Cognitive Advantages and Disadvantages in Early and Late Bilinguals

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Abstract

Previous research has documented advantages and disadvantages of early bilinguals, defined as learning a second language by school age and using both languages since that time. Relative to monolinguals, early bilinguals manifest deficits in lexical access but benefits in executive function. We investigated whether becoming bilingual *after* childhood (late bilinguals) can produce the cognitive advantages and disadvantages typical of early bilinguals. Participants were 30 monolingual English speakers, 30 late English-Spanish bilinguals, and 30 early Spanish-English bilinguals who completed a picture naming task (lexical access) and an Attentional Network task (executive function). Late and early bilinguals manifested equivalent cognitive effects in both tasks, demonstrating lexical access deficits and executive function benefits. These findings provide support for the hypothesis that cognitive effects associated with bilingualism arise as the result of proficient, habitual use of two languages and not from developmental changes associated with becoming bilingual during childhood.

Keywords: bilingualism; executive function; lexical access; late bilinguals

Cognitive Advantages and Disadvantages in Early and Late Bilinguals

Previous studies have demonstrated that monolinguals and bilinguals perform differently on various verbal and nonverbal tasks. On verbal tasks such as picture naming, monolinguals identify and name pictures more rapidly than bilinguals do in either of their languages (Bialystok, Craik, & Luk, 2008; Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008). Similarly, on semantic verbal fluency tasks, where individuals are given sixty seconds to name as many words that belong to a particular semantic category, e.g., animals, 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 bilinguals (Gollan, Bonanni, & Montoya, 2005). In contrast to these deficits in lexical retrieval, bilinguals demonstrate superior performance on nonverbal tasks of executive function compared to monolinguals. Tasks such as the Simon or Stroop task require participants to respond to one aspect of a stimulus while ignoring another salient but irrelevant aspect of the same stimulus; these tasks involve inhibition of a prepotent response, which requires engagement of executive function to inhibit that response. On these tasks, bilinguals often respond more quickly overall than monolinguals and have smaller *conflict* effects than monolinguals, i.e., incongruent minus congruent reaction times were smaller for bilinguals (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Carlson & Meltzoff, 2008; Costa, Hernández, & Sebastián-Gallés, 2008; but see Hilchey & Klein, 2011; Paap & Greenberg, 2013). The purpose of the present study was to investigate whether the age at which a person becomes bilingual influences the degree of lexical retrieval deficits and/or executive function benefits.

To date, most of the research on the advantages and disadvantages of bilingualism has been limited to *early*, balanced bilinguals, i.e., bilinguals who have been bilingual since early childhood (early) and have spoken both of their languages approximately equally since acquiring those languages (balanced)[1]. Furthermore, previous research has rarely investigated lexical retrieval deficits and executive function benefits in the same study with the same group of bilingual participants (see Bialystok et al., 2008, for an exception). In the present study, two groups of bilinguals, early and late bilinguals, as well as a group of monolinguals were compared on a lexical retrieval task (picture naming) and an executive function task (the Attentional Network task, or ANT, a type of flanker task; Fan, McCandliss, Sommer, Raz, & Posner, 2002). Investigating both lexical access and executive function in the same group of monolinguals, early bilinguals, and late bilinguals can provide important insight into the theoretical underpinnings of bilingual advantages and disadvantages, which are discussed separately for lexical access and executive function in the sections below.

Lexical Access

The degree to which age of becoming bilingual affects the lexical access disadvantages associated with bilingualism is useful in testing the predictions of several theoretical perspectives. One possibility is that *developmental changes* in cognitive and/or neural mechanisms that occur when people learn two languages during a sensitive or critical period, i.e., childhood, are responsible for the lexical access deficits associated with bilingualism. These mechanisms may be linked to the automaticity with which bilinguals produce words in each language as well as potential interference from the other language, which in turn could negatively influence speech production relative to monolinguals. Research on bilingualism has

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[1]See Bialystok, Craik, & Ruocco (2006) for a study comparing unbalanced and balanced bilinguals.

reported that cognitive deficits in language abilities emerge early on in bilingual children, evidenced by poorer performance on verbal tests (Tsushima & Hogan, 1975) and smaller vocabularies in each of their languages (e.g., Pearson, Fernández, Lewedeg, & Oller, 1997). Therefore, the cognitive disadvantages in lexical access observed in adult bilinguals may be longitudinal, a function of those developmental changes that began in childhood and affected lexical access, and those deficits persisted into adulthood.

Within this perspective, we would expect late bilinguals to have differential lexical access deficits as a function of producing words in their L1 (first language) or L2 (second language) and whether this language is their dominant (i.e., more proficient) language. When producing picture names in their dominant language, late bilinguals should perform more like monolinguals and not show lexical access deficits, in contrast to early bilinguals, because late bilinguals were monolingual during childhood and consequently developed automatic access to their dominant language. As a consequence, when producing picture names in their non-dominant language, late bilinguals should exhibit *greater* lexical access deficits than early bilinguals by virtue of their experiencing greater interference from their dominant language. In contrast, by becoming fluently bilingual in childhood, early bilinguals would have developed a better ability to better control interference from their dominant language when naming in their non-dominant language. This would result in early bilinguals producing words in their non-dominant language faster than late bilinguals (but still slower than monolinguals).

An alternative possibility is that the cognitive effects associated with bilingualism arise from proficient, *habitual use* of two languages. With respect to lexical access, previous research has proposed that using two languages effectively reduces the frequency with which bilinguals access the words in each of their languages (e.g., Gollan, Montoya, Cera, & Sandoval, 2008),

with a longer duration of bilingualism associated with a greater difference in bilinguals' and monolinguals' frequency of lexical access. Research in speech production has revealed robust word frequency effects such that low-frequency words are produced reliably slower (e.g., Jescheniak & Levelt, 1994) and less accurately (e.g., Dell, 1988) than high-frequency words. Consequently, early bilinguals' use of two languages results in lexical access deficits in both languages due to their having accessed the words in each of their languages less frequently than monolinguals. While all bilinguals regularly use two languages, the duration of habitual use is dependent on the point at which a person became bilingual: Late bilinguals have not used both languages equally across their lifetime, whereas early bilinguals have. Therefore, by comparing early and late bilinguals, we can investigate whether or not the habitual use of two languages influences bilingual advantages and disadvantages as a function of the amount of time engaging in habitual use.

If the *duration* of habitual use of two languages is critical, we would expect late bilinguals to have differential lexical access deficits as a function of whether they were being tested in their dominant or non-dominant language, albeit differently from the predictions of the developmental change account. Specifically, relative to monolinguals, late bilinguals should have lexical access deficits. However, these deficits should be *smaller* than early bilinguals' when producing words in their dominant language because late bilinguals did not divide their use among two languages at an early age, resulting in more frequent use of words in the dominant language compared to early bilinguals. On the other hand, we would expect late bilinguals to have *greater* lexical access deficits than early bilinguals when compared in their non-dominant language. Late bilinguals have accessed words in their non-dominant language considerably less often than early bilinguals by virtue of acquiring that language later in life, and this reduction in

frequency of use should make them more susceptible to lexical access deficits than early bilinguals when producing words in their non-dominant language. However, if habitual use of two languages results in lexical access deficits *independent of duration of* proficient bilingualism, then early and late bilinguals should perform equivalently in terms of lexical access, when producing in either the dominant or non-dominant language, with both groups manifesting lexical access deficits to the same degree, relative to monolinguals.

