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The Relationship between Bilingualism, Cognitive Control, and Mind Wandering

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THE RELATIONSHIP BETWEEN BILINGUALISM, COGNITIVE CONTROL, AND MIND WANDERING

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The unique linguistic experience of bilingualism purportedly produces cognitive control advantages. Although there is a significant body of evidence supporting this view, there are also several recently published research studies that failed to replicate bilingual advantages. Furthermore, there is some evidence of a publication bias that favors findings supporting a bilingual advantage. The purpose of this study was to address this discrepancy in the literature by examining performance of bilinguals and monolinguals on a variety of cognitive control tasks. A second purpose was to determine how bilinguals are able to achieve better performance if they do indeed have an advantage. Specifically, we were interested in whether there were differences in the tendency for bilinguals and monolinguals to mind wander, a phenomenon associated with poorer cognitive control performance. We hypothesized that bilinguals would demonstrate better performance than monolinguals on Operation Span, Numerical Stroop, SART, Color-Shape, and Letter Memory tasks, which are measures of working memory, proactive inhibition, reactive inhibition, shifting, and updating, respectively. We further hypothesized that if bilinguals outperformed monolinguals on these tasks, this would be associated with less mind wandering for bilinguals. Participants completed all measures of cognitive control and were probed periodically throughout the tasks for mind wandering. Accuracy and reaction times where appropriate were recorded for each task, and data from 52 monolinguals and 52 bilinguals were analyzed. The results did not reveal any bilingual advantages. For all tasks, performance of the two groups was equivalent with the exception that monolinguals had faster reaction times for Numerical Stroop, SART, and Color-Shape tasks. There were also no differences between language groups in mind wandering tendencies. Secondary analyses examining age of acquisition (i.e., early versus late) and similarity of languages (i.e., same-script versus different-script) did not change the overall pattern of no bilingual advantages. The lack of a bilingual advantage supports recent calls to temper bilingual advantage claims and shows a need for future research to address which underlying factors of bilingualism may or may not have an effect on cognitive control.

Introduction

It is believed that more than half the world's population speaks more than one language (Grosjean, 2014), making the pursuit to understand these individuals' language and cognitive abilities an important one. It is well known that speakers of two languages, hereafter referred to broadly as bilinguals (BLs), experience unique linguistic phenomena not experienced by monolinguals (MLs). For example, a wealth of research demonstrates that BLs activate mental representations of both languages during both language production (Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Colomé, & Caramazza, 2000; Hermans, Bongaerts, De Bot, & Schreuder, 1998) and language comprehension tasks (Bijeljac-Babic, Biardeau, & Grainger, 1997; De Groot, Delmaar, & Lupker, 2000; Jin, 1990). This co-activation of languages is so pervasive that it occurs in BLs during ML tasks with words presented in isolation (De Groot et al., 2000), in a sentential context (Jouravlev & Jared, 2013; Libben & Titone, 2009; Titone, Libben, Mercier, Whitford, & Pivneva, 2011), and even when embedded in larger discourse (Balling, 2012; see Kroll, Dussias, Bogulski, & Valdes Kroff, 2012 for a recent review of cross-linguistic activation in comprehension and language production). In other words, having both languages active in the mind at the same time results in competition between the two languages that must be dealt with efficiently in order to quickly and accurately comprehend or produce the intended language (i.e., the language being used in the task or communication at hand). Recently, some researchers have argued that the extensive practice BLs have in managing the competition between two languages produces cognitive advantages that are not specific to the domain of language (i.e., they are domain-general rather than domain-specific), such that proficient bilingualism produces advantages for a wide variety of tasks requiring fluid cognition (Bialystok, Craik, Klein, Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Kroll & Bialystok, 2013; Kroll et al., 2012).

