay ranging from 400 to 1300 ms, where only the fixation was visible on the screen. After that, the target tone played for 250 ms, and participants had 1700 ms to respond. The trial then continued with only the fixation point on the screen until 3000 ms had passed, after which the next trial began. The time course for each trial resulted in variable inter-trial intervals and unpredictable timing of the target on each trial.

Table 3-1. Monolinguals and bilinguals' demographic characteristics and cognitive tests

	Group					
	Monolinguals		Late Bilinguals		Early bilinguals	
Variable	Mean	SD	Mean	SD	Mean	SD
Age (years)***	19.15	2.05	22.37	3.31	20.11	1.96
Education (years)***	13.44	2.74	15.90	2.50	15.22	1.72
Health (1-10 scale)	8.43	1.16	8.07	1.44	8.41	1.16
College GPA (out of 4.0)	3.36	0.68	3.47	0.37	3.33	0.41
Forward Digit Span	9.11	1.95	9.17	2.59	8.86	2.19
Backward Digit Span*	6.48	1.92	7.53	2.05	7.02	2.63

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 3-2. Bilinguals' L1 & L2 self-reported language history

	Group			
	Late Bilinguals		Early bilinguals	
Variable	Mean	SD	Mean	SD
Age of L2 Acquisition (years)**	11.60	4.77	3.70	2.11
Age Fluent in L2 (years)**	17.97	3.21	5.73	2.32
Years Fluently Bilingual**	4.4	2.76	14.38	2.74
% Exposure to L1*	55.33	24.88	40.62	21.36
% Exposure to L2*	41.47	24.09	57.55	21.69
% Time Speaking L1**	60.17	20.06	39.98	23.83
% Time Speaking L2**	34.77	21.05	58.85	24.49
Proficiency Speaking L1 (1-10 scale) **	9.73	0.52	8.64	1.10
Proficiency Speaking L2 (1-10 scale)**	7.63	1.07	9.20	1.09
Proficiency Understanding L1 (1-10 scale)*	9.8	0.48	9.48	0.74
Proficiency Understanding L2 (1-10 scale)**	8.14	1.13	9.46	0.93

* $p = .05$, ** $p < .001$

Table 3-3. Bilinguals' dominant & non-dominant self-reported language history

	Group			
	Late Bilinguals		Early bilinguals	
Variable	Mean	SD	Mean	SD
% Exposure to Dominant Language*	56.00	24.19	64.71	16.73
% Exposure to Non-Dominant Language*	40.80	23.84	33.45	17.18
% Time Speaking Dominant Language	58.83	20.71	64.53	21.56
% Time Speaking Non-Dominant Language	36.10	22.04	34.31	20.48
Proficiency Speaking Dominant Language (1-10 scale)	9.67	0.61	9.57	0.68
Proficiency Speaking Non-Dominant Language (1-10 scale)**	7.70	1.15	8.27	1.10
Proficiency Understanding Dominant Language (1-10 scale)	9.73	0.58	9.75	0.48
Proficiency Understanding Non-Dominant Language (1-10 scale)***	8.21	1.18	9.20	1.02

* $p < .10$, ** $p < .05$, *** $p < .01$

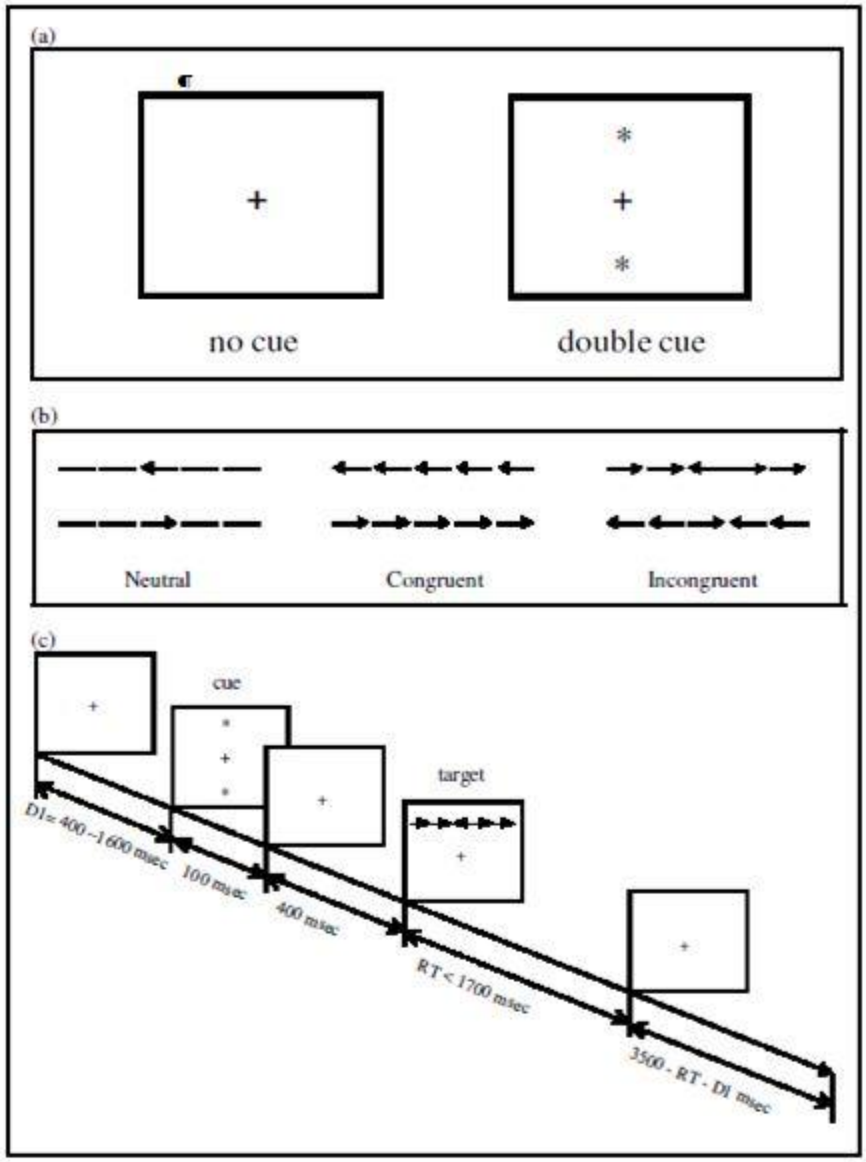

Figure 3-1. Stimuli & procedure for modified attentional network task

CHAPTER 4
RESULTS

Picture Naming

Reaction Times

Prior to performing ANOVAs on the reaction time data for the picture naming task, practice trials, incorrect responses where participants provided the wrong picture-name, trials where participants provided dysfluent responses (i.e., coughing or stuttering before saying a picture's name), and trials where participants said extra words prior to naming the picture (e.g. saying "a book", instead of "book") were excluded. The data were then examined for normalcy, and results indicated that the data were positively skewed such that the z-scores for the skew values exceeded the maximum allowable threshold (± 2) for parametric statistical analyses. Consequently, the data were trimmed of outliers as described below. Mean reaction times were calculated by participant group and picture naming language, and using the resulting means and standard deviations, the data were trimmed of outliers that were more than 3 standard deviations above or below the mean. Trimming resulted in a loss of 2.1% of the data for the monolingual participants, 2.0% of the late bilingual data, and 3.2% of the early bilingual data. The trimmed data were then explored for normalcy, and all data were found to be normal except for the early bilinguals' picture naming times in their dominant language. Given this, the trimmed data were transformed using a square root transformation, which normalized the data. Analyses on the transformed data are reported below, although the means and SD from the untransformed data are also presented for clarity. Analyses on the untransformed data led to identical outcomes as the transformed data.

Comparisons of monolinguals and bilinguals.

One-way ANOVAs compared the three groups on their naming times in their dominant language, and Table 4-1 provides the means and standard deviations for each group on both the transformed and untransformed data. Analysis yielded a significant main effect, $F(2, 135) = 4.26$, $MSE = 18.45$, $p < .016$, $\eta^2 = .06$. Bonferroni post-hoc tests revealed that monolinguals named pictures more quickly than early bilinguals, $p = .03$, and marginally more quickly than late bilinguals, $p = .08$, with no difference between the bilingual groups ($p = 1.0$).

Comparisons of late and early bilinguals

Bilingual participants were then compared when naming pictures in the dominant, non-dominant language, and either language conditions, and the 2 (Group: Late Bilinguals, Early bilinguals) x 3 (Instructed Language: Dominant Language, Non-Dominant Language, Either Language) mixed-factorial ANOVA revealed a main effect of instructed language, $F(2, 164) = 49.60$, $MSE = 3.11$, $p < .001$, $\eta^2 = .37$, such that participants produced picture names significantly more slowly in their non-dominant language ($M_{\text{untransformed}} = 1072.59$, $SD = 175.39$) than in the either language condition ($M_{\text{untransformed}} = 1003.20$, $SD = 185.80$), which was slower than picture naming times in their dominant language ($M_{\text{untransformed}} = 895.65$, $SD = 147.04$). However, there was no main effect of group and no interaction, *F*s < 1. Table 4-2 shows these data.

Accuracy and Errors

Picture naming accuracy and errors were broken down into several categories each discussed in turn below. Accurately named pictures were calculated as the percentage of correctly named pictures out of all the pictures that were presented; hence, total errors would be 1 minus the proportion of accurately named pictures. *No response* errors were calculated as the percentage of trials to which participants failed to respond out of all the pictures that were presented. *Wrong word* errors were calculated as the percentage of incorrectly named pictures out of all the pictures that were named. Responses were considered to be wrong-word errors if they were clearly not an acceptable name for the picture (e.g. saying 'fox' for a picture of a 'skunk'). If participants provided a name for a picture that was not the intended target but was nonetheless a possible name for the picture (e.g. saying 'pistol' for a picture of a handgun where the target was 'gun'), such responses were considered correct alternates and were not included as wrong-word errors. Also not included in wrong-word errors were superordinate labels for pictures (e.g. saying 'bird' for a picture of an eagle). *Dysfluency* errors, i.e., providing the correct word but stammering stuttering or otherwise pausing after first making a sound or beginning to say the word, were calculated as the percentage of picture names that were produced with a dysfluency out of all picture names that were produced.