Executive Function

One measure of executive function that has been used with bilinguals in previous research is performance on the ANT. In the ANT, a centrally presented arrow is the target, and participants must press a button on the side of the computer keyboard corresponding to the direction in which the target arrow is pointing. Target arrows are surrounded by distractors (i.e., flankers) that are horizontal lines (neutral condition), arrows pointing in the same direction as the target (congruent condition), or arrows pointing in the opposite direction of the target (incongruent condition). The ANT differs from Simon and Stroop tasks in that the centrally-presented target arrow does not elicit a prepotent response. Instead, conflict arises from the flankers and the congruency of their direction with the target. We chose the ANT as our measure of executive function because it measures participants' ability to suppress interference from distractors, a type of executive control that most closely mimics executive control processes engaged when bilinguals speak. For example, when bilinguals want to produce a word in one language, the target for production is the word in the desired language, while the word in the non-desired language can be viewed as a distractor. Furthermore, conflict effects in the ANT have been shown to be smaller for bilinguals than monolinguals (Costa et al., 2008), similar to other executive function tasks.

The theoretical perspectives discussed above are also relevant for understanding the advantages associated with executive function tasks like the ANT. One possibility is that bilinguals' executive function benefits arise as a result of cognitive and neural changes in development that occur when people become fluently bilingual during childhood, which has a positive effect on executive function by enhancing early bilinguals' ability to suppress interference that is created by distractors. Previous research has found advantages for bilingual children on tasks that require control of attention (e.g., Martin-Rhee & Bialystok, 2008), the ability to switch mental sets (e.g., Bialystok & Martin, 2004), and theory of mind (e.g., Goetz, 2003). If these advantages that began in childhood persist into adulthood, then early bilinguals should be better at controlling interference from distractors, such as the flanking arrows in the ANT task, than late bilinguals. That is, early bilinguals will show executive function benefits relative to monolinguals, whereas late bilinguals will not.

Alternatively, habitual use of two languages may serve to enhance bilinguals' attentional control. When bilinguals access words in one language, words in the non-use language are activated all the way to the point of retrieving the words' sound segments (e.g., Colomé & Miozzo, 2010), which is assumed to create a language conflict. That is, when bilinguals speak words in one language, the words in both languages are fully available for articulation, which generates a conflict that must be resolved for successful production of the intended words. Neuroimaging research has shown that the brain regions activated during language conflict in bilinguals, such as the anterior cingulate cortex (ACC), are the same areas that engage executive function for response selection, task-switching, and inhibition of distractors (Abutalebi & Green, 2007; Rodriguez-Fornells et al., 2005; van Heuven, Schriefers, Dijkstra & Hagoort, 2008). Bilinguals' use of two languages requires them to regularly control cross-language interference,

which results in their constant use of neural pathways associated with executive control of attention. This may serve to strengthen and maximize the efficiency of these pathways, resulting in superior performance relative to monolinguals on tasks requiring attentional control. Consistent with this possibility, Abutalebi et al. (2012) found that while both monolinguals and bilinguals showed greater activation in the ACC on incongruent trials than congruent trials during a flanker task, bilinguals had proportionally smaller increases in ACC activation on incongruent trials than monolinguals while manifesting smaller conflict effects, suggesting greater efficiency. Bilinguals' smaller conflict effects were also correlated with increased grey matter density in the ACC.

Two previous studies with late bilinguals found conflicting results in that late bilinguals exhibited an executive function benefit relative to monolinguals in one study (Linck, Hoshino, & Kroll, 2008) but not the other (Luk, De Sa, & Bialystok, 2011). In the Linck et al. (2008) study, late immersed and non-immersed bilinguals as well as monolinguals completed a Simon task, and late immersed bilinguals exhibited executive function benefits compared to the monolinguals. In contrast, Luk et al. (2011) compared monolinguals, late bilinguals, and early bilinguals' performance on a flanker task and found that only early bilinguals, not late bilinguals, manifested executive function benefits relative to monolinguals. Given these conflicting results, the circumstances under which late bilinguals possess executive function benefits in comparison to early bilinguals require further investigation.

To the extent that habitual use of two languages and the associated experience of controlling language interference results in bilinguals' executive function advantages, late bilinguals should exhibit smaller executive function benefits than early bilinguals if the *duration* of habitual use is relevant. Otherwise, late bilinguals should show advantages similar to early

bilinguals in executive function if it is simply habitual use of two languages irrespective of duration.

Summary

We have proposed three possible accounts for the lexical access disadvantages and executive function advantages associated with bilingualism, which are summarized in Table 1. The first possibility is that becoming proficiently bilingual during childhood alters the course of cognitive development so that the accompanying cognitive and neural changes result in lifelong lexical access deficits and executive function benefits for early bilinguals. These developmental changes are specific to early bilinguals, predicting that early bilinguals will manifest the advantages and disadvantages typically associated with bilingualism, while late bilinguals will not exhibit executive function advantages and will only exhibit lexical access disadvantages when producing in their non-dominant language. A second possibility is that the duration of bilingualism accounts for the cognitive effects associated with bilingualism. If so, by virtue of late bilinguals having less regular and proficient use of both languages than early bilinguals, late bilinguals will manifest smaller dominant language lexical access deficits, larger non-dominant language lexical access deficits, and smaller executive function benefits relative to early bilinguals. The third possibility is that the advantages and disadvantages associated with bilingualism arise from the proficient use of two languages, irrespective of the duration of that use. If so, then both bilingual groups should perform equivalently, exhibiting lexical access deficits and executive function benefits compared to monolinguals.

Table 1 about here

Method

Participants

Thirty monolingual English speakers (63% female, 83% Caucasian), 30 late bilinguals fluent in English and Spanish (53% female, 20% Caucasian and 80% Hispanic), and 30 early bilinguals also fluent in both English and Spanish (53% female, 100% Hispanic) were recruited from graduate and undergraduate courses at the University of Florida as well as 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. Data were initially collected from 53 monolingual and 54 early bilingual participants, but we were unable to test a comparable number of late bilinguals because of the difficulty in finding potential participants who met our stringent study criteria (see below). We therefore analyzed a subset of the original data to compare equal numbers of participants in the three groups and to make the groups more comparable in terms of demographics that differed within the full sample, specifically their backward digit span and their age. To achieve this, we removed the youngest monolinguals and early bilinguals with the shortest backward digit spans. Although not reported here, analyses were also conducted including all participants, and the results were the same as those described herein.