Recent research has sought to identify which domain-general cognitive functions display a BL advantage. For example, research has focused on advantages BLs may have in working memory (Arêas da Luz Fontes & Schwartz, 2011; Linck, Osthus, Koeth, & Bunting, 2013) which has been defined by Conway et al. (2005) as the ability to remember information while continuing to process other information. Other researchers have examined whether BLs have an advantage in the ability to inhibit automatic, prepotent responses (Bialystok et al., 2004, 2008), switching between task goals/sets, and/or updating the contents of working memory (Colzato et al., 2008; Hilchey & Klein, 2011; Marzecová et al., 2013), which is akin to what Miyake et al. (2000) referred to as inhibition, shifting and updating respectively. Although initially, many researchers agreed that BLs have advantages for some of these cognitive control abilities, it has become clear that the field is uncertain precisely how these BL advantages may operate, and furthermore, recent papers have argued that the BL advantage may not actually exist (de Bruin, Treccani, & Della Sala, 2014; Paap & Greenberg, 2013; Paap & Sawi, 2014). To help adjudicate this debate, many researchers have focused on how BLs perform on a myriad of simple and complex cognitive tasks, each of which requires attention regulation, which underlies each of the aforementioned aspects of cognitive control (e.g., inhibition, shifting, and updating; Miyake & Friedman, 2012).

At the same time that bilingualism researchers have been studying attentional control in BLs, other cognitive psychologists have been studying a type of lapse in attentional control known as mind wandering. Mind wandering refers to the phenomenon of attention shifting away from an external environment or task to other off-task thoughts (McVay & Kane, 2009; Smallwood & Schooler, 2006). Previous research has found a relationship between mind wandering and cognitive control mechanisms (McVay & Kane, 2009; Smallwood & Schooler, 2006), and some research suggests that mind wandering may mediate the well-documented relationship between cognitive mechanisms such as working memory and task outcomes such as reading comprehension (McVay & Kane, 2012b), which has important implications for language processing researchers and educators. Importantly, despite the overlapping cognitive mechanisms studied in mind wandering research and bilingualism research, there have been no investigations regarding the relationship between bilingualism and mind wandering. Because mind wandering research has examined many of the same cognitive mechanisms as bilingualism research, studying the relationship between mind wandering and bilingualism has the potential to provide important insight into the nature of any BL advantage, if it exists. As such, the focus of the current study will be to a) further delineate the cognitive mechanisms for which BLs may have an advantage, and b) investigate the nature of mind wandering in BLs in order to offer possible explanations for existing questions in the research literature regarding the cognitive advantages of bilingualism. To establish the importance and rationale for uniting these two disparate areas of research, we will next review the research on both the BL cognitive advantage and mind wandering.

Are There Bilingual Cognitive Advantages?

As stated earlier, there is substantial evidence that two languages can be active in the mind simultaneously and compete for use by a BL. It has been argued by some researchers that cognitive control mechanisms are necessarily involved in the BL's ability to correctly select the language to be used, and the repeated demand placed on these mechanisms creates domain-general cognitive advantages (Bialystok et al., 2004, 2008; Kroll & Bialystok, 2013); however, not all researchers are confident that these advantages exist (Paap & Greenberg, 2013; Paap & Sawi, 2014). Precisely which cognitive mechanisms are used and may be improved through bilingualism has been the subject of much investigation. Several important findings have arisen from these investigations; however, before reviewing this research, it will be helpful to provide a brief cognitive framework within which to understand these findings.