Accurately named pictures: monolinguals and bilingual comparisons

One-way ANOVAs compared the three groups on their percentage of correctly named pictures, and results revealed a significant main effect, $F(2, 134) = 4.71$, $MSE = .008$, $p = .01$, $\eta^2 = .07$, such that late bilinguals accurately named significantly fewer pictures ($M = 92.02\%$, $SD = 7.96\%$) than monolinguals ($M = 95.50\%$, $SD = 2.93\%$), $p = .008$. However, early bilinguals ($M = 94.21\%$, $SD = 4.46\%$) did not differ from monolinguals, $p = .55$, or from late bilinguals, $p = .17$.

Accurately named pictures: late and early bilingual comparisons

The bilingual groups' percent of accurately named pictures was compared in their dominant language, non-dominant language and in the either language condition in a 2 (Group) x 3 (Instructed Language) mixed-factorial ANOVA. Results revealed a significant effect of instructed language, $F(1, 81) = 5.73$, $MSE = .002$, $p = .02$, $\eta^2 = .07$, such participants accurately produced significantly more picture names when instructed to name in either language ($M = 94.61\%$, $SD = 4.22\%$) than in their dominant language ($M = 93.42\%$, $SD = 6.01\%$) , $p = .02$, both of which resulted in more accurate picture naming than pictures named in the non-dominant language (M = 72.75%, SD = 14.21%) , ps < .001 (Table 4-3). However, there was no main effect of group and no significant interaction, $F < 1$.

No-response errors: monolinguals and bilingual comparisons

A one-way ANOVA compared the three groups in their dominant language on the proportion of trials on which they provided no response, and there was a significant effect of group, $F(2, 134) = 4.85$, $MSE = .001$, $p = .009$, $\eta^2 = .07$, such that late bilinguals (M = 5.38%, SD = 6.07%) failed to respond on significantly more trials than monolinguals (M = 2.75%, SD = 3.90%), $p = .008$, but late bilinguals did not differ from early bilinguals (M = 4.13%, SD = 3.58%), $p = .45$, who did not differ from monolinguals, $p = .19$.

No-response errors: late and early bilingual comparisons

The bilingual groups' proportion of no response errors was compared in their dominant, non-dominant language and in the either language condition via a 2 (Group) x 3 (Instructed Language) mixed-factorial ANOVA. Results revealed a main effect of instructed language, $F(2, 162) = 123.67$, $MSE = .007$, $p < .001$, $\eta^2 = .06$, such that participants had significantly more trials where they failed to provide a response when using their non-dominant language (M = 23.05%, SD = 13.73%) than when naming pictures in their dominant language (M = 4.58%, SD = 4.64%), which in turn resulted in marginally more no–response errors than when naming pictures in the either language condition (M = 3.82%, SD = 3.87), $p < .06$. However, there was no main effect of group, $F < 1$, and no significant interaction, $F(1, 81) = 2.49$, $MSE = .001$, $p = .12$, $\eta^2 = .02$.

Wrong-word errors: monolinguals and bilingual comparisons

A one-way ANOVA compared the three groups on mean proportion of incorrectly named pictures. When naming in their dominant language, the ANOVA revealed no main effect of group ($F < 1$), with errors occurring infrequently overall: Monolinguals (M = 1.62%, SD = 1.61%), late bilinguals (M = 1.36%, SD = 1.73%), and early bilinguals (M = 1.34%, SD = 1.59%) made a similar proportion of errors when naming pictures in their dominant language.

Wrong-word errors: late and early bilingual comparisons

Comparing only bilingual participants, a 2 (Group) x 3 (Instructed Language) mixed-factorial ANOVA revealed a main effect of group, $F(1, 82) = 11.61$, $MSE = .001$, $p = .001$, $\eta^2 = .12$, such that late bilinguals incorrectly named more pictures (M = 2.4%, SD = 1.10%) than early bilinguals (M = 1.4%, SD = .77%) . There was also a main effect of instructed language, $F(2, 164) = 29. 87$, $MSE = .000$, $p < .001$, $\eta^2 = .27$, where participants produced more incorrect words in their non-dominant language (M = 2.83%, SD = 3.07%) than in either their dominant language (M = 1.35%, SD = 1.63%), $p < .001$, or in the either language condition (M = 1.14%, SD = 1.43%), $p < .001$, with no difference between the dominant and either language conditions, $p = .39$. In addition, there was a significant interaction, $F(2, 164) = 15.45$, $MSE = .000$, $p < .001$, $\eta^2 = .16$, such that late bilinguals produced significantly more errors in the non-dominant language (M = 4.73%, SD = 3.80%) than did early bilinguals (M = 1.78%, SD = 1.91%), $p < .001$, $\eta^2 = .22$). However, no differences between the bilingual groups occurred when naming in the dominant language, $p = .96$, or in either language condition, $p = .71$. See Table 4-4 for all these data.

Dysfluencies: monolinguals and bilingual comparisons

A one-way ANOVA compared the three groups on mean proportion of dysfluencies. When naming in their dominant language, the ANOVA revealed no main effect of group ($F < 1$), indicating that monolinguals (M = 4.14%, SD = 5.78%), late bilinguals (M = 5.30%, SD = 6.87%), and early bilinguals (M = 4.49%, SD = 5.64%) all produced a similar proportion of dysfluent responses.

Dysfluencies: late and early bilingual comparisons

A 2 (Group) x 3 (Instructed Language) mixed-factorial ANOVA comparing the bilingual groups revealed a significant effect of instructed language, $F(2, 162) = 8.07$, $MSE = .003$, $p < .001$, $\eta^2 = .09$, such that participants had more dysfluencies when producing words in their non-dominant language ($M = 8.11\%$, $SD = 9.34\%$) than when producing words in their dominant language ($M = 4.78\%$, $SD = 6.08\%$), $p = .003$, or in the either language condition ($M = 4.89\%$, $SD = 6.29\%$), $p = .002$, with no difference between the dominant and either language conditions, $p = .93$. However, there was no main effect of group, $F < 1$, and no significant interaction, $F(2, 162) = 2.18$, $MSE = .003$, $p = .12$, $\eta^2 = .03$.

Verbal Fluency

Number of Exemplars

Prior to completing the verbal fluency task, participants were instructed as to what constituted acceptable exemplars. For the letter categories, exemplars were considered correct if the word began with the correct letter, the word was not a proper name, the word was not a repetition of a previous word, and the word was not related to a previously produced word (e.g. for the 'p' category, if a participant said, “price” followed by “pricey” and “priceless”, only the first word would be counted as a correct exemplar and the other two words would be counted as errors). In addition, bilinguals had to produce the word in the instructed language, and any words produced in the other language were considered errors. When producing exemplars in the 'either language' condition, when the same word was given in both languages (e.g. for the 'p' category if a participant first said “puerco” [meaning pork] and then said “pork”), only the first word was counted as a valid exemplar, while the second word was counted as an error.

For the semantic categories, determining the number of exemplars often required some subjective judgments, and the criteria used for those judgments are discussed here. For the category "fruits and vegetables", exemplars were considered correct if the word represented a fruit or vegetable but an error if the words represented a spice. Additionally, words like *raisin* or *prune* were only considered correct if the word for the undried fruit (i.e., *grape* and *plum* respectively) had not previously been produced. For the category "animals", words for distinct animals were considered correct, but in cases where participants provided different words for the same animal, only the first word was considered correct. For example, if participants provided the words *puppy* and *dog*, only one of these was counted as correct. Another example was the exemplars *chicken*, *hen*, and *rooster*, where only the first word was considered correct because roosters and hens are both chickens and only differ by gender, and they are therefore not exemplars for animals that differ from a chicken. In cases where the same words were repeated in naming animals, the words that represented distinct species were considered correct while the general category word was considered a repetition. For example, if the participant said, *black bear* followed by the other exemplars (e.g., *grizzly bear*, *polar bear*, *panda bear*, *koala bear*), *black bear* along with all the other exemplars would all have been counted as correct exemplars since they are all distinct species of bears. However, if participants simply said *bear* followed by *grizzly bear*, *polar bear*, etc., *bear* would not have been counted as correct since it represents a superordinate category of which grizzly bear and polar bear are a part, although both *grizzly bear* and *polar bear* would have been counted as correct exemplars. If the participant said *bear* and provided no other exemplars containing the word bear, it would have been considered a correct exemplar. For the "occupations" category, words for occupations that differed by gender only were not considered separate correct exemplars (e.g., *waiter* and *waitress*). In addition, if participants produced words for occupations that were all essentially the same occupation, (e.g., *bus driver*, *limousine driver*, *taxi driver*), only one of these was considered a valid exemplar.

Finally, if participants produced odd exemplars for activities not generally recognized as occupations (e.g., *sandwich artiste*), these were not considered valid exemplars.

Comparison of monolinguals and bilinguals

A one-way ANOVA compared the three participant groups on the mean number of exemplars that they provided. Prior to conducting these ANOVAs, the data were analyzed for normalcy and found to be normal, therefore making them appropriate for parametric statistical analyses. The ANOVA was conducted on exemplars given by monolinguals in English and by bilinguals in their dominant language. Results revealed no significant main effect of group, $F(2, 135) = 1.16$, $MSE = 13.78$, $p = .32$, $\eta^2 = .02$, with late bilinguals ($M = 16.48$, $SD = 5.12$), early bilinguals, ($M = 15.53$, $SD = 3.71$), and monolinguals, ($M = 14.49$, $SD = 2.54$) producing an equivalent number of exemplars.