Monolinguals' and bilinguals' demographic characteristics as well as performance on several cognitive tests are presented in Table 2. The groups differed significantly in terms of age, $F(2, 87) = 8.26$, $MSE = 6.59$, $p = .001$, where late bilinguals were older than both early bilinguals, $p = .01$, and monolinguals, $p < .001$, who did not differ, $p = .14$. The groups also differed in years of formal education, $F(2, 86) = 4.49$, $MSE = 5.53$, $p = .01$, with monolinguals

having fewer years of formal education than both late bilinguals, $p = .01$, and early bilinguals, $p = .02$, who did not differ, $p = .73$. It is worth noting that the mean age and education for all three groups were within the normal range of college students, so there is no obvious reason to predict that these slight differences would be relevant. Nonetheless, we covaried age and education in one of our picture naming analyses to ensure that these variables were not contributing to our findings. The three groups did not differ on their self-reported college grade point averages, $F(2, 63) = 1.34$, $MSE = .24$, $p = .27$, self-reported health ratings $F(2, 86) = 1.05$, $MSE = 1.58$, $p = .36$, or their forward or backward digit spans, $Fs < 1$.

Table 2 about here

Participants were prescreened for their monolingual or bilingual status, either through a pre-screening questionnaire on the university's psychology participant pool website or via e-mail through questions about the number of languages spoken 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 other languages well below this threshold (speaking proficiency, M = 1.12, SD = .60; understanding proficiency, M = 1.20, SD = .87). In addition, the majority of participants had never spent any time in a place where this other language 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 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). 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 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 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. This resulted in the early age of onset of acquisition that these participants reported. However, only participants who indicated 1) that they were not immersed in an L2 environment until after middle school, and 2) that they never began studying their second language seriously until middle school or later were included in the late bilingual group.

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 seven years of age. While seven years may seem somewhat older than traditional cutoffs for early bilinguals, which is around 4-5 years of age, the limitation of self-reported fluency should be acknowledged. The reported age of attainment of fluency was highly variable, even in L1. For example, while 20% of the early bilinguals reported attaining fluency in their L1 by 1-2 years of age, another 20% of the early bilinguals reported that they did not attain fluency in their L1 until 5-7 years of age, which is highly unlikely given that none of the participants had any history of language disorders. Though immersion in both languages was not a requirement for participants to be included in the study, all participants had some duration of immersion, defined as living in a country where that language is the dominant or official language, in both of their languages. The late bilingual group spent an average of 1.6 years ($SD = 2.4$) immersed in their second language and an average immersion of 20.3 years ($SD = 3.9$) in their first language. Early bilinguals had an average of 4.4 years of immersion in Spanish ($SD = 5.4$) and an average of 16 years immersion in English ($SD = 5.6$).

Independent-samples t-tests were conducted on several aspects of late and early bilinguals' language history, which are shown in Table 3. Late bilinguals began acquiring L2 about 8 years later than early bilinguals, $t(58) = 8.93$, $p < .001$, became fluent in their L2 13

years later than early bilinguals, $t(58) = 18.25$, $p < .001$, and had been fluently bilingual for 12 years less than early bilinguals, $t(58) = 12.81$, $p < .001$. However, with respect to the other self-report ratings, late bilinguals reported higher ratings in L1 than early bilinguals, citing more daily exposure to, time speaking, and proficiency speaking L1 (all ps $< .003$). Conversely, early bilinguals reported higher ratings on these measures than late bilinguals in L2 (see Table 3).

Table 3 about here

The above differences between the bilingual groups in their L1 and L2 appear to result from the majority of early bilinguals (26 of 30) reporting reversed dominance, i.e., their dominant language (English) was their L2, while their L1 (Spanish) was their non-dominant language. For the remaining four early bilinguals, their first language and dominant language was English. In contrast, only 7 of the 30 late bilinguals reported being reversed dominance, and for those participants, their L2 (English) was their dominant language. Of the remaining 23 late bilinguals, 16 were L1 English dominant, and 7 were L1 Spanish dominant. Thus, comparisons of groups within L1 or L2 would be misleading because differences would likely result from the majority of one group using their dominant language while the majority of the other group used their non-dominant language. To avoid this confound, we compared late and early bilinguals on ratings in their dominant and non-dominant languages (see Table 4). T-tests revealed that the groups differed significantly on only two measures: their proficiency understanding their dominant language, $t(58) = 2.23$, $p = .03$, and their proficiency understanding their non-dominant language, $t(57) = 2.87$, $p = .006$, with early bilinguals reporting better proficiency in understanding both their dominant and non-dominant language than late bilinguals. The groups differed marginally in their daily exposure to their dominant language, $t(57) = 1.98$, $p = .053$, and their non-dominant language, $t(57) = 1.86$, $p = .07$, with early bilinguals reporting greater daily

exposure to their dominant language than late bilinguals but less daily exposure to their non-dominant language than the late bilinguals. They also differed marginally in their proficiency speaking their dominant language, $t(58) = 1.74$, $p = .09$, with early bilinguals reporting greater proficiency than late bilinguals. The groups were equivalent in their percentage of time speaking in their dominant language, $t(57) = 1.37$, $p = .18$, their percentage of time speaking their non-dominant language, $t < 1$, and their proficiency speaking their non-dominant language, $t < 1$. These findings suggest that language dominance is a more equitable basis for comparing the bilingual groups than L1/L2.

<center>Table 4 about here</center>

Materials and Procedure

Both experimental tasks were presented via computer programs written in Visual Basic 5.0.

Lexical Access: Picture Naming. For the picture naming task, 195 black and white line drawings used in the present study were selected from the Snodgrass and Vanderwart (1980) picture set, and none were cognates or homophones. All 195 pictures were normed for Spanish on the dimensions of name agreement, image agreement, familiarity, and visual complexity (Sanfeliu & Fernandez, 1996), and word frequency data in Spanish and English (Cuetos, Ellis, & Alvarez, 1996) were available for 179 of our pictures. These 179 pictures were divided into three blocks that were matched on mean English word frequency and Spanish word frequency, and a one-way ANOVA using block 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 16 pictures for which no frequency data were

available were divided between the three blocks. Each block of 65 pictures began with two practice pictures followed by 63 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 in whichever language came to mind first. The English and Spanish naming conditions for the bilinguals were included to allow for comparison of the groups when they named in their dominant or non-dominant language. The either-language condition has been used in previous research with early bilinguals (Gollan et al., 2002; Gollan et al., 2008). Results from the Gollan et al. study (2002) showed that having the option to use either language on a semantic fluency task did not improve bilinguals' performance but actually resulted in their producing slightly fewer exemplars.[2] This result suggests that having the option to name pictures in either language may create more language conflict than when naming is restricted to only one language. If so, the either language condition may be particularly likely to reveal differences between the two bilingual groups if they exist, since early bilinguals had considerably more years of experience in controlling language interference than late bilinguals.

Order of blocks was counterbalanced across participants, and order of instructed language to use was counterbalanced across bilingual participants. 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 began when the participant pressed the Enter key. For each picture, the program recorded an

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[2]Analyses from the either language condition were not reported in the Gollan et al. (2008) study.

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

(Jennings & Abrams, 2013).