One cognitive system heavily investigated in bilingualism research is working memory. The nature and components of working memory are still hotly debated; however, it has been broadly conceptualized as "a multicomponent system responsible for active maintenance of information in the face of ongoing processing and/or distraction" (Conway et al., 2005, p. 770). Similarly, Baddeley (2002) has described working memory as a multicomponent system consisting of four components: the phonological loop, the visuo-spatial sketchpad, the episodic buffer, and the central executive. Although each of these components are undoubtedly involved in aspects of language, research on the benefits and costs of cross-linguistic activation has focused primarily on the central executive or "executive function" (EF) in BLs. In seminal work by Miyake and colleagues, EF has been described in terms of the related but separate functions of updating, shifting and inhibition (Friedman et al., 2008; Miyake et al., 2000; Miyake & Friedman, 2012). According to this framework, updating involves the ability to update working memory and monitor information relevant to the current task. An example of a common task used to measure updating is the Letter Memory task, where the goal is to always remember the last three letters presented in a sequence of letters. Shifting involves the ability to switch between tasks or goals and is measured by tasks such as the Color-Shape task in which the participant has to rapidly switch between classifying a target by its shape or its color. Inhibition involves the ability to inhibit an automatic response. The Stroop Task (Stroop, 1935), which requires participants to identify the color of a word while ignoring an incongruent word that indicates a different color (e.g., identifying a blue word that says "green"), and the Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) in which participants have to suddenly withhold a prepotent response, have been used as measures of inhibition (Bialystok et al., 2008; Colzato et al., 2008). Although some research has focused on working memory as a unitary construct in the development and consequences of bilingualism (e.g., Engel de Abreu, 2011; Linck et al., 2013; Luo, Craik, Moreno, & Bialystok, 2013), other research has focused on the various sub-components of EF, more in line with Miyake's (2000) functions of inhibition, updating, and shifting. Overall in bilingualism research, the long-standing emphasis has been on inhibition, but some investigation of the other mechanisms has also occurred.

Working memory. Research exploring the relationship between working memory and bilingualism has generally found a significant positive relationship between the two (Arêas da Luz Fontes & Schwartz, 2011; Linck et al., 2013; van den Noort, Bosch, & Hugdahl, 2006). For instance, a meta-analysis study consisting of 3,707 participants from 79 different samples revealed a positive relationship between measures of working memory (both complex and simple) and proficiency in a second language, with complex measures correlating more strongly with proficiency than simple ones (Linck et al., 2013). This relationship manifests itself in important ways. For example, Arêas da Luz Fontes and Schwartz (2011) showed that BLs with a low working memory capacity were less able to resolve cross-linguistic interference than those with a high working memory capacity, inferring that working memory plays a key role in managing two languages and thus is important in the development of bilingualism.

Although such research demonstrates that working memory may be important for managing bilingualism, it does not demonstrate whether BLs possess a domain-general advantage for working memory. In other words, it is unclear whether the beneficial relationship between working memory and second language acquisition is bidirectional (Linck et al., 2013). Is it possible that simply learning a second language positively affects general working memory ability and produces an advantage over MLs? Research comparing BLs to MLs in an attempt to answer this question has certainly been equivocal. For instance, Luo et al. (2013) found that adult BLs outperformed their ML counterparts on a spatial working memory task but not a verbal working memory task. In a longitudinal study that followed children for three years, Engel de Abreu (2011) found no difference between MLs and BLs on simple and complex working memory measures. Bialystok et al. (2008) also failed to find a BL advantage on a simple measure of working memory, the forward and backward Corsi block measures. A recent review paper on other cognitive mechanisms argued that BL advantages are best observed when task difficulty is high (Hilchey & Klein, 2011). The fact that different measures of working memory (varying in difficulty) have produced mixed results is consistent with the hypothesis that examining the relationship between such broad working memory measures and bilingualism fails to capture specific underlying cognitive mechanisms, such as the inhibition, updating, and shifting components of cognitive control. Therefore, examining these specific cognitive mechanisms is important.

Inhibition. Inhibition has long been thought of as a primary cognitive mechanism involved in the BL ability to manage two competing language systems; therefore, prominent models of BL language activation and selection include some form of inhibitory control. For instance, Green (1998) proposed the inhibitory control (IC) model to explain how words in the target language are successfully produced in the presence of two competing languages. His model proposed that based on the language schema, the nontarget language is inhibited at the lemma level (i.e., the level where syntactic information such as part of speech and gender of words exists). He proposed that this inhibition occurs largely in a bottom-up fashion once a language task schema has been established, but a supervisory attentional system is needed for ongoing monitoring. Similarly, Dijkstra and van Heuven (2002) proposed the Bilingual Interactive Activation + Model (BIA+) to explain how the correct language is selected in a visual recognition context. According to the model, there is simultaneous lexical activation of both languages, and this creates competition. A competitor in one language will ultimately receive more activation than a competitor in another language, and this is influenced by top-down processes such as the goal of the speaker to speak in an intended language. This increased activation for one competitor results in inhibition of the other language options and the selection of the desired competitor. Although the IC model and BIA+ model propose different loci for inhibition, they both serve as notable examples of the view that inhibition is a cognitive mechanism involved in both BL visual word recognition and word production.