The data were divided into mean exemplars in response to letter categories and mean exemplars in response to semantic categories. To compare the three groups, a 3 (Group: Monolingual, Late Bilingual, Early Bilingual) X 2 (Verbal Fluency Type: Semantic or Letter) mixed-factorial ANOVA was conducted on mean exemplars produced in English by monolinguals and in the dominant language by bilinguals, and Table 4-5 shows the means and standard deviations for each group. Results revealed a main effect of verbal fluency type, $F(1, 135) = 138.42$, $MSE = 14.03$, $p < .001$, $\eta^2 = .51$, such that participants provided more exemplars in response to semantic categories ($M = 18.43$, $SD = 4.71$) than to letter categories ($M = 12.80$, $SD = 4.41$). However, there was no effect of group, $F(1, 135) = 1.16$, $MSE = 27.57$, $p = .32$, $\eta^2 = .02$, nor was there a significant interaction ($F < 1$).

Comparison of late and early bilinguals

To see if a similar difference between letter and semantic fluency existed for the bilingual groups alone as a function of the language in which they were instructed to produce exemplars, a

2 (Group) X 3 (Instructed Language: Dominant, Non-Dominant, Either) X 2 (Verbal Fluency Type: Semantic or Letter) mixed-factorial ANOVA was conducted on mean number of exemplars provided by bilinguals. While there was no main effect of participant group, $F < 1$, there was a significant main effect of instructed language, $F(1, 82) = 13.34$, $MSE = 6.23$, $p < .001$, $\eta^2 = .38$, such that all participants provided more exemplars in their dominant language ($M = 16.01$, $SD = 4.45$) than when either language was allowed ($M = 14.53$, $SD = 4.05$), which resulted in more exemplars than those given in the non-dominant language ($M = 11.32$, $SD = 3.80$), all *p*s < .001. There was also a main effect of verbal fluency type, $F(1, 82) = 82.46$, $MSE = 20.99$, $p < .001$, $\eta^2 = .5$, such that participants produced more exemplars in response to the semantic categories ($M = 15.89$, $SD = 3.43$) than to the letter categories ($M = 12.02$, $SD = 4.07$). There was also a significant Instructed Language x Verbal Fluency Type interaction, $F(2, 164) = 5.62$, $MSE = 17.68$, $p = .004$, $\eta^2 = .06$. Following up the interaction, significant effects of instructed language occurred for both semantic categories, $F(2, 166) = 34.35$, $MSE = 24.62$, $p <.001$, $\eta^2 = .29$, and for letter categories, $F(2, 166) = 20.10$, $MSE = 10.53$, $p <.001$, $\eta^2 = .19$. For both categories, more exemplars were produced in the dominant language than in the either language condition, $p_{semantic} = .01$, $p_{letter} = .03$, which produced more exemplars than the non-dominant language, *p*s < .001, but these differences between instructed language conditions were greater for semantic than letter categories (see Table 4-6). Alternatively, the interaction can be interpreted in terms of the effects of verbal fluency type (giving more exemplars for semantic categories than letter categories), which were significant at each level of instructed language. The verbal fluency type effect was smaller in the non-dominant language condition, $F(1, 83) = 12.06$, $MSE = 16.17$, $p = .001$, $\eta^2 = .13$, compared to the dominant language condition, $F(1, 83) =$

61.11, *MSE* = 18.69, $p < .001$, $\eta^2 = .42$, and the either language condition, *F(*1, 83) = 39.21, *MSE* = 20.89, $p < .001$, $\eta^2 = .32$. All other interactions were nonsignificant, *p*s > .62.

Verbal Fluency Errors

Comparison of monolinguals and bilinguals

A 3 (Group) x 2 (Verbal Fluency Type) mixed factorial ANOVA compared the groups on the proportion of errors they made in their dominant language, i.e., producing invalid responses. There was a marginally significant effect of group, $F(2, 134) = 4.82$, *MSE* = .008, $p = .10$, $\eta^2 = .07$, such that early bilinguals (*M* = 4.13%, *SD* = 4.95%) made fewer errors than monolinguals (*M* = 6.38%, *SD* = 4.62%), $p = .06$, and late bilinguals (*M* = 8.36%, *SD* = 9.62%), $p = .003$, but monolinguals and late bilinguals did not differ, $p = .16$. There was also a significant effect of verbal fluency type, $F(1, 134) = 8.10$, *MSE* = .007, $p = .005$, $\eta^2 = .07$, such that participants made significantly more errors in response to letter categories (*M* = 7.63%, *SD* = 7.99%) than in response to semantic categories (*M* = 4.22% *SD* = 9.48%). The interaction was not significant, $F(1, 134) = 1.06$, *MSE* = .007, $p = .35$, $\eta^2 = .07$. See Table 4-7 for these results.

Comparison of late and early bilinguals

A 2 (Group) x 2 (Verbal Fluency Type) x 3 (Instructed Language) mixed-factorial ANOVA compared the bilingual groups' errors. There was a significant effect of group, $F(1, 82) = 16.32$, *MSE* = .006, $p < .001$, $\eta^2 = .07$, such that early bilinguals (*M* = 5.1% *SD* = 5.84%) made significantly fewer errors than late bilinguals (*M* = 9.3%, *SD* = 7.77%), $p < .001$. There was also a significant main effect of verbal fluency type, $F(1, 81) = 8.49$, *MSE* = .01, $p = .005$, $\eta^2 = .10$, such that participants made more errors in responding to letter categories (*M* = 8.6% *SD* = 6.78%) than in responding to semantic categories (*M* = 5.8% *SD* = 6.18%). However, the main effect of instructed language was nonsignificant, $F(2, 162) = 1.10$, *MSE* = .01, $p = .33$, $\eta^2 = .01$ and there were no significant interactions, *F*s < 1. All these data are summarized in Table 4-8.

Summary & Discussion of Lexical Access Results

Results from the lexical access tasks demonstrate both similarities and differences between late and early bilinguals (Table 4-9 below for a summary of the findings). In terms of similarities, both bilingual groups were slower to name pictures than monolinguals, replicating results from previous studies reporting a bilingual disadvantage on tasks of lexical access. However, this pattern was specific to picture naming and did not occur on the verbal fluency task, where monolinguals and both groups of bilinguals were equivalent in number of exemplars produced. This lack of a bilingual disadvantage in verbal fluency is not uncommon, as some past studies have found lexical access deficits for bilinguals on verbal fluency tasks across all semantic categories (e.g., Portocarrero et al., 2007) while others have not found such deficits (e.g., Luo, Luk, & Bialystok, 2010). However, in the present study, no bilingual disadvantage was found for any of the categories. One possible explanation for these conflicting findings is that verbal fluency differences between monolinguals and early bilinguals may occur only when the groups are compared in their L1s, which may be participants' dominant language. Since American Spanish-English bilinguals attending universities in the US, bilinguals are frequently reversed dominance, comparing them in their L1 to monolinguals could artificially create differences between groups. While many past studies have compared bilinguals in their L1 and in either language (e.g., Gollan et al., 2002) few have confirmed that participants' L1 was also their dominant language (e.g., Ivanova & Costa, 2008), leaving open the possibility that differences found in past studies resulted from the fact that bilinguals' performance in their non-dominant language was being compared to monolinguals performance in their only (dominant) language.

When looking at accuracy and error rates in the lexical access tasks, some interesting differences did emerge that dissociated the two bilingual groups in comparison to monolinguals.

On picture naming, late bilinguals were overall less accurate, which was likely due to their making more "no response" errors than monolinguals. This result is probably not due to late bilinguals knowing fewer of the picture names in their dominant language since the picture names are of fairly common objects (see Appendix B for a list of picture names). Rather, this finding suggests that late bilinguals had more difficulty *accessing* the words in their dominant language than monolinguals. This finding is consistent with anecdotal evidence and common reports from people who are just becoming fluently bilingual that they cannot keep the words straight in either of their languages. It also suggests that in the earlier stages of being fluently bilingual, people have not had sufficient practice in managing their two lexicons to avoid lexical access failures even in their dominant language.

In contrast, early bilinguals had no disadvantage relative to monolinguals in terms of errors on picture naming and actually exhibited a bilingual advantage by giving fewer invalid responses, even in comparison to late bilinguals on the verbal fluency task. One possibility for why this advantage might arise is by organizing the lexicons of two languages, bilinguals develop more accurate and precisely delineated semantic networks, i.e., fewer categories with fuzzy boundaries, fewer ‘errors’ in categorization, and more categories and sub categories. These enhanced semantic networks might arise due to the fact that while bilinguals have two words for virtually every concept, words in different languages frequently have slightly different concepts associated with them. For example, the verb ‘drown’ in English entails death. However, in many languages (e.g., Spanish and Japanese to name only two), one can drown and not die. Such minor conceptual differences between words in a bilinguals two languages abound, and the necessity of organizing those conceptual differences may result in enhanced semantic networks in fluent bilinguals. Bilinguals’ better semantic system would result in fewer errors on verbal fluency tasks for those who were highly practiced in managing their two languages, as is the case for early bilinguals. This reduction-in-errors advantage would be more likely to emerge in verbal fluency tasks than in picture naming tasks because providing exemplars on verbal fluency tasks is a conceptually driven and less constrained task than picture naming. Under those circumstances, a superior semantic network would prevent one from providing exemplars that are not part of the semantic category because words for erroneous concepts would not be activated. However, this advantage would not extend to picture naming tasks where a picture corresponds to a specific semantic concept, so bilinguals are not free to respond with whatever concept fits a general category. Rather, they must produce a particular word for one particular concept. While this idea can potentially explain why early bilinguals made fewer errors on the semantic categories on the verbal fluency task, it cannot explain their better performance on the letter categories verbal fluency task, where phonological relations, not semantic ones, are utilized. Future research is needed to clarify why this early vs. late bilingual advantage occurs and whether it could occur in other tasks that do not have the constraints that picture naming does.