       Executive Function: Attentional Network Task (ANT). 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. The target arrow appeared in the middle of the computer and pointed either to the right

or left. The flankers that surrounded the arrow appeared in one of three ways: 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 our implementation of the ANT, appearance of the target and flankers on each trial

occurred following one of two cue types: (1) a double alerting cue, which consisted of one

asterisk appearing above the fixation point and another appearing below the fixation point, or (2)

no cue (just the fixation). This cue condition was included to keep the task implementation

similar to that used by Costa et al. (2008), but the presence of a cue was irrelevant to the focus of

the present experiment, which was bilinguals' ability to control attention without any boost from

cuing. Hence, trials presented with a cue were treated as fillers and not analyzed. 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 about their accuracy given on each trial, and then they completed three 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, and the onset of the target and flankers was variable as shown in Figure 1. 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 initial variable delay, a cue or no cue appeared (depending on the trial) for 100 ms, followed by a 400 ms fixed delay after which the target and flankers appeared. The target and flankers remained on the screen for 1700 ms or until the participant responded. Then, another variable delay occurred, which was computed by subtracting the first delay and the participant's RT from 3500 ms; this ensured that the duration of each trial lasted exactly 4000 ms. The design of the time course for each trial resulted in variable (and therefore unpredictable) timing of the appearance of subsequent targets after responses were given. This variable time course was also used in the original implementation of the ANT (Fan et al., 2002). In other flanker studies, the target and distractors for each trial always appeared after a fixed time interval following participants' response to a preceding trial (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa et al., 2008; Luk et al., 2011). However, a fixed interval could make the appearance of the target and distractors predictable because the offset of the stimuli from one trial serves as a temporal cue to the appearance of the stimuli for the next trial, and temporal cueing can decrease participants' response times (Coull & Nobre, 1998). To avoid these potential temporal cueing effects, we followed Fan et al. (2002) and used the variable time course described above.

Figure 1 about here

Results

Picture Naming

Response Times. Prior to performing ANOVAs on the RT data for the picture naming task, practice trials, incorrect responses where participants provided the wrong picture name, 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. Mean RTs were calculated within participant group and picture naming language (i.e., dominant or non-dominant), 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 means. 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. Only responses using the intended picture name were included in the analyses reported below.

Comparisons of monolinguals and bilinguals. One-way ANOVAs compared the three groups on their mean naming times in their dominant language. Analysis yielded a significant main effect, $F(2, 87) = 8.3$, $MSE = 9165.8$, $p < .001$, $\eta^2 = .16$. Post-hoc tests revealed that monolinguals named pictures more quickly ($M = 761.6$, $SD = 72.3$) than early bilinguals ($M = 849.7$, $SD = 104.9$), $p = .001$, and late bilinguals ($M = 848.2$, $SD = 106.2$), $p = .001$, with no difference between the bilingual groups ($p = .95$). However, the above ANOVA included both English-dominant late bilinguals and Spanish-dominant late bilinguals, the latter of which named the pictures in Spanish. Since Spanish words are typically longer than English words, and word length has been shown to affect picture naming times such that longer words are produced more slowly than shorter words (D'Amico, Devescovi, & Bates, 2001), inclusion of Spanish-dominant

late bilinguals could potentially have slowed the mean RT for this group. Consequently, a one-way ANOVA was conducted excluding the seven late bilingual participants whose dominant language was Spanish and again revealed a significant main effect of participant group, $F(2, 80)$ = 7.96, MSE = 9234.3, $p < .001$, $\eta^2 = .17$, with monolinguals naming pictures significantly faster than both bilingual groups, who did not differ. Furthermore, this effect of group remained significant when age and education were added as covariates, ps $< .004$. For clarity, all subsequent analyses with late bilinguals will be conducted with English dominant participants only, excluding Spanish-dominant participants.

To ensure that monolinguals' faster response times were not due to practice effects, i.e., monolinguals naming three blocks of trials in English compared to bilinguals' naming only one block, we conducted a one-way ANOVA on mean naming times in the dominant language where monolinguals' naming times from only the first block were included. This analysis revealed the same pattern of results: A significant main effect of participant group, $F(2, 80)$ = 10.74, MSE = 9133.17, $p < .001$, $\eta^2 = .21$, with monolinguals naming pictures significantly faster than both bilingual groups, ps $< .001$, who did not differ, $p = .97$.

Effects of Word Frequency and Block Order. Previous research has shown that a word's frequency influences the speed of word production. Both monolinguals and bilinguals name pictures with low-frequency names more slowly than those with high-frequency names (Gollan, Slattery, Godenberg, van Assche, Duyck, & Rayner, 2011; Wingfield, 1968), and the most robust differences between monolinguals and bilinguals in picture naming times typically emerge for low-frequency words (Gollan et al., 2008). In addition, the order in which bilinguals' dominant and non-dominant languages are used can affect picture naming times. When bilinguals name pictures in their non-dominant language first, subsequent picture naming in their dominant

language is often slower than when they name in their dominant language first (Guo, Liu, Misra, & Kroll, 2011; Misra, Guo, Bobb, & Kroll, 2012). In contrast, naming first in bilinguals' dominant language does not result in slower subsequent picture naming times in the non-dominant language. These findings have been attributed to bilinguals' need to suppress interference from their dominant language more strongly when using their non-dominant language than vice versa; this act of suppression slows naming times when bilinguals are again allowed to use their dominant language. Therefore, it is possible that bilinguals' overall slower picture names in our previously reported analyses were influenced by word frequency and/or lingering suppression of the dominant language from blocks where pictures were named in their non-dominant language first, rather than a general slowing of lexical access.

To evaluate these possible influences, we conducted analyses on participants' naming times for high- and low-frequency words when the dominant language was used in the first block (to evaluate naming times when the dominant language has not been strongly suppressed). We first divided pictures into two groups as a function of word frequency. Word frequency in English was taken from Francis and Kucera (1982), while Spanish word frequency was taken from Cuetos et al. (1999). Using cutoffs similar to those used by Gollan et al. (2008), 133 pictures were able to be categorized as low- or high-frequency. Low-frequency picture names (N = 95) had a mean English frequency of 4.9 (SD = 4.5) and a mean Spanish frequency of 4.8 (SD = 3.9), with all picture names having a frequency of 15 per million or lower in both English and Spanish. High-frequency picture names (N = 38) had a mean English frequency of 179.9 (SD = 136.4) and a mean Spanish frequency of 151.5 (SD = 135.0), with picture names in this group having a frequency of 50 per million or higher in both English and Spanish.

Using the frequency cutoffs described above, a 3 (Participant Group) X 2 (Word Frequency) repeated-measures ANOVA was carried out on dominant-language (i.e., English) picture naming times for high- and low-frequency pictures named in the first block by all three groups.[3] When only pictures that were named in the dominant language in the first block were included, results revealed a marginal main effect of participant group, $F(2, 42) = 3.06$, $MSE = 12680.92$, $p = .06$, $\eta^2 = .13$; a main effect of word frequency, $F(1, 42) = 28.5$, $MSE = 3654.4$, $p < .001$, $\eta^2 = .4$, and a Participant Group x Word Frequency interaction, $F(2, 42) = 4.7$, $MSE = 3654.4$, $p = .01$, $\eta^2 = 18$. Post-hoc tests on the interaction showed that monolinguals named low-frequency pictures in the first block faster ($M = 755.7$, $SD = 81.6$) than early bilinguals ($M = 852.3$, $SD = 85.9$), $p = .01$, and late bilinguals ($M = 844.9$, $SD = 166.9$), $p = .04$, although the bilingual groups did not differ, $p = .54$. In contrast, there were no significant group differences in picture naming times for high-frequency pictures named in the first block, although late bilinguals named pictures marginally faster than early bilinguals, $p = .10$. These results are displayed in Figure 2.