Not only do theoretical models propose inhibitory control as a primary cognitive mechanism in BL language processes, results from a variety of different language tasks provide support for this view. The evidence for the need to inhibit cross-linguistic interference has been demonstrated in both word recognition and production tasks (Levy, McVeigh, Marful, & Anderson, 2007; Martín, Macizo, & Bajo, 2010; Misra, Guo, Bobb, & Kroll, 2012). For example, in visual word recognition, researchers have strategically placed interlexical homographs (i.e., words that share similar orthographic forms in two languages but have different meanings) before target word pairs in semantic relatedness decision tasks to demonstrate the effects of inhibition (Macizo, Bajo, & Martín, 2010; Martín et al., 2010). These studies found that when an interlexical homograph appeared in a word pair (e.g., pie-toe, where pie in Spanish means foot) before a target trial in which participants were to indicate whether the pair was related (e.g., foot-hand), participants took longer to respond to that target trial, suggesting that participants had to inhibit the translation of the interlexical homograph (e.g., pie) and that this carried over into the target trial.

In another study, evidence for inhibition in word production was demonstrated by participants' costs in switching back into their first language (L1) after repeated trials of second-language (L2) word production (Levy et al., 2007; Misra et al., 2012). It is important to note that both the visual word recognition and word production studies demonstrated that it is the more dominant L1 that is inhibited, and in the case of Levy et al. (2007), the participants were L2 learners (i.e., not proficient BLs), which shows the need to inhibit L1 interference begins early. It makes sense that inhibition of the L1 is most observable because it has been noted that cross-linguistic activation is more observable when performing tasks in the L2 than in the L1 for individuals with low proficiency (van Hell & Tanner, 2012), suggesting that it is the L1 that interferes with learning the L2. Brain imaging studies also indicate that for low proficiency BLs (i.e., L2 learners), there is greater activity in the prefrontal cortex than in those with higher proficiency (Chee, Hon, Lee, & Soon, 2001), which has been interpreted as reflecting the need for low proficiency BLs to engage in more controlled processing.

Thus far, the evidence reviewed demonstrates that inhibition is a cognitive mechanism involved in BL language processes. However, a major unanswered question is whether the increased need for and practice of this domain-*specific* inhibition produces BL advantages in domain-*general* tasks requiring inhibition. Answering this question is challenging. One challenge is the lack of unification in terminology and conceptualizations of inhibition used by researchers, a problem that becomes evident in a survey of the research literature. Another challenge to answering this question is that research investigating whether BLs outperform MLs on domain-*general* inhibitory tasks have found mixed results that depend on both the tasks used and age group being studied. For example, inhibitory advantages have not been found for a simple variant of the antisaccade task in which participants are cued to look either in the direction of a briefly presented asterisk (i.e., prosaccade) or the opposite direction (i.e., antisaccade), which required the participant to inhibit the prepotent tendency to look in the direction of the asterisk stimulus (Bialystok, Craik, & Ryan, 2006). Similarly, Bialystok et al. (2008) did not find a difference between MLs' and BLs' performance on a SART that required participants to inhibit a strong prepotent response. However, inhibitory advantages have been found for other tasks. For example, in the antisaccade task described above, where participants had to indicate either the direction of the asterisk or the opposite direction with a *key press* rather than with eye gaze alone, differences between BLs and MLs did emerge (Bialystok et al., 2006). BLs have also outperformed MLs on the Stroop and Simon tasks in some studies. In the Simon task, participants indicate the direction of an arrow regardless of which side of a screen it appears on, and thus like the Stroop, it has an irrelevant but prepotent response to be inhibited (Bialystok et al., 2004, 2008). Although BL advantages are observed for Stroop and Simon tasks, the age of the participants may be a factor in whether the BL advantage is observed. For example, these advantages have been readily observed in children and older adults, but they are sometimes absent or only weakly observed in young adults (Bialystok et al., 2004, 2006, 2008; Bialystok, Martin, & Viswanathan, 2005).