With respect to between-group comparisons of bilinguals, the late bilingual group performed similarly to the early bilingual group on most measures. Both groups had equivalent reaction times on the picture naming task independent of the language in which they named the pictures, and they produced equivalent exemplars on both semantic and letter verbal fluency tasks. However, when looking at accuracy and specific types of errors, some differences between late and early bilinguals emerged. Specifically, late bilinguals made more wrong word errors during picture naming than early bilinguals when naming in their non-dominant language, and late bilinguals made more errors than early bilinguals on the verbal fluency tasks. Past research has not typically analyzed errors on lexical access tasks and generally has not focused on relative numbers of errors as an indicator of lexical access advantages or disadvantages, instead relying only on number of correct exemplars. However, it seems clear that on the kinds of lexical access tasks used in the present study, such measures may have the potential to reveal group differences when other measures may fail to do so. In regard to this study, the late and early bilingual groups appear to be identical across tasks when looking at their correct responses but not when looking at errors. It is only in regard to errors that late bilinguals show a lexical access deficit relative to early bilinguals, both on the picture naming task and the verbal fluency task. Late bilinguals' increased errors on verbal fluency independent of language condition lends some credibility to the speculation proposed above regarding enhanced semantic networks in early bilinguals. Since late bilinguals have considerably less practice in managing their two lexicons (an average of 10 years less) than early bilinguals, they manifest significantly more errors on verbal fluency tasks, not only in their non-dominant language, but also in their dominant language and in the either language condition.

Comparisons of the bilingual groups’ performance as a function of instructed language also revealed some important differences. Both groups of bilinguals named pictures in the either language condition more slowly than in the dominant language condition. However, both groups were also more accurate in producing picture names in the either language condition, introducing the possibility that the slower picture naming times in the either language condition is simply a speed/accuracy tradeoff, rather than a lexical access deficit for bilinguals. Alternatively, another possible explanation for this pattern of results (where both groups were slower yet more accurate in the either language condition) is related to whether a participant knows the name of a picture in only one or both of his/her languages. When allowed to name a picture in either language, knowing the word in only one language is likely to increase accuracy in this condition, relative to the other language response conditions where one specific language must be used (and that language may or may not be the language in which the person knows the name of the picture). On the other hand, when the picture's name is known in both languages, this may slow responses times in the either condition by increasing competition between the words in the participant's languages in deciding which one to produce.

Results from the verbal fluency task were not as difficult to interpret in that both bilingual groups produced fewer exemplars in the either language condition than in their dominant language, although they did not differ in the percentage of errors they made in the dominant and either language conditions. If these results reflect a bilingual lexical access disadvantage, they seem counterintuitive in that if participants can use either language, they should be able to respond with the word that comes to mind without having to concern themselves with which language to use, a flexibility that might allow participants to produce picture names more quickly and provide more exemplars than when they are constrained to one language or the other. Furthermore, participants could simply choose to adopt the strategy of only using their dominant language in the 'either language' response condition (though they may not have realized this was an option), in which case their performance in this condition would not be expected to differ from their performance in the dominant language condition. Nonetheless, bilingual participants' performance did differ between the dominant and either language response conditions, with slower picture naming latencies and fewer verbal fluency exemplars in the either language condition, suggesting the possibility that introducing the either language option actually increases interference between a bilingual's languages. Furthermore, both bilingual groups performed similarly in both language conditions, indicating that to whatever extent language interference affected the participants' performance on these tasks, it generally affected both late and early bilinguals to the same degree.

Overall, the results suggest that late bilinguals manifest the same degree of lexical access deficits as early bilinguals relative to monolinguals, if not a greater degree, despite their having been fluent in a second language for only 4.4 years, on average. These findings are especially interesting given that late bilinguals had lexical access deficits in a language that was almost always their first language, the one they had been speaking their whole lives as well their *only* language for the majority of their lives. Hence, whatever effect bilingualism has on lexical access, it appears to exert those effects directly, rather than as a byproduct of some phenomenon correlated with, but not directly related to, bilingualism, e.g., frequency of language use. That is, the simple fact of being bilingual and the resulting necessity of managing two lexicons, determining which of one's two languages to use at any given time and then employing that language while inhibiting the other, appears to cause the lexical access deficits associated with bilingualism, and this may have been enhanced by the language switching within the experiment. Perhaps also, bilingualism may cause a lexical access advantage in terms of the organization and efficiency of the lexical access system insofar as managing two languages may result in a more precisely delineated semantic network. Such a benefit, if it exists, may not have been revealed in past research because it may only be obvious when analyzing the difference in errors between groups, an analysis that most previous research has not done.

Executive Function

Attentional Network Task

Response times

Prior to performing ANOVAs on the reaction time data for the Attentional Network Task (ANT), incorrect responses, and practice trials were excluded from analysis. Following these exclusions, the data were examined for normalcy, and results indicated that the data were positively skewed such that the z-scores for the skew values exceeded the maximum allowable threshold ($\pm$2) for parametric statistical analyses. Consequently, the data were trimmed of outliers that were more than 2.5 standard deviations above or below each group's mean in each of the six Flanker-Cue conditions. Trimming resulted in equivalent data loss across groups (3.0% for monolinguals, 2.9% for late bilinguals, and 2.6% for early bilinguals). The trimmed data were then explored for normalcy, and skew and kurtosis values for all data in each participant group were within acceptable limits, i.e., z-scores for both skew and kurtosis fell between -2 and 2, indicating that the data were normal and therefore appropriate for parametric statistical analysis.

A 3 (Group: monolingual, late bilingual, and early bilingual) x 3 (Flanker Type: neutral, congruent, incongruent) x 2 (Cue Type: no cue, double cue) mixed factorial ANOVA was conducted on mean reaction times, shown in Table 4-10. While there was no main effect of group, $F(2, 132) = 1.02$, $MSE = 30211.11$, $p < .53$, $\eta^2 = 0.009$, there was a main effect of flanker type, $F(2, 264) = 769.04$, $MSE = 1206.69$, $p < .001$, $\eta^2 = .85$, such that reaction times to targets with neutral flankers ($M = 601.81$, $SD = 65.06$) were faster than targets with congruent flankers ($M = 612.43$, $SD = 69.49$), which were faster than targets with incongruent flankers ($M = 712.41$, $SD = 92.80$), all *p*s < .001. There was also a main effect of cue type, $F(1, 132) = 633.57$, $MSE = 466.63$, $p < .001$, $\eta^2 = .83$, where reaction times to trials preceded by the double asterisk($M = 622.33$, $SD = 73.53$) were faster than those not preceded by a cue($M = 662.10$, $SD = 75.32$), $p < .001$. These main effects were qualified by a significant Flanker Type x Cue Type interaction, $F(2, 264) = 5.27$, $MSE = 247.86$, $p = .005$, $\eta^2 = .04$, a Group x Flanker Type interaction, $F(4, 264) = 2.77$, $MSE = 898.66$, $p = .028$, $\eta^2 = .04$, as well as a Group x Flanker Type x Cue Type interaction, $F(4, 264) = 2.83$, $MSE = 247.86$, $p = .03$, $\eta^2 = 04$.

Follow-up *F*-tests on the highest order (three-way) interaction were conducted beginning with the Group x Cue Type within each level of flanker type, which revealed a significant Group x Cue interaction for incongruent flanker trials, $F(2, 132) = 3.94$, $MSE = 396.88$, $p = .02$, $\eta^2 = .06$, but no significant Group x Cue Type interaction for the congruent trials, $F(2, 132) = 2.25$, $MSE = 338.65$, $p = .11$, $\eta^2 = .03$, or neutral flanker trials, $F < 1$. Following up on the significant interaction for incongruent flankers, each group had a significant effect of cue type, *p*s < .001, and examination of the *F*-statistics suggested that monolinguals had a larger effect of cue than either late bilinguals or early bilinguals. When looking at the interaction for incongruent trials within each level of cue type, no significant difference emerged between groups for trials not preceded by a cue, $p = .18$, or trials that were preceded by a cue, $p = .42$.

The three-way interaction was also explored by looking at the Group x Flanker Type interaction within each level of cue type. While there was no significant Group x Flanker Type interaction for trials preceded by a cue, $F < 1$, there was a significant Group x Flanker Type interaction for trials not preceded by a cue, $F(4, 264) = 4.58$, $MSE = 741.65$, $p = .001$, $\eta^2 = 07$. (Figure 4-1 below). When exploring this interaction for no-cue trials, no significant differences occurred between groups for any of the flanker types, *p*s > .18. However, each group had a significant effect of flanker type, *p*s < .001. Comparing the effects of flanker types within each group for trials not preceded by a cue, there were significant differences between all flanker types. Comparing incongruent trials to neutral trials yielded the largest effects between flanker types, with the monolingual group having the largest interference from incongruent flankers relative to the bilinguals. In comparing neutral and congruent trials, surprisingly all groups also showed interference from congruent trials, with late bilinguals having the largest effect. Comparing congruent and incongruent trials, which is a metric typically reported in studies using the ANT, monolinguals had the largest interference effect from incongruency compared to both bilingual groups.

Finally, a Flanker Type x Cue Type within each level of group showed that there was a significant interaction within the early bilingual group, $F(2, 264) = 5.21$, $MSE = 1291.44$, $p = .006$, $\eta^2 = .04$, and the late bilingual group, $F(2, 264) = 5.21$, $MSE = 813.37$, $p = .04$, $\eta^2 = .02$, but not the monolingual group, $F(2, 264) = 1.88$, $MSE = 465.22$, $p = .16$, $\eta^2 = .01$.

ANT errors

Errors were computed on all experimental trials. A 3 (Group: monolingual, late bilingual, and early bilingual) x 3 (Flanker Type: neutral, congruent, incongruent) x 2 (Cue Type: no cue, double cue) ANOVA on mean proportion of erroneous responses revealed a significant main effect of flanker type, $F(2, 266) = 47.81$, $MSE = .001$, $p < .001$. Means and standard errors from this analysis (converted into percents) are shown in Table 4-11. Although errors overall were infrequent, participants made more errors on trials with incongruent flankers (M = 3.3%, SD = 4.8%) than trials with neutral flankers (M = .8%, SD = 1.1%), which were more erroneous than trials with congruent flankers (M = .4%, SD = .8%). There was also a main effect of cue type, $F(2, 266) = 7.45$, $MSE = .000$, $p = .007$, such that participants made more errors in responding to trials not preceded by a cue (M = 1.7%, SD = 2.3%) than those with a cue preceding them (M = 1.3%, SD = 1.8%). However, there was no main effect of group, $F < 1$, nor were there any significant interactions, ps > .36.