<div align="center">Figure 2 about here</div>

Comparisons of late and early bilinguals. Bilingual participants were then compared when naming pictures in the dominant, non-dominant language, and either language conditions. While the above results demonstrated no differences between early and late bilinguals in naming in their dominant language, differences in the non-dominant condition may be more likely to emerge (see Table 2). We also included the either-language condition for exploratory purposes. The option to use both languages might create greater language interference than producing

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[3]Analyses of naming times when the dominant language was used in the 2nd and 3rd blocks are not reported, as those blocks were sometimes preceded by a non-dominant and sometimes by an either-language block, making interpretation of results unclear. Nonetheless, in these analyses monolinguals produced words significantly faster than the bilingual groups, who did not differ.

picture names in only one language if both languages are activated. If so, late bilinguals may

have increased difficulty managing this language conflict and experience greater lexical access

deficits relative to early bilinguals because of fewer years of experience in controlling language

interference.

A 2 (Participant Group: Late Bilingual, Early Bilingual) X 3 (Instruction Language:

Dominant, Non-Dominant, Either) X 2 (Word Frequency: Low, High) mixed-factorial ANOVA

was conducted on mean picture naming times, and means and SDs from this analysis are shown

in Table 5. Results revealed a main effect of instructed language, $F(2, 90) = 26.32$, $MSE =$

24058.34, $p < .001$, $\eta^2 = .37$, such that both bilingual groups produced picture names more

slowly in their non-dominant language than in the either language condition, which was slower

than picture naming times in their dominant language. There was also a main effect of word

frequency, $F(1, 45) = 117.40$, $MSE = 10991.45$, $p < .001$, $\eta^2 = .72$, which revealed that

participants produced high frequency picture names faster than low frequency picture names, and

a significant two-way interaction between instructed language and word frequency, $F(2, 90) =$

4.55, $MSE = 9387.36$, $p = .01$, $\eta^2 = .09$. The interaction revealed that the effect of word

frequency was greatest when naming pictures in the non-dominant language (low-frequency

pictures were named 182 ms slower than high-frequency pictures), smallest in the dominant

language ($M_{diff} = 97$ ms), and the either language condition had an intermediate frequency effect

($M_{diff} = 139$ ms). However, all factors involving participant group were nonsignificant, ps > .18,

illustrating that early and late bilinguals' naming times were equivalent in all conditions.

Table 5 about here

Accuracy. Accuracy was calculated as the percentage of pictures named correctly.

Correct responses included either the target name (e.g., *couch*) or an appropriate synonym (e.g.,

sofa), since many of the pictures had more than one plausible correct name, and participants were not trained on the expected picture names prior to naming the pictures. Responses were considered to be incorrect if participants provided no response, a response in the wrong language (even if they provided the correct word in the wrong language), or an undecipherable response.

Comparisons of monolinguals and bilinguals. One-way ANOVAs compared the three groups on their percentage of correctly named pictures, and results revealed a marginally significant main effect, $F(2, 87) = 3.1$, $MSE = .003$, $p = .051$, $\eta^2 = .07$, such that monolinguals ($M = 95.5\%$, $SD = 2.6\%$) named more pictures correctly than late bilinguals ($M = 92.2\%$, $SD = 7\%$), $p = .02$, but did not differ from early bilinguals ($M = 93.6\%$, $SD = 4.6\%$), $p = .16$, and the early and late bilingual groups did not differ, $p = .30$.

Comparisons of late and early bilinguals. The bilingual groups' picture naming accuracy was then analyzed as a function of the instructed language in which to respond via a 2 (Participant Group) x 3 (Instructed Language) mixed-factorial ANOVA. Results revealed a significant effect of instructed language, $F(2, 116) = 127.54$, $MSE = .01$, $p < .001$, $\eta^2 = .69$, such that participants accurately produced marginally more picture names when instructed to name in either language ($M = 94.3\%$, $SD = 4.4\%$) than in their dominant language ($M = 92.9\%$, $SD = 7\%$), $p = .07$, both of which resulted in greater accuracy than naming pictures in the non-dominant language ($M = 68.8\%$, $SD = 16.1\%$) , ps $< .001$. However, there was no main effect of participant group and no significant interaction, Fs < 1.

Attentional Network Task

Response Times. Prior to performing ANOVAs on the RT data for the Attentional Network Task (ANT), incorrect responses and practice trials were excluded from analysis. Data were trimmed of outliers that were more than 2.5 standard deviations above or below each

group's mean in each of the conditions. Trimming resulted in equivalent data loss across groups (3.0% for monolinguals, 2.9% for late bilinguals, and 2.6% for early bilinguals).

A 3 (Participant Group: monolingual, late bilingual, and early bilingual) x 3 (Flanker Type: neutral, congruent, incongruent) mixed factorial ANOVA was conducted on mean RTs for accurate trials, and results are shown in Figure 3. While there was no main effect of participant group, $F < 1$, there was a main effect of flanker type, $F(2, 174) = 402.1$, $MSE = 867.8$, $p < .001$, $\eta^2 = .82$, such that RTs to targets with neutral flankers ($M = 619.6$, $SD = 65.1$) were faster than targets with congruent flankers ($M = 633.2$, $SD = 68.8$), which were faster than targets with incongruent flankers ($M = 733.6$, $SD = 96.8$), all ps < .001, and a significant Participant Group x Flanker Type interaction, $F(4, 174) = 4.0$, $MSE = 3428$, $p = .004$, $\eta^2 = .08$. We evaluated this interaction by examining whether the groups differed in terms of the degree of slowing they experienced on incongruent trials, i.e., their conflict effects, calculated as the difference in RTs between incongruent and congruent trials. Results revealed that monolinguals were more slowed on incongruent trials, revealing larger conflict effects ($M = 122.8$ ms) than late bilinguals ($M = 92.5$ ms), $p = .02$, and early bilinguals ($M = 85.9$ ms), $p = .003$, while the bilingual groups did not differ, $p = .59$.

Figure 3 about here

Accuracy. Accuracy was calculated in terms of the mean proportion of erroneous responses on the ANT. A 3 (Participant Group: monolingual, late bilingual, and early bilingual) x 3 (Flanker Type: neutral, congruent, incongruent) ANOVA revealed a significant main effect of flanker type, $F(2, 174) = 19.54$, $MSE = .026$, $p < .001$, $\eta^2 = .18$, but no main effect of participant group and no interaction, Fs < 1. Although errors overall were infrequent, participants were made more errors on trials with incongruent flankers ($M = 3.8\%$, $SD = 6.5\%$) than trials with

neutral flankers ($M = 1.1\%$, $SD = 1.7\%$), which were more erroneous than trials with congruent flankers ($M = .6\%$, $SD = 1.3\%$).