The reasons for this rather disparate set of findings for inhibitory control are still unclear, but several factors seem plausible. One variable that may introduce considerable error into BL research when uncontrolled is participant language proficiency (i.e., their experience with and usage of their multiple languages). Some researchers have commonly used group designs where participants are categorized as either ML or BL. Although within a single study, proficiency may be controlled to a certain degree, proficiency of participants varies substantially across studies. Furthermore, the complex relationship between proficiency, language experience, and frequency of language use with performance on cognitive measures has not been taken into consideration by most researchers; however, there is evidence that these factors need to be considered in order to more precisely understand the relationship between bilingualism, inhibition, and other cognitive functions. Linck, Hoshino, and Kroll (2008) shed some light on this factor when they observed (unlike previous research; Bialystok et al., 2008) a BL advantage in inhibitory control for younger adults on a Simon task. In their study, the participants were not the usual simultaneous BL (i.e., having acquired two languages early in life) or highly proficient participants as have been studied in similar studies (e.g., Bialystok et al., 2004, 2008). Instead, the researchers observed advantages on the Simon task in *intermediate* L2 learners, suggesting that inhibitory advantages may not be constrained to highly proficient or simultaneous BLs. Findings such as this demonstrate that experience with and context of the L2 may affect inhibitory control; that is, BLs' experiences and usage of the language may play an important role in developing an inhibitory advantage, and this should be taken into consideration by future research. The call for considering such factors have been recently emphasized by many researchers who have both theoretically proposed and empirically demonstrated that bilingualism is multidimensional (Green & Abutalebi, 2013; Kroll & Bialystok, 2013; Linck et al., 2008; Luk & Bialystok, 2013; Soveri, Rodriguez-Fornells, & Laine, 2011; van Hell & Tanner, 2012).

Inhibition as a multivariate construct. Although proficiency and experience with L2 will most definitely need to be considered by future research, they certainly are not the only factors that are likely contributing to cognitive control in BLs. Other researchers have focused on the differences found for different types of inhibitory tasks in hopes to explain why results have been mixed. Researchers taking this approach have argued that inhibition is not unitary and thus different tasks may tap into different aspects of inhibition (Bialystok et al., 2008). As mentioned, researchers do not use a unified set of terminology to describe these different aspects of inhibition; therefore, to provide some clarification, we will use two terms to describe the different aspects of inhibition: "proactive control" and "reactive control." Morales, Gómez-Ariza, and Bajo (2013) used these terms and described proactive control as referring to goal maintenance (i.e., keeping the goal active to prevent interference) and reactive control as referring to directly inhibiting irrelevant or conflicting information. It is important to note that the terminology provided by Morales et al. (2013) is based on a different theoretical framework than that of others such as Miyake et al. (2000), and it is more aligned with the dual mechanisms of control framework (Braver, 2012) and the executive attention view of working memory (Engle & Kane, 2004), which propose that cognitive control consists of two components: goal maintenance and competition resolution. Although discussed in different terms, the Morales et al. framework is not necessarily at odds with the Miyake et al. (2000) framework, and it aligns with descriptions of different aspects of inhibition used by other bilingualism researchers (e.g., Bialystok et al. 2008; Colzato et al., 2008). These descriptions along with tasks used to measure the different aspects of inhibition in BLs are provided in Table 1.

By distinguishing between proactive and reactive control, some researchers have argued that BLs may possess an advantage only for proactive control (Bilaystok et al., 2008; Colzato et al., 2008). This view is supported by evidence that BLs outperform MLs on complex tasks of inhibition such as the Stroop and Simon tasks where irrelevant information must be ignored to respond correctly, whereas on the SART and simple antisaccade tasks (where an automatic response must be inhibited only at the moment that it is cued), there are no observed differences (Bialystok et al., 2008). The Stroop and