Simon Task

Response times

As with the ANT, data for the Simon task were trimmed of outliers that were 2.5 standard deviations above or below the mean and evaluated for normalcy prior to performing ANOVAs on the *reaction times* for correct responses. After trimming, there were no extreme values, and the values for skew were all between 0 and 1.1. In terms of kurtosis, all but one of the values were between –0.68 and 1.57, with the remaining value at 2.02. Given that all the data values were within normal limits for skew (± 2), and only one kurtotic value was minimally outside the normal limits (± 2), the data were deemed appropriate for parametric statistical analyses.

For the Simon task, a 3 (Group: monolingual, late bilingual, and early bilingual) x 3 (Tone Congruency: neutral [tone presented in both ears], congruent [tone presented in the ear on the same side as the required response], incongruent [tone presented in the ear on the side opposite of the required response]) ANOVA was conducted on mean reaction times for trials where the correct keypress was made. Means and standard errors from this analysis are shown in Table 4-12. There was a main effect of tone congruency, $F(2, 264) = 486.67$, $MSE = 290.45$, $p < .001$, $\eta^2 = .79$, such that reaction times to congruent tones ($M = 659.78$, $SD = 87.76$) were faster than reaction times to neutral tones ($M = 695.36$, $SD = 93.20$), which in turn were faster than reaction times to incongruent tones ($M = 727.25$, $SD = 91.06$), $ps < .001$. These results also revealed a robust Simon effect, where reaction times to incongruent tones were slower than congruent tones, $p < .001$. The main effect of group was marginally significant, $F(2, 132) = 2.48$, $MSE = 23632.14$, $p = .09$, $\eta^2 = .04$, such that monolinguals ($M = 716.48$, $SD = 102.35$) responded more slowly than either late bilinguals ($M = 681.76$, $SD = 93.46$), $p = .09$, or early bilinguals ($M = 681.05$, $SD = 84.03$), $p = .04$, with no difference between the bilingual groups, $p = .97$. However, there was no significant Group x Tone Congruency interaction ($F < 1$), which suggests that the Simon effect was equivalent for the three groups.

Simon task errors

A 3 (Group) x 3 (Tone Congruency) ANOVA was conducted on mean proportion of errors, i.e., pressing an incorrect key. Means and standard errors (converted into percents) are displayed in Table 4-13. The analyses revealed a main effect of tone congruency, $F(2, 244) = 124.86$, $MSE = .01$, $p < .01$, $\eta^2 = .50$, such that responses to incongruent tones (M = 6.4%, SD = 1.2%) resulted in more errors than neutral tones (M = 1.6%, SD = 2.0%), $p < .001$, which had more errors than congruent tones (M = 0.63%, SD = 1.2%), $p < .001$. Neither the main effect of group nor the interaction between group and tone congruency were significant ($Fs < 1$).

Summary & Discussion of Executive Function Results

In considering the performance of the three participant groups on the executive function tasks, recall that according to Costa et al. (2009), bilingual advantages may manifest as either faster reaction times overall, a reduced conflict effect, or both. In many instances, both these types of executive function benefits have been found on the same task (e.g., Bialystok, 2004). However, similar to our findings with the lexical access tasks, the results of the executive function tasks in the present study demonstrated differences *between* the two tasks in terms of a bilingual advantage. These results are summarized in Table 4-14 below. On the ANT, both early and late bilinguals manifested an executive function benefit relative to monolinguals evidenced by smaller conflict effects created by incongruent trials than did monolinguals, consistent with previous research (e.g., Bialystok et al., 2005), although there was no benefit in terms of bilinguals having faster reaction times overall, which has been observed in some studies (e.g., Costa et al., 2009). In contrast, bilinguals and monolinguals had equivalent interference effects from incongruency on the Simon task, although both early bilinguals (significantly) and late bilinguals (marginally) were faster overall on the Simon task than monolinguals. Furthermore, monolinguals and bilinguals did not differ from one another in terms of errors on either of the executive function tasks. As for comparing early and late bilinguals, they did not differ on any of the executive function tasks on any measure. These findings are critical in establishing that the executive function benefits heretofore associated only with early bilinguals also occur in bilinguals who begin learning and become fluent in a second language after childhood.

Different outcomes between the two executive function tasks may be the result of the fact that the ANT tested visual attention and the Simon task tested auditory attention, which altered the time course of stimulus presentation in the two tasks. With the auditory stimuli in the Simon task, the stimuli ‘disappeared’ after 250 milliseconds, whereas for the ANT, the visual stimuli remained on the screen for 1700 milliseconds or until participants responded, whichever came first. Because the stimuli on the Simon task ‘disappeared’ after 250 milliseconds (an average of 400 milliseconds before participants responded), this difference may have reduced the interference that all participants experienced on the Simon task because as soon as the stimuli disappeared, the interference from the stimuli may have begun to decay. In contrast, the stimuli on the ANT remained on the screen along with the distractors until participants responded, continuing to be a source of interference until participants provided a response. This difference between tasks may be responsible for participants responding more quickly to trials with congruent stimuli than neutral stimuli on the Simon task, but responding more slowly to congruent stimuli than neutral stimuli on the ANT. On the Simon task, the stimuli disappeared, allowing the congruent stimuli to facilitate responses on that task. However, on the ANT, the congruent distractors remained on the screen until the each trial ended, and these still had to be ignored so that one could focus on the central target arrow. Therefore, rather than facilitating a response, the congruent arrows slowed responding compared to the presence of neutral distractors.

Support for the idea that the auditory stimuli on the Simon task were less distracting than the visual stimuli on the ANT can be gleaned from the size of the conflict effects for the two tasks, which were clearly larger for the ANT task than for the Simon task, as seen in Tables 13 and 15. The overall average conflict effect was 67 ms for the Simon task and 102 ms for the ANT. If, as the data suggest, the stimuli on the Simon task was less distracting than that on the ANT, that would explain why bilinguals did not have reduced conflict effect relative to monolinguals on the Simon task, i.e., interference on the task was sufficiently low so that monolinguals’ executive function capabilities allowed them to suppress that interference as effectively as the bilinguals. However, on the ANT, where interference was higher, monolinguals’ executive function was not sufficient to allow them to suppress interference as effectively as the bilinguals. The same underlying cause may have resulted in bilinguals' overall reaction time advantage in the Simon task, i.e., early bilinguals’ overall faster reaction times and late bilinguals’ marginally faster overall reaction times on the Simon task relative to monolinguals. That is, since the Simon task was easier than the ANT, bilinguals were able to use their superior executive function to respond more quickly than monolinguals on this task since they did not need to engage as much effort in suppressing interference from distracting stimuli. In this view, task monitoring and interference suppression draw from a the same limited cognitive resource pool, so when bilinguals' need for interference suppression is lower, more resources are available for task monitoring.

Another difference to consider is that results from the auditory Simon task in this study differed from results of past research using the visual Simon task. Many such studies have found smaller conflict effects for bilinguals relative to monolinguals (Bialystok et al., 2004; Bialystok et al. 2005; Martin-Rhee & Bialystok, 2008), but no such reduction in the conflict effect was found for the Simon task in this study. It is important to note that this was the first study to compare monolinguals and bilinguals using an auditory Simon task of executive function, so we cannot make any direct comparisons with previous research. All previous studies using the Simon task were exclusively visual stimuli, so the inability to detect a bilingual advantage in reduced conflict effects in the present study using an auditory Simon task may suggest that the modality of distracting information could be a critical determinant of conflict effects. Indeed, we did detect a reduced conflict effect on the ANT, which was visual.

Table 4-1. Picture naming times in participants' dominant language

	Group					
	Monolinguals		Late Bilinguals		Early Bilinguals	
Data Type	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Transformed	28.78	1.68	29.84	2.24	29.85	2.34
Untransformed	831.23	97.66	895.16	136.41	896.13	143.31

Table 4-2. Bilinguals' picture naming times in dominant, non-dominant, & either language

	Group			
	Late Bilinguals		Early Bilinguals	
Language Condition	*Mean*	*SD*	*Mean*	*SD*
Transformed Data				
Dominant	29.84	2.24	29.85	2.34
Non-Dominant	32.82	2.85	32.47	2.39
Either	31.70	3.14	31.4	2.49
Untransformed Data				
Dominant	895.16	136.41	896.13	143.31
Non-Dominant	1085.13	186.12	1060.05	157.33
Either	1014.22	208.86	992.17	158.69

Table 4-3. Percent picture naming accuracy in the dominant, non-dominant, & either language

	Group			
	Late Bilinguals		Early Bilinguals	
Language Condition	*Mean*	*SD*	*Mean*	*SD*
Dominant	92.02%	7.96%	94.21%	4.46%
Non-Dominant	72.93%	18.35$	72.64%	11.42%
Either	94.43%	4.23%	94.81%	4.24%

Table 4-4. Percent wrong word errors in the dominant, non-dominant, & either language

	Group			
	Late Bilinguals		Early Bilinguals	
Language Condition	*Mean*	*SD*	*Mean*	*SD*
Dominant	1.36%	1.73%	1.34%	1.59%
Non-Dominant	4.73%	3.80%	1.78%	1.91%
Either	1.22%	1.46%	1.10%	1.41%

Table 4-5. Exemplars to letter & semantic verbal fluency categories in dominant language

	Group					
	Monolinguals		Late Bilinguals		Early Bilinguals	
Verbal Fluency Type	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Letter Categories	12.07	3.19	14.07	5.84	12.81	5.19
Semantic Categories	18.35	3.21	18.90	6.02	18.24	4.49

Table 4-6. Exemplars to letter & semantic verbal fluency categories in three language conditions