Discussion

This study was the first to compare the performance of monolinguals, early bilinguals, and late bilinguals on both lexical access and executive function tasks. We sought to determine whether people who become fluently bilingual after childhood have the same cognitive advantages and disadvantages as early bilinguals. The present results demonstrate that late bilinguals generally performed like early bilinguals, experiencing the same degree of lexical access deficits and executive function benefits. Hence, these cognitive effects associated with bilingualism do not depend on learning a second language as a child, nor are they strictly related to the duration that one has been fluently bilingual. Rather, they support the interpretation that proficient, habitual use of two languages, which is not contingent on a lifetime duration of use, results in both lexical access deficits and executive function benefits. Furthermore, these results cannot be explained by educational differences between the two bilingual groups, as they reported equivalent years of formal education.

With respect to lexical access, the picture naming task demonstrated that both early and late bilinguals produced low-frequency picture names in their dominant language more slowly and less accurately than monolinguals (despite having more education), replicating previous research of a bilingual disadvantage in lexical access for early bilinguals (Bialystok et al., 2008; Gollan et al., 2007; Gollan et al., 2008; Gollan et al., 2005; Ivanova & Costa, 2008) and extending it to late bilinguals. However, the bilingual groups did not differ from each other in picture naming times for either low- or high-frequency words, suggesting that the degree of bilingual disadvantage was similar for the two groups. Furthermore, these findings remained

when bilinguals named pictures in their dominant language in the first block. Previous research has documented that naming pictures in the non-dominant language requires inhibition of the dominant language, which can linger after the non-dominant language is no longer in use (Guo et al., 2011; Misra et al., 2012) and exacerbate lexical access deficits. When potential consequences of prior non-dominant naming were ruled out, both bilingual groups exhibited lexical access deficits, to the same degree. The only difference that emerged between the groups was a marginal decrease in picture naming accuracy for late bilinguals, although both groups were highly accurate overall.

The equivalence of bilinguals' naming times remained regardless of the language used for naming. Although both bilingual groups produced dominant responses more quickly than non-dominant responses, supporting the self-reported distinction for which language was dominant or non-dominant, early and late bilinguals' naming times did not differ whether pictures were named in the dominant language, non-dominant language, or in the condition where either language was acceptable. These results are problematic for both a developmental change account and a duration of habitual use account, both of which predicted differences between early and late bilinguals as a function of language dominance (see Table 1). In particular, naming in the non-dominant language was expected to be particularly difficult for late bilinguals under both accounts, although for different reasons. Within a developmental change account, late bilinguals would have experienced more interference than early bilinguals from their dominant language when naming in their non-dominant language. Within a duration of habitual use account, late bilinguals had a shorter duration of proficient, habitual use ($M = 4$ years) than early bilinguals ($M = 15$ years), which would result in late bilinguals having a much lower frequency of accessing

words in the non-dominant language. However, late bilinguals were not disadvantaged relative to early bilinguals when naming words in their non-dominant language.

Regarding executive function, both bilingual groups exhibited executive function benefits relative to monolinguals by having reduced conflict effects created by incongruent trials, consistent with previous research for early bilinguals (Bialystok et al., 2004; Bialystok et al. 2008; Carlson & Meltzoff, 2008; Costa et al., 2008) and again extending these findings to late bilinguals. Conflict effects on the ANT also emerged in accuracy, where more errors were made on incongruent trials than congruent trials. However, unlike RTs, there were no group differences in accuracy, which could have resulted from a ceiling effect, given the paucity of errors that were made across all types of trials. Nonetheless, the equivalence of the two bilingual groups on the ANT suggests a similar bilingual advantage for the groups, paralleling the findings of a similar bilingual disadvantage in lexical access. These findings are inconsistent with both developmental change and duration of habitual use accounts for bilingual advantages in executive function and instead support the interpretation that executive function benefits arise due to the habitual use of two languages, independent of the duration of fluent bilingualism. The mechanism postulated to underlie this effect is bilinguals' constant engagement of general executive control resources/brain regions to control interference between their two languages (Bialystok, 2009; Rodriguez-Fornells et al., 2005). The present results indicate that a relatively short period of fluent bilingualism provides sufficient practice for the emergence of executive function benefits.

Because our data do not clarify the locus of these benefits, it is possible that the bilingual groups' enhanced executive function arises from different sources. For example, early bilinguals' executive function benefits might arise from developmental changes in neural networks

responsible for controlling attention and controlling language, i.e., early bilinguals may have developed different and/or more connections in and between those neural networks; in contrast, late bilinguals' benefits could be a consequence of improved efficiency of those networks, perhaps arising from higher resting levels of activation in attentional control networks and resulting from practice in the effortful control of attention when using their two languages. Another possibility is that early bilinguals may have developed better executive function abilities due to their lifelong use of two languages, whereas late bilinguals may have had enhanced executive function early on, influencing their choice to become bilingual by making learning and using a second language easier. While we cannot conclusively rule out differential influences for the two bilingual groups, it is worth noting that if late bilinguals possessed executive function benefits before becoming fluently bilingual, one might expect late bilinguals to have superior executive function to early bilinguals. This would result from the combined influences of late bilinguals' initially better executive function in conjunction with their regular engagement of executive function in controlling language interference from their two languages. None of our data are consistent with this prediction.

It is important to note that executive function benefits for late bilinguals have not always emerged in other studies (Luk et al., 2011; but see Linck et al., 2008, who did find EF benefits). One issue that may have resulted in the null finding for late bilinguals in the Luk et al. study is that participants were classified as (proficiently) bilingual based solely on self-report. We discovered in the present study that self-report of second language proficiency was frequently inaccurate. Of the 30 late bilinguals that participated in our study, there were originally 40 who provided self-reports indicating that they were fluently bilingual, i.e., they reported a proficiency in speaking and understanding their second language of 7 or higher on the LEAP-Q (Marian et

al., 2007), which corresponds to good proficiency or better. 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 some late bilingual participants in previous

studies had low proficiency in their L2 despite their self-reports, the presence of low-proficiency

late bilinguals might easily have obscured any EF benefits.

The technique of first interviewing bilingual participants in their dominant language is

not typically done (or at least not reported in published studies). We acknowledge the possibility

that interviewing our participants in Spanish prior to having them complete the executive

function task may have had an unexpected executive function benefit for bilinguals. Past

research has demonstrated that language-switching contexts engage neural substrates associated

with executive function (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001). 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 executive function to a greater degree than if participants had only used English for the

entire experiment. This initial engagement of executive function among the bilinguals may have

'primed' their executive function processes, contributing to their better executive function on the

ANT task relative to monolinguals. Future research should investigate whether requiring

participants to switch between their languages immediately before engaging in executive

function 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 regard to late bilinguals' lexical access deficits, several observations are worth noting.