Simon tasks are measures of proactive control because participants must maintain the goal to prevent interference by monitoring "attention to the relevant feature so that the response is chosen on the correct basis" (Bialystok et al., 2008, p. 869). In contrast, typical SART and antisaccade tasks are measures of reactive inhibition because participants' prepotent responses are acceptable except for trials in which they must withhold that response and are then faced with interference. Other research has also provided some evidence that BLs may possess an advantage in proactive control rather than reactive control. Colzato et al. (2008) compared the performance of ML and BL participants on tasks that tap into proactive and reactive control. To measure reactive control, they used a stop signal task, which involved participants building up a prepotent response then terminating the response upon a given cue (similar to a SART task). To measure proactive control, they used a rapid serial vision presentation (RSVP) task, attentional blink, where participants had to report two numbers that were presented in a stream of letters where the number of letters between the numbers varied. Because the items are presented rapidly, it is difficult to report the second number when it occurs close to the first number (i.e., they experience an "attentional blink"). For this task, it was argued that greater proactive control would result in poorer performance (i.e., more attentional blink). For the stop-signal task, Colzato et al. found that BLs and MLs performed equally, but on the RSVP task, BLs demonstrated a greater attentional blink. Similar to Bialystok et al. (2008), this suggests that BLs do not have an advantage in reactive control but do have an advantage in proactive control, where keeping the current goal active indirectly prevents interference from distractions and irrelevant stimuli.

Although some researchers (e.g., Bialystok et al., 2008; Colzato et al., 2008) have found evidence that BLs have an advantage in proactive control but not in reactive control, other researchers have not entirely discounted a reactive control advantage in BLs. For example, Morales et al. (2013) suggested that BLs may possess an advantage in both proactive and reactive control, and that these two mechanisms working together produce the advantages observed on various tasks. To test this idea, they used an "AX-CPT" task in which participants were to respond with a "yes" when the letter X followed the letter A, and respond "no" for all other pairings. Different combinations are thought to require either proactive or reactive control to correctly respond. For example, proactive control is needed when the letter "A" is presented, (i.e., participants must keep active the goal that they must respond "yes" if they see letter X and "no" to any other letter). On the other hand, when participants see a string of letters not containing "A" and are then presented with "X," which is a cue for a "yes" response, they need reactive control to inhibit this inappropriate cued response. The results showed that BLs had an advantage compared to MLs on trials that required proactive control as well as on trials that required reactive control, a contrast to Colzato et al. (2008) and Bialystok et al. (2008). Because of such conflicting findings, it remains unclear whether BLs possess an advantage for only certain aspects of inhibition.

While some researchers have emphasized the role of inhibition in a BL cognitive advantage, others have questioned whether inhibition is really the primary mechanism for which BLs have an advantage, and they have argued instead that BLs possess a much broader advantage in cognitive control, allowing them to outperform MLs on a variety of tasks (Hilchey & Klein, 2011; Marzecová et al., 2013). This research has pointed out that in Simon and Stroop tasks, there are response time advantages for BLs on *both* compatible (where inhibition is not needed) and incompatible trials. Additionally they point out that with a larger number of trials, the BL advantage on incongruent trials disappears, suggesting BLs have only an early inhibitory advantage (Hilchey & Klein, 2011). Taken together, it is argued that these results support a "bilingual executive processing advantage" (BEPA) hypothesis rather than a "bilingual inhibitory control advantage" (BICA) hypothesis. With much of the research that occurred before this proposition being focused on inhibitory control, this hypothesis is still in need of more research. If BEPA is correct, then BLs should have an advantage for tasks tapping into cognitive control functions other than inhibition. For example, using the unity and diversity framework proposed by Miyake et al. (2000), one may expect that if the BEPA hypothesis is correct, BLs should outperform MLs on tasks measuring updating and shifting as well.

Updating and shifting. Research on the relationship between bilingualism and the cognitive control mechanisms of updating and shifting has been comparatively scarce. Because working memory and updating are closely related and because proficiency in a second language is positively correlated with performance on working memory tasks (Linck et al., 2013), it could be argued that BLs do possess an advantage in updating; however, as reviewed earlier, research examining working memory in BLs have varied in complexity, and little research has compared MLs and BLs on tasks specifically purporting to tap into the function of updating. One study that did directly measure updating (Soveri et al., 2011) did not find a significant relationship between updating and amount of language switching. However, this study consisted of only BLs who were supposedly all equivalent in proficiency, but varied on their language switching tendencies and use of both languages on a daily basis; therefore, the purpose was not to compare BLs and MLs, which leaves open the question of whether BLs have an advantage in updating.