		Group			
		Late Bilinguals		Early Bilinguals	
Language Condition	Verbal Fluency Type	*Mean*	*SD*	*Mean*	*SD*
Dominant					
	Letter Categories	14.07	5.84	12.81	4.49
	Semantic Categories	18.90	6.02	18.24	5.19
Non-Dominant					
	Letter Categories	10.77	4.47	9.82	4.23
	Semantic Categories	12.50	5.19	12.20	4.75
Either					
	Letter Categories	12.53	5.19	12.13	4.60
	Semantic Categories	16.93	5.13	16.56	5.38

Table 4-7. Errors to letter & semantic verbal fluency categories in dominant language

	Group					
	Monolinguals		Late Bilinguals		Early Bilinguals	
Verbal Fluency Type	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Letter Categories	8.87%	7.48%	8.88%	8.71%	5.65%	7.81%
Semantic Categories	3.88%	3.62%	7.84%	18.50%	2.53%	4.50%

Table 4-8. Errors to letter & semantic verbal fluency categories in 3 language conditions

		Group			
		Late Bilinguals		Early Bilinguals	
Language Condition	Verbal Fluency Type	Mean	SD	Mean	SD
Dominant					
	Letter Categories	8.88%	8.71%	5.65%	7.81%
	Semantic Categories	7.84%	18.50%	2.53%	4.50%
Non-Dominant					
	Letter Categories	12.55%	15.08%	6.54%	10.60%
	Semantic Categories	8.11%	9.04%	3.33%	5.49%
Either					
	Letter Categories	9.83%	11.96%	8.01%	10.48%
	Semantic Categories	8.82%	12.66%	4.44%	7.03%

Table 4-9. Summary of lexical access results

Task	Response Language	Response Type	Monolinguals vs. Late Bilinguals	Monolinguals vs. Early Bilinguals	Early Bilinguals vs. Late Bilinguals
			Comparison Groups		
Picture naming					
	Dominant Language				
		Response Times	M < LB*	M < EB*	EB = LB
		Accuracy	M > LB***	M = EB	EB = LB
		No-Response Errors	M < LB***	M = EB	EB = LB
		Wrong-Word Errors	M = LB	M = EB	EB = LB
		Dysfluencies	M = LB	M = EB	EB = LB
	Non-Dominant Language				
		Response Times	-	-	EB = LB
		Accuracy	-	-	EB = LB
		No-Response Errors	-	-	EB = LB
		Wrong-Word Errors	-	-	EB < LB***
		Dysfluencies	-	-	EB = LB
	Either Language				
		Response Times	-	-	EB = LB
		Accuracy	-	-	EB = LB
		No-Response Errors	-	-	EB = LB
		Wrong-Word Errors	-	-	EB = LB
		Dysfluencies	-	-	EB = LB
Verbal Fluency					
	Dominant Language				
		Exemplars	M = LB	M = EB	EB = LB
		Invalid Response Errors	M = LB	M > EB	EB < LB***
	Non-Dominant Language				
		Exemplars	-	-	EB = LB
		Invalid Response Errors	-	-	EB < LB***
	Either Language				
		Exemplars	-	-	EB = LB
		Invalid Response Errors	-	-	EB < LB***

*p < .10, **p < .05, ***p < .01

Table 4-10. ANT reaction times across and within cue types for each flanker type

		Group					
		Monolinguals		Late Bilinguals		Early Bilinguals	
Flanker Type		*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Congruent							
	Cue	637.75	76.48	633.85	61.08	633.30	63.70
	No Cue	595.84	80.09	581.13	53.75	592.70	60.75
Incongruent							
	Cue	750.38	108.81	722.63	78.47	719.14	79.13
	No Cue	702.04	104.62	682.83	76.84	691.46	77.60
Neutral							
	Cue	626.82	73.31	613.70	55.44	621.34	58.80
	No Cue	592.01	73.48	574.01	46.94	588.95	58.42

Table 4-11. Percent errors on ANT

		Group					
		Monolinguals		Late Bilinguals		Early Bilinguals	
Flanker Type		*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Congruent							
	Cue	.48%	1.13%	.51%	1.08%	.62%	1.44%
	No Cue	.40%	.93%	.43%	1.02%	.19%	.61%
Incongruent							
	Cue	3.52%	4.81%	4.63%	9.37%	3.03%	4.01%
	No Cue	3.63%	5.11%	3.31%	5.61%	2.33%	3.14%
Neutral							
	Cue	1.12%	1.67%	.79%	1.42%	1.01%	1.52%
	No Cue	.76%	1.31%	.58%	1.10%	.58%	1.18%

Table 4-12. Simon task reaction times

	Tone Congruency					
	Congruent		Incongruent		Neutral	
Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Monolinguals	681.818	96.20	748.26	98.09	717.38	103.46
Late Bilinguals	647.82	86.21	714.55	92.01	682.89	92.87
Early bilinguals	646.37	77.69	715.91	98.09	680.86	79.60

Table 4-13. Percent errors on Simon task

	Tone Congruency					
	Congruent		Incongruent		Neutral	
Group	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Monolinguals	0.6%	1.14%	5.4%	4.82%	1.6%	2.17%
Late Bilinguals	0.7%	1.69%	7.3%	5.87%	1.7%	2.36%
Early bilinguals	0.6%	.96%	6.6%	5.52%	1.6%	1.76%

Table 4-14. Summary of executive function results

		Comparison Groups		
Task	Response Type	Monolinguals vs. Late Bilinguals	Monolinguals vs. Early Bilinguals	Early Bilinguals vs. Late Bilinguals
ANT				
	Response Times	M = LB	M = EB	EB = LB
	Conflict Effect	M > LB**	M > EB***	EB = LB
	Errors	M = LB	M = EB	EB = LB
Simon				
	Response Times	M > LB*	M > EB**	EB = LB
	Conflict Effect	M = LB	M = EB	EB = LB
	Errors	M = LB	M = EB	EB = LB

*p < .10, **p < .05, ***p < .01

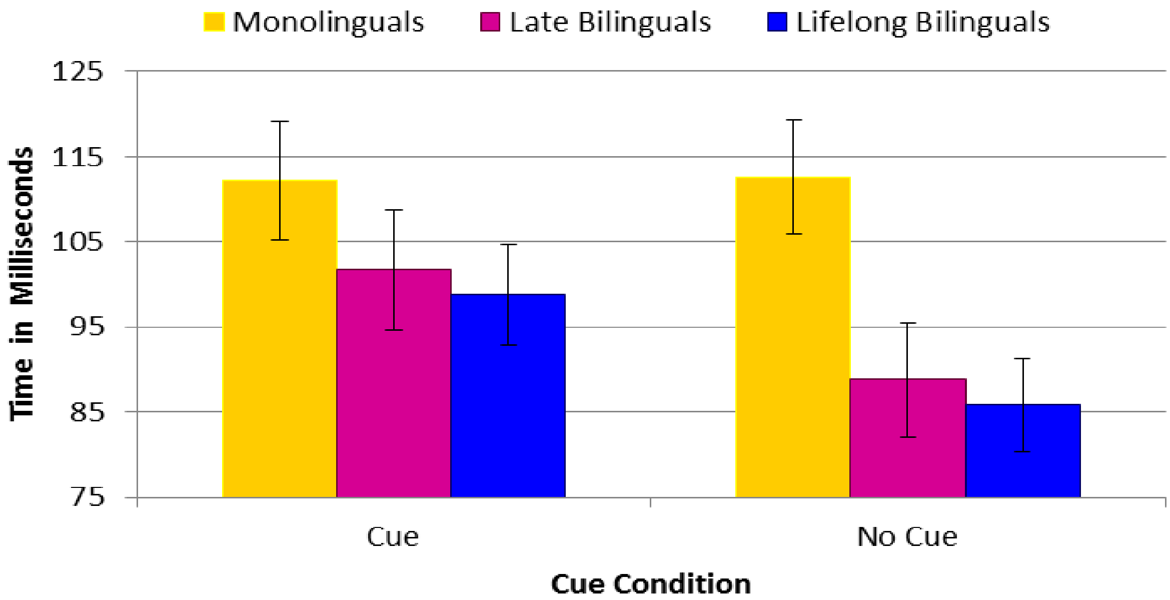

Figure 4-1. ANT conflict effect for both cue types

CHAPTER 5
GENERAL DISCUSSION

The present study sought to answer two research questions. The first was whether people who become fluently bilingual after childhood have the same cognitive advantages and disadvantages as early bilinguals. The second was which of two different theoretical frameworks, the Language Interference hypothesis (Bialystok et al., 2008) and the Frequency Lag hypothesis (Gollan et al., 2002; Gollan & Acenas, 2004; Gollan et al., 2005), best predicts the results of the present study. The present results provide answers to both of these questions.

Regarding the first hypothesis about lexical access tasks made earlier, I hypothesized that when producing words in their dominant language, early bilinguals would show lexical access deficits relative to monolinguals, whereas late bilinguals were expected to perform equivalently to monolinguals. This hypothesis was not supported by performance on either picture naming or verbal fluency. The picture naming task demonstrated that late bilinguals produced picture names in their dominant language as slowly as early bilinguals, both of whom were slower than monolinguals, replicating previous research of a bilingual disadvantage in lexical access (Bialystok et al., 2008; Gollan & Fennema-Notestine, 2007; Gollan et al., 2008; Gollan et al., 2005; Ivanova & Costa, 2008). Additionally, late bilinguals were less accurate in producing picture names in their dominant language by having more no response errors than monolinguals, suggesting that late bilinguals may experience a greater lexical access deficit than early bilinguals when the measure involves accuracy instead of speed. This might be especially likely in language switching contexts where late bilinguals may have to suppress their dominant language in order to use their non-dominant language more than early bilinguals, who have had more practice managing their two languages. On the verbal fluency task, neither bilingual group exhibited a disadvantage relative to monolinguals, either in terms of number of exemplars produced or invalid responses, contrary to some previous findings (Rosselli et al., 2000; Gollan et al., 2002) but not others (Bialystok et al., 2008b). In fact, an unexpected bilingual advantage occurred for early bilinguals, where early bilinguals produced fewer invalid responses than the other groups. Although the results of the reaction time data on the picture naming task provide some support for the Language Interference hypothesis but not the Frequency Lag hypothesis, results on the verbal fluency task are not consistent with either of these theoretical frameworks.