One is that frequency effects arising from habitual use of two languages (e.g., Gollan et al.,

2008) may potentially be stronger as a function of *recency* of access, such that the cumulative

frequency with which bilinguals have accessed words in their lexicons over the past *x* number of years may be more predictive of lexical access than the frequency of accessing words over their lifetimes. Indeed, self-reports indicated that the two bilingual groups did not differ in the amount of time that they currently spoke in their dominant and non-dominant languages, suggesting that currency of language use may be a useful metric in predicting lexical access deficits in bilinguals. A second point is that the duration of habitual use cannot be easily dissociated from age of acquisition (AoA), a variable known to affect lexical access (Ellis & Morrison, 1998). Indeed, early and late bilinguals by definition differed on both measures with regard to their non-dominant language. Nevertheless, the fact that the two bilingual groups did not differ in their picture naming times indicates that neither AoA nor duration of habitual use is responsible for bilinguals' lexical access deficits. Furthermore, the difference in naming times between monolinguals and late bilinguals in their dominant language cannot be explained by AoA, which was identical for both groups. Even though late bilinguals have been using their dominant language their entire lives (similar to how monolinguals have functioned with a single language) and have been fluently bilingual for only 4.4 years, they nonetheless exhibited lexical access deficits relative to monolinguals.

In sum, the present study shows that 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 and the advantages in executive function. We have interpreted the results as supporting the idea that the habitual use of two languages, not the duration of that habitual use, is responsible for the effects associated with bilingualism. However, *some* duration of proficient and regular use must be necessary for the emergence of bilingual advantages and disadvantages, and the present data cannot inform us as to what that minimum duration might be.

While 4.4 years of being fluently bilingual was sufficiently long for the emergence of those

effects in our late bilingual group, it is unknown whether similar results would emerge for late

bilinguals who had been fluently bilingual for a shorter period of time. Another limitation of the

present results is that they do not allow for a determination of precisely how long after childhood

one may become fluently bilingual and still manifest cognitive effects associated with

bilingualism. Future research should investigate whether participants who become fluently

bilingual considerably later in life or who have been fluently bilingual for a shorter duration also

demonstrate similar patterns of performance as the late bilinguals in our research.

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Table 1

Predictions of Bilinguals' Lexical Access and Executive Function Performance

Lexical Access (LA) relative to monolinguals	Executive Function (EF) relative to monolinguals
Developmental Change	
Dominant language: Early bilinguals will have LA deficits; late bilinguals will not.	Early bilinguals will have EF benefits; late bilinguals will not.
Non-dominant language: Late bilinguals will have larger LA deficits than early bilinguals.	
Habitual Use (as a function of duration)	
Dominant language: Late bilinguals will have smaller LA deficits than early bilinguals.	Late bilinguals will have smaller EF benefits than early bilinguals.
Non-dominant language: Late bilinguals will have larger LA deficits than early bilinguals.	
Habitual Use (independent of duration)	
Early and late bilinguals will have equivalent LA deficits in their dominant and non-dominant languages	Early and late bilinguals will have equivalent EF benefits.

Table 2

Monolinguals and Bilinguals' Demographic Characteristics and Cognitive Tests

	Group					
	Monolinguals		Late Bilinguals		Early Bilinguals	
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age (years)**	19.3	2.2	22.0	3.4	20.3	1.8
Education (years)*	14.1	2.7	15.8	2.6	15.6	1.7
Health (1-10 scale)	8.2	1.3	8.0	1.4	8.5	1.0
College GPA (out of 4.0)	3.2	0.7	3.5	0.4	3.4	.4
Forward Digit Span	9.4	2.0	9.3	2.5	9.3	2.1
Backward Digit Span	7.2	2.0	7.9	2.2	7.3	2.0

* $p < .05$; ** $p < .01$

Table 3

Bilinguals' L1 and L2 Self-Reported Language History

| | Group | | | |
| | Late Bilinguals | | Early Bilinguals | |
Variable	*Mean*	*SD*	*Mean*	*SD*
Age of L2 Acquisition (years)***	11.6	4.6	3.3	2.2
Age Fluent in L2 (years)***	17.9	3.2	4.9	2.2
Years Fluently Bilingual***	4.1	2.8	14.9	3.7
% Exposure to L1***	58.5	23.9	39.9	22.0
% Time Speaking L1***	60.5	19.8	39.1	26.5
Proficiency Speaking L1 (1-10 scale)***	9.9	1.1	8.6	1.2
Proficiency Understanding L1 (1-10 scale)	9.6	1.0	9.4	0.9
% Exposure to L2***	39.0	23.8	58.3	21.6
% Time Speaking L2***	35.2	21.1	58.9	27.3
Proficiency Speaking L2 (1-10 scale)***	7.6	1.1	9.3	1.2
Proficiency Understanding L2 (1-10 scale)***	8.1	1.1	9.6	0.7

*** $p < .003$

Table 4

Bilinguals' Dominant and Non-Dominant Self-Reported Language History

| | Group | | | |
| | Late Bilinguals | | Early Bilinguals | |
Variable	*Mean*	*SD*	*Mean*	*SD*
% Exposure to Dominant Language*	58.2	23.4	68.1	13.7
% Time Speaking Dominant Language	59.3	20.5	67.0	22.8
Proficiency Speaking Dominant Language* (1-10 scale)	9.2	1.2	9.7	0.7
Proficiency Understanding Dominant Language** (1-10 scale)	9.5	0.8	9.8	0.5
% Exposure to Non-Dominant Language*	39.3	23.3	30.9	20.9
% Time Speaking Non-Dominant Language	36.4	22.0	29.2	19.5
Proficiency Speaking Non-Dominant Language (1-10 scale)	8.1	1.1	8.3	1.3
Proficiency Understanding Non-Dominant** Language (1-10 scale)	8.4	1.3	9.2	0.9

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

Table 5

Early and Late Bilinguals' Picture Naming Times for High- and Low-Frequency Pictures as a Function of Instructed Language

		Group			
		Late Bilinguals		Early Bilinguals	
Instructed Language	Frequency	*Mean*	*SD*	*Mean*	*SD*
Dominant	High	775	120	775	134
	Low	869	128	874	103
Non-Dominant	High	900	206	885	172
	Low	1085	162	1065	144
Either	High	909	218	840	137
	Low	995	134	1018	154
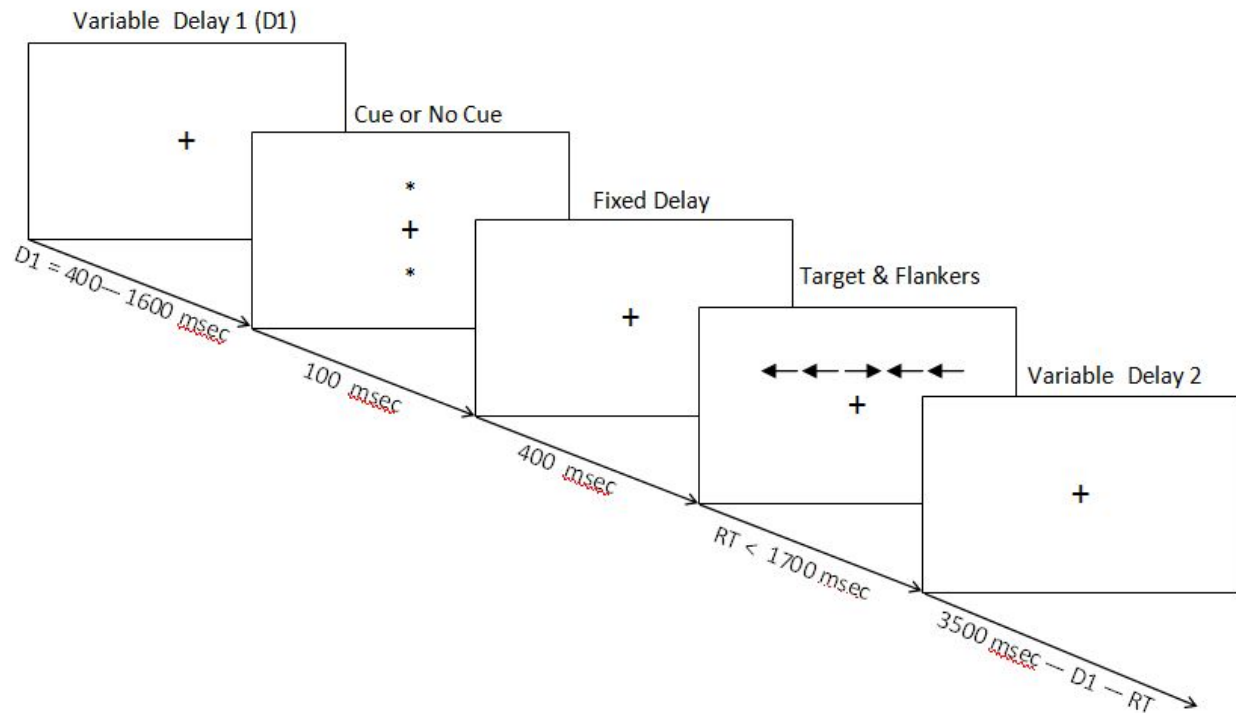
Figure 1. Example of a single trial for the Attentional Network Task (modified from Fan et al.,