Although the mechanism of updating in BLs has received little attention, the mechanism of shifting has received more attention. In discussing BEPA, Hilchey and Klein (2011) predicted that BLs should have an advantage in task switching, akin to the cognitive control mechanism of shifting. This prediction has received support from research examining task switching in BLs (Marzecová et al., 2013; Prior & MacWhinney, 2010; Soveri et al., 2011). As would be predicted by BEPA, Prior and MacWhinney (2010) found that BLs did indeed demonstrate an advantage in task switching (i.e., less switch costs for BLs compared to MLs). BEPA was further supported by demonstrating that BL advantages could be observed in two tasks, temporal orienting and social category switching, not used in prior BL research (Marzecová et al., 2013). Finally, within a group of BLs, frequency of daily language switching predicted error rates on a nonlinguistic switching task such that higher uses of both languages on a daily basis resulted in fewer errors (Soveri et al., 2011). Such evidence hints at the breadth of the BL advantage and suggests BLs possess greater cognitive flexibility. Together, these results suggest that the BL experience may indeed affect the cognitive control mechanism of shifting.

Arguments Against the Bilingual Advantage

Thus far, the literature reviewed suggests that BLs tend to outperform MLs on a wide variety of tasks, but is this necessarily an accurate picture of bilingualism? There has been some recent evidence that instances of a cognitive advantage in BLs may be magnified by a publication bias (de Bruin et al., 2014). In their study, de Bruin et al. (2014) conducted a meta-analysis with 104 abstracts from 169 conferences from the years 1999 to 2012 and classified studies as either a) fully supporting the BL advantage, b) having mixed results that mostly supported the BL advantage, c) having mixed results that partly challenged the BL advantage, or d) fully challenging the BL advantage. Of these abstracts, only 38% fully supported a BL advantage for cognitive control, yet 63% of these went on to be published. Comparatively, only 36% of those that challenged the BL advantage were eventually published, a difference that was statistically significant. Although publication bias may make it harder for studies with results that challenge the BL advantage to be published, there have been some recent published studies that have failed to find any BL advantage for a variety of tasks tapping into different aspects of cognitive control such as inhibition, updating, and shifting (Paap & Greenberg, 2013; Paap & Sawi, 2014). These recent findings highlight the importance of understanding the true consequences of bilingualism for cognition. Although these findings challenge BL advantage claims, there are also studies, clearly, that do provide evidence of BLs outperforming MLs on cognitive control tasks, suggesting that what is still particularly unsettled is precisely *how* BLs might sometimes outperform MLs on these tasks. Is it because they possess greater inhibitory control as some earlier research suggests, or is it because they show superiority for other cognitive mechanisms as more recent research suggests? For instance, are they better at monitoring and updating goals and shifting between goal sets? Are they perhaps better at regulating control of attention? The present study purported to address this gap in part by focusing on mind wandering, an area of cognition that has received virtually no attention in the bilingualism literature.

Mind Wandering

Mind wandering has been defined several different ways. It has been described as daydreaming, attention being decoupled from the external environment, having stimulus independent thoughts, and having task unrelated thoughts (TUTs; Giambra, 1989; McVay & Kane, 2009; Schooler et al., 2011). Although terminology varies, what unites these descriptions is the phenomenon of attention shifting away from the external environment or task at hand to other off-task thoughts. Mind wandering occurs quite frequently, with estimates of TUTs being around 30% - 50% of daily awake thoughts (Kane et al., 2007; Killingsworth & Gilbert, 2010). Although there are some possible benefits of mind wandering, such as facilitation of creative problem solving and autobiographical planning (Baird et al., 2012; Mooneyham & Schooler, 2013), mind wandering can also be detrimental to performance on many cognitive tasks. For example, participants who mind wander more frequently perform poorly on SART, Stroop, and working memory tasks (McVay & Kane, 2009, 2012b; Mrazek et al., 2012), all tasks that have also been used in bilingualism research. Not only can mind wandering have a negative effect on laboratory cognitive tasks, it can also lead to negative consequences for common, daily activities such as poor reading comprehension, increased risk for accidents while driving, and negative mood (He, Becic, Lee, & McCarley, 2011; McVay & Kane, 2012b; Reichle, Reineberg, & Schooler, 2010; Smallwood, McSpadden, & Schooler, 2007; Yanko & Spalek, 2013).