The Language Interference hypothesis predicted that both early and late bilinguals would have lexical access deficits in their dominant language relative to monolinguals because the effort of controlling or ignoring interference from the non-use language, which theoretically should slow both groups' lexical access in their dominant language and cause them to produce fewer exemplars on the verbal fluency task. While this occurred for picture naming RTs, it did not occur when producing exemplars in either verbal fluency task. Furthermore, by virtue of having been fluently bilingual for a considerably shorter time than the early bilinguals, late bilinguals have had less practice in controlling interference from the non-used language and therefore might manifest even greater lexical access deficits than early bilinguals. While there is some support for this prediction when focusing on no response errors in verbal fluency, the remaining comparisons in either picture naming or verbal fluency do not illustrate exacerbated declines in lexical access for late bilinguals. With respect to the Frequency Lag hypothesis, late bilinguals were predicted to perform more like monolinguals and exhibit no lexical access deficits in their dominant language (compared to early bilinguals) because late bilinguals will have produced words in their dominant language much more frequently than the early bilinguals. The similarity of both bilingual groups was apparent across both tasks and multiple measures, and when differences between the groups did arise, early bilinguals were performing better than late bilinguals, inconsistent with the Frequency Lag hypothesis.

The present results suggest that the bilingual disadvantage in lexical access may be more limited than previous research has suggested, only emerging consistently on timed, single-word production tasks. There may be several reasons that verbal fluency tasks do not always reveal bilingual lexical access deficits. First, the time constraint on verbal fluency tasks is less immediate than on picture naming tasks. Although there is a 60-second time frame to provide exemplars, there is no constraint on the time to produce individual exemplars, a constraint that is inherent in tasks where participants have only a few seconds to respond. Another reason the participant groups may not have differed on the verbal fluency task is that the semantic categories (animals, fruits and vegetables, occupations) were relatively easy in that they contained numerous exemplars with many common words. Had we used more difficult categories (e.g., musical instruments), bilinguals may have differed from the monolinguals.

The second hypothesis predicted that late bilinguals would exhibit greater lexical access deficits than early bilinguals when producing words in their non-dominant language. This hypothesis was not supported because late and early bilinguals did not differ in their picture naming RTs or number of exemplars produced on the verbal fluency task. While this finding contradicts the Frequency Lag hypothesis, the lack of differences in picture naming RTs can be explained by the Language Interference hypothesis in that early and late bilinguals would have similarly slowed picture naming latencies relative to monolinguals due to the fact that language interference affects both groups equally. However, this assumption was not made a priori by the theory and therefore can only be a post hoc interpretation of support.

There was some support for the second hypothesis in accuracy measures, where late bilinguals produced more wrong word errors in their non-dominant language on the picture naming task as well as more overall errors on the verbal fluency task than early bilinguals. However, these differences may not actually reflect lexical access deficits for late bilinguals but instead reflect a general knowledge deficit rather than a lexical access deficit. Many of the wrong words that the late bilinguals produced appeared to be guesses at the correct word perhaps when they did not actually know the target (e.g., saying “celeria” instead of ‘apio’ [Spanish for ‘celery’]) mispronunciations of the correct word (e.g., saying “aveja” instead of ‘oveja’ [Spanish for sheep] or “nina” instead of ‘niña’ [Spanish for ‘girl’]) or failures to provide the correct word ending (e.g., saying “foco” instead of ‘foca’ [Spanish for ‘seal’] or “trompeto” instead of ‘trompeta’ [Spanish for ‘trumpet’]). Such responses were counted as wrong word errors, but they may actually reflect a problem with the participant’s accent, failing to learn the correct word ending, or some combination of these, neither of which actually is indicative of a lexical access deficit per se. The finding that late bilinguals produced incorrect picture names in their non-dominant language more frequently than early bilinguals is not surprising, given that late bilinguals have spoken that language for a much shorter period of time than early bilinguals. It also is not surprising that late bilinguals did not make more wrong-word errors than monolinguals in their *dominant* language. However, it is perplexing that late bilinguals were less accurate and had more no-responses errors than monolinguals in their dominant language. This asymmetry in error types in the different language response conditions across the different groups is not easily accounted for by either the Frequency Lag or Language Interference hypotheses. Future research should consider other variables on which early and late bilinguals might differ, e.g., the way in which they learned Spanish and English (in school only or in an immersion environment), to see if these variables might explain this unexpected finding.

The third hypothesis was that on lexical access tasks performed in either language, bilinguals' performance would either not differ from or would be better than their performance on those tasks when their responses were in the dominant language. This hypothesis was not supported in that both bilingual groups produced picture names more slowly and produced fewer exemplars in the either language condition than in their dominant language. These results are not consistent with the Frequency Lag hypothesis, in that when given the opportunity to respond in either language, the words that would come to mind first would be the ones with the highest frequency. Since words in either language were acceptable, they should be produced at least as quickly as words produced in the dominant language condition, but this did not occur in picture naming. With regard to the verbal fluency results, a similar argument applies. That is, the highest frequency words, irrespective of language, should come to mind more quickly and easily allowing participants to produce more exemplars on a verbal fluency task in the either language condition than in the dominant language condition, which did not happen.

In contrast, these results might be accounted for by the Language Interference hypothesis in that when participants are given the option of producing words in either of their languages, this could create more competition between the words in the two languages and hence more interference from the words that are ultimately not used in the following way, something that should both slow picture naming (which occurred) and reduce the number of exemplars on verbal fluency tasks (which did not occur). When bilinguals have the intention to speak one language and not the other, they automatically suppress interference from activation of words in the language they do not intend to use. When they do not have an intention to speak only one of their languages, words from both languages may initially be equally activated, but words from neither language will receive automatic inhibition. This results in more (or a longer period of) competition between a bilinguals' languages, which causes longer RTs in the either language conditions because neither language is automatically suppressed. However, an alternative interpretation that does not speak to either of the theoretical frameworks is that picture naming is slower in the either language condition because participants had to decide which language to use, and the time it took them to make this decision slowed their picture naming times compared to when they knew ahead of time which language there were to use. On balance, the results for hypothesis 3 do not unequivocally support either the Frequency Lag or Language Interference hypothesis.

The last hypothesis related to executive function tasks, and it was postulated that early bilinguals would show greater executive function benefits than late bilinguals, relative to monolinguals, evidenced by superior interference suppression and greater inhibitory control on the two executive function tasks. Both bilingual groups had EF benefits relative to monolinguals by having reduced conflict effects on the ANT and faster overall RTs on the Simon tasks, consistent with the hypothesis and previous research (Bialystok et al., 2004; Bialystok et al. 2008a; Carlson & Meltzoff, 2008; Costa et al., 2008). However, the two bilingual groups did not differ from one another either on the ANT or Simon task, contrary to the hypothesis. It can therefore be concluded that the size of EF benefits is not strictly related to the duration that one has been fluently bilingual. It appears that being fluently bilingual confers EF benefits even if one becomes bilingual after childhood. However, results of the present study do not allow for a determination of precisely how long one must be fluently bilingual before such benefits manifest. That is, based on the present study, participants with an average of 4.4 years of being fluently bilingual had EF benefits, but would participants who had only been fluently bilingual for an average of one year also have EF benefits? Nonetheless, results of the present study provide evidence that one need not be fluently bilingual for as long as was previously thought in order to attain the EF benefits associated with bilingualism, and these results are consistent with the Language Interference hypothesis that EF benefits arise for bilinguals as a result of bilinguals' need to constantly manage interference between their two languages. However, the authors of that hypothesis have suggested that these benefits are only conferred by a lifetime of being bilingual (e.g., Bialystok et al., 2011), an idea that the present results clearly contradict.

It is important to note that previous research investigating whether or not late bilinguals manifest EF benefits relative to monolinguals has found that they do not differ in their EF performance relative to monolinguals (Bialystok et al., 2006; Luk, De Sa, & Bialystok, 2011), but methodological differences between the present research and these studies may be responsible for the contradictory findings. One possible issue is that in the Luk et al. study, participants were classified as (fluently) bilingual based solely on self-report. As was discovered in the present study, self-report of second language proficiency is frequently inaccurate. In the present study, of the 30 late bilinguals that participated, there were originally 40 who provided self-reports indicating that they were fluently bilingual. However, upon interview in their second language, it became clear that their self-reported proficiency was inaccurate and that they were in fact not fluent in their second language. If late bilingual participants were actually not fluent in their L2, one would not expect that group to differ significantly from the monolingual group, consistent with Luk et al. (2011). Another issue with the Luk et al. study was that their bilingual participants did not all speak the same two languages, whereas ours were solely Spanish and English speakers. Using various languages with a bilingual group could affect different participants' executive function in that the similarity or difference between a bilingual's two languages could potentially affect the degree to which the two languages interfere with one another. For example, Spanish and Italian, which are quite similar, might create more interference than Spanish and Thai, which are very different.

In a different study, Bialystok and colleagues (2006) compared three groups of participants: monolinguals, unbalanced bilinguals who became bilingual at about 6 years of age, and balanced bilinguals who became bilingual at about 3.5 years of age. Balanced bilinguals in this study reported daily use of both their languages, while unbalanced bilinguals reported using their second language between once a week and once a month. They found that balanced bilinguals had better EF than monolinguals, but the unbalanced bilinguals did not differ from either group in their executive function. This result suggests that one must be fluently bilingual and must be using both of his/her languages regularly, or EF will not be evident. However, as with the previously described study, bilinguals' proficiency in their second language was determined solely based on self-report, the two languages spoken were not uniform, and in this study, the number of participants in each group was relatively small (N = 24). Despite these methodological issues, an important idea that emerges here is that for bilinguals to manifest EF advantages, regular use of both of their languages is likely an important prerequisite, while becoming bilingual during childhood does not appear to be a crucial factor in this regard.