2002). Each trial began with a variable delay between 400 and 1600 ms, followed by either a 100

ms cue or a 100 ms period with no cue. Next, there was a fixed delay of 400 ms prior to the

appearance of the target and flankers. Participants had 1700 ms to respond, after which there was

a second variable delay that was calculated so that each trial lasted exactly 4000 ms.
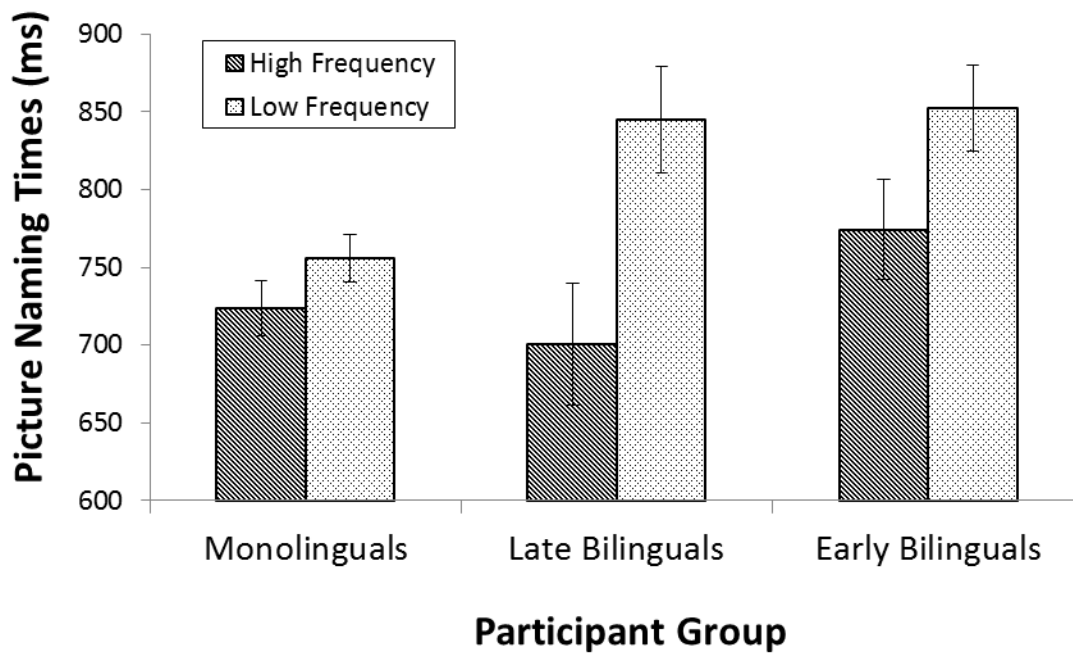
Figure 2. Monolingual and bilingual picture naming times in their dominant language for high- and low-frequency picture names, first block only.
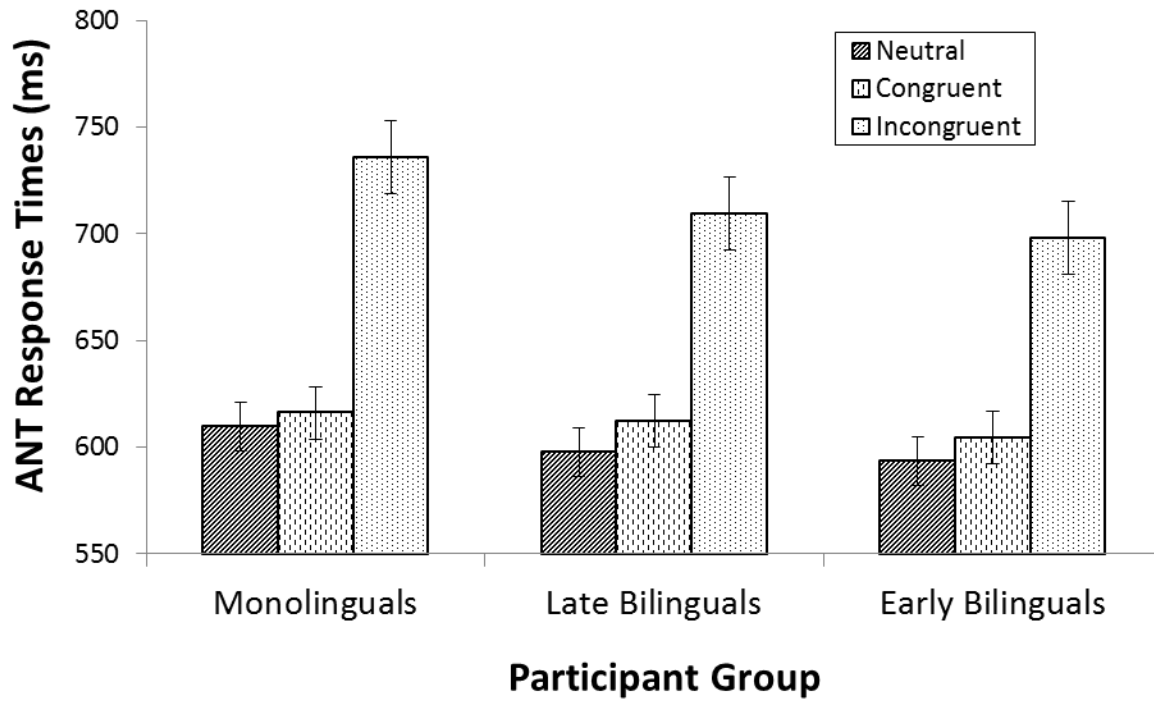
Figure 3. ANT response times on neutral, congruent, and incongruent trials for monolinguals, late bilinguals, and early bilinguals.