Interviewing the bilingual participants in Spanish prior to having them complete the EF tasks could also have had an unexpected EF benefit for late bilinguals in the present study, relative to previous studies that did not find EF benefits for this group. Past research has demonstrated that language-switching contexts engage neural substrates associated with EF (Rodriguez-Fornells et al., 2005). Because all bilingual participants used Spanish during the interview and then switched to English to read task instructions before any of the experimental tasks began, this language switching may have engaged EF to a greater degree than if participants had only used English for the entire experiment. This initial engagement of EF among the bilinguals may have 'primed' their EF processes, resulting in their better EF on the ANT and Simon tasks relative to monolinguals. Future research should investigate whether or not requiring participants to switch between their languages immediately before engaging in EF tasks affects the participants' performance on those tasks compared to others who have only used one of their languages prior to completing the task.

In sum, the present study yields two conclusions. First, becoming fluently bilingual in young adulthood confers the same cognitive effects as becoming fluently bilingual in childhood, both in terms of the disadvantages in lexical access (which may actually be greater for late bilinguals in some regards) and the advantages in executive function. Second, of the two hypotheses proffered to account for bilingual advantages and disadvantages, we found mixed support. The Language Interference hypothesis was consistent with the RT results from picture naming and both EF tasks, while those data contradict the Frequency Lag hypothesis. However, results from errors on the picture naming task and from multiple measures on the verbal fluency task are not consistent with either of these theoretical frameworks. Hence, the present study has provided a clear answer to the first research question about whether becoming fluently bilingual after childhood would result in the same cognitive effects as becoming bilingual during childhood, but results were more ambiguous for the second research question. This study has also highlighted important methodological considerations while also raising other intriguing questions. One methodological issue regards the fact that when doing bilingual research, ensuring that one's participants are fluently bilingual is paramount and should not be assumed from participants' self-reports. A measurement issue raised in this study illustrates the importance of reporting errors as a measure of lexical access deficits and/or advantages, particularly with regard to verbal fluency tasks. This measure revealed another issue that deserves further investigation, i.e. the possibility that relative to monolinguals, early bilinguals may have a lexical access advantage on verbal fluency tasks that has heretofore been undetected, and if such an advantage exists, identifying its source will require cleverly and carefully designed experimental tasks.

APPENDIX A
SAMPLE SCRIPT TO ENGAGE BILINGUALS IN CONVERSATION IN SPANISH

For reader clarity, the script is shown in English but was actually administered in Spanish. Questions asked by the experimenter are shown in italics.

"Hi, my name is _______."

- Give the participant time to respond in Spanish.
- If they do not do so, say in Spanish: *"You will need to speak Spanish for this part of the study"*.
- Continue with: *"It's nice to meet you. I will be running the first part of this experiment with you today. Please have a seat in the yellow chair."*

As they are getting settled, say: *"Oh, it's so cold in here. Does it feel cold to you?"*

- If they say yes, ask: "Do you want to put on a jacket/sweater before we start the experiment?"
- If they say no, ask: "Well, I hope it doesn't get too cold in here."

Next, ask one of the following questions. If the participant answers with a one-word response, elaborate on the question with follow-up questions to elicit a more complex response (suggested questions are indicated below). If that fails to elicit a multi-word response, ask another one of the questions below.

Are you excited to watch the Gator football/basketball game this weekend?

- If yes: "Who do you think is the best player?" and "Why do you think he's the best?"
- If no: "Are there any sports that you follow?" and "How did you get interested in that sport?"
- If they say that they don't follow any sports, ask "What do you like to do in your free time?"

"What year are you?"

- Follow up with: "So how have you liked UF and Gainesville since you started?"
- If they answer briefly, ask "Why do you/don't you like it?"

"What are you studying?"

- Follow up with: "So how did you get interested in that?" or "So what do you plan to do with your degree after you graduate?"

"Did you have any trouble finding your way here/the room?"

- If yes: "How did you end up finding us here?"
- If no: "How did you know where we were located?"

Once the participant has demonstrated that s/he can converse fluently in Spanish, continue by saying in Spanish, *"I am going to give you some paperwork to fill out. The first paper is the informed consent. Please read through the informed consent. If you want to participant, please print your name, sign it, and date the paper. This is the only paper with your name on it. It will be kept separate from your data."*

Then say: *"Now I have some questions to ask you about your language history."* Then administer the Language History Questionnaire in Spanish and record the participant's answers. Comment on their responses and ask questions that require the participant to elaborate his/her responses. For example: if the participant says s/he was born in Colombia, Say *"Wow, I've always wanted to visit there! What is your favorite city/place there….really? Why?"* Or *"What should I do/see if I ever get a chance to go there?"*

APPENDIX B
PICTURE NAMES IN ENGLISH AND SPANISH

Block 1		Block 2		Block 3	
English Name	Spanish Name	English Name	Spanish Name	English Name	Spanish Name
accordion	acordeón	airplane	avión	apple	manzana
arm	brazo	anchor	ancla	ashtray	cenicero
arrow	flecha	ant	hormiga	axe	hacha
asparagus	esparrago	artichoke	alcachofa	balloon	globa
banana	plátano	ball	pelota	beetle	cucaracha
basket	cesta	barn	casa	bicycle	bicicleta
bed	cama	barrel	barril	boot	bota
bee	abeja	bear	oso	cake	tarta
bell	campana	bird	pájaro	camel	camello
belt	cinturón	blouse	camisa	car	coche
book	libro	bowl	cuenco	carrot	zanahoria
bottle	botella	broom	escoba	caterpillar	gusano
bow	lazo	brush	cepillo	chair	silla
box	caja	butterfly	mariposa	cherry	cereza
cap	gorra	button	botón	chicken	gallina
cat	gato	candle	vela	cigarette	cigarro
celery	acelgas	chain	cadena	clock	reloj
cigar	puro	chisel	destornillador	cloud	nube
cow	vaca	church	iglesia	coat	abrigo
crown	corona	clothespin	pinza	comb	peine
deer	ciervo	clown	payaso	corn	maiz
donkey	burro	couch	sofa	doll	muñeca
dresser	cómoda	desk	escritorio	dress	vestido
duck	pato	dog	perro	envelope	sobre
elephant	elefante	door	puerta	eye	ojo
fence	valla	doorknob	pomo	flower	flor
finger	dedo	drum	tambor	flute	flauta
fly	mosca	eagle	Águila	fork	tenedor
foot	pie	ear	preja	giraffe	jirafa
fox	zorro	fish	pez	glass	vaso
frog	rana	flag	bandera	glove	guante
goat	cabra	glasses	gafas	gorilla	gorila
guitar	guitarra	grapes	uvas	hammer	martillo
hand	mano	grasshopper	saltamontes	horse	caballo
hanger	percha	gun	pistola	jacket	chaqueta
harp	arpa	hair	pelo	key	llave
hat	sombrero	heart	corazón	lamp	lámpara
house	casa	helicopter	helicóptero	leg	pierna
kangaroo	canguro	iron	plancha	leopard	leopardo

Block 1		Block 2		Block 3	
English Name	Spanish Name	English Name	Spanish Name	English Name	Spanish Name
knife	cuchillo	kettle	tetera	lips	labios
ladder	escalera	kite	cometa	mitten	manopla
lemon	limón	leaf	hoja	moon	luna
lettuce	lechuga	lock	candado	mushroom	seta
lion	león	mountain	montaña	nail	clavo
lobster	cangrejo	mouse	ratón	onion	cebolla
monkey	mono	nose	nariz	orange	naranja
motorcycle	moto	nut	tuerca	paintbrush	pincel
necklace	collar	ostrich	avestruz	peacock	pavo real
needle	aguja	owl	buho	pen	boligrafo
pants	pantalón	peanut	cacahuete	penguin	pingüino
peach	melocotón	pear	pera	pineapple	piña
pencil	lápiz	pig	cerdo	plug	enchufe
pepper	pimiento	pipe	pipa	potato	patata
piano	piano	pliers	alicates	rabbit	conejo
pitcher	jarra	pot	cazo	refrigerator	refrigerator
purse	bolso	pumpkin	calabaza	ring	anillo
raccoon	mapache	ruler	regla	sailboat	barca
rhinoceros	rinoceronte	sandwich	sandwich	saw	sierra
rooster	gallo	scissors	tijeras	screw	tornillo
screwdriver	destornillador	shirt	camisa	seal	foca
sheep	oveja	sock	calcetín	shoe	zapato
skunk	mofeta	squirrel	ardilla	skirt	falda
snail	caracol	star	estrella	sled	trinea
spider	araña	strawberry	fresa	snake	serpiente
spoon	cuchara	suitcase	maleta	stool	taburete
stove	cocina	telephone	teléfono	swan	cisne
sun	sol	television	televisión	sweater	jersey
swing	columpio	tomato	tomate	table	mesa
thumb	dedo	train	tren	thimble	dedal
toaster	tostador	tree	arbol	tie	corbata
trumpet	trompeta	truck	camión	tiger	tigre
umbrella	paraguas	violin	violín	top	peonza
vest	chaleco	wagon	carrito	vase	jarrón
wheel	rueda	watch	reloj	watermelon	sandía

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BIOGRAPHICAL SKETCH

Sabra Pelham was born in New Orleans, Louisiana but grew up in Lawrence, Kansas where she attended the University of Kansas. She received bachelor's degrees in linguistics and anthropology and a Master of Arts degree in applied linguistics from KU, and shortly after completing the course work for her master's degree, she relocated to Florida and began teaching English as a second language at Daytona Beach Community College (DBCC). She received tenure in her third year at DBCC and was promoted from the status of faculty to assistant and then associate professor. During her time at DBCC, she pursued independent research in child language acquisition and began taking courses in psychology with the view to returning to graduate school to pursue a Ph.D. in psychology. After eight years teaching at DBCC, she returned to graduate school at the University of Florida where she received a Master of Science degree in cognitive psychology in the spring of 2012.