Because the effects of mind wandering can be serious, it is important to understand the factors that contribute to or are related to mind wandering. Researchers have focused on both situational features (e.g., interest, task difficulty, task characteristics) and individual differences in cognitive ability (e.g., working memory; Feng, D'Mello, & Graesser, 2013; Krawietz, Tamplin, & Radvansky, 2012; Levinson, Smallwood, & Davidson, 2012; Smallwood, 2011; Unsworth & McMillan, 2013). For example, research on situational features has found that tasks placing high demand on working memory (i.e., a more difficult task) resulted in less mind wandering (Levinson et al., 2012) while other research has found that a more difficult task such as reading a difficult text resulted in more mind wandering (Feng et al., 2013). Additionally, greater interest in the task at hand has, independently from working memory capacity, been associated with fewer reports of mind wandering (Krawietz et al., 2012; Shake, Shulley, & Soto-Freita, 2015; Unsworth & McMillan, 2013).

Although there are situational features related to mind wandering, research has also focused on individual differences in cognitive ability, and because cognitive ability has been shown to be affected by bilingualism, it will be the focus here. Researchers seeking to understand the relationship between cognitive ability and mind wandering have focused on cognitive control, especially working memory, and they have offered hypotheses about *how* the mind wanders (i.e., decoupling hypothesis; Smallwood & Schooler, 2006) and *why* the mind wanders (i.e., executive failure hypothesis; McVay & Kane, 2009, 2010, 2012b). The former is addressed by research demonstrating that working memory resources are needed for both on- and off-task thoughts (Levinson et al., 2012). The latter proposes that failure in cognitive control leads to more mind wandering and is supported by research that demonstrated that regardless of task demands, those with higher working memory capacity report fewer TUTs (McVay & Kane, 2009).

Both views make one important prediction. If cognitive resources are drawn away from a current task and are used to support TUTs, or if there is a failure in cognitive control which leads to a mind wandering episode, this disruption or loss of attention to the current task will result in poorer performance on that current task. In other words, tasks requiring cognitive control should especially result in changes in reaction times and errors. McVay and Kane (2012b) provided support for this prediction by demonstrating that rates of mind wandering were negatively correlated with task performance on cognitive control tasks. They showed that TUTs could mediate the relationship between what they called "executive attention," which in their view consisted of shared variance from working memory and three cognitive control task performances, and reading comprehension. Participants in their study completed working memory tasks, a numerical Stroop task, a semantic SART, an antisaccade task, and reading tasks where they were probed for TUTs on the Stroop, SART, and reading tasks. As predicted, aspects of performance on the Stroop and SART (i.e., overall Stroop accuracy, accuracy on incongruent trials, reaction times on Stroop incongruent trials, and variability of reaction time for the SART) were negatively correlated with the rate of mind wandering. Using structural equation modeling, they also found that TUTs partially mediated the relationship between "executive attention" and reading comprehension. The authors argued that this evidence demonstrated that mind wandering is related to poorer performance on a variety of tasks because it interrupts goal maintenance (i.e., proactive control processes) thereby allowing interference from off-task thoughts.

The Potential Connection between Mind Wandering and Bilingualism

As reviewed, researchers in the mind wandering literature consider proactive control important for maintaining on-task thoughts and doing well on current tasks (McVay & Kane, 2012b). At the same time, some researchers in the bilingualism literature believe BLs have an advantage for proactive control. Both areas of research test their hypotheses by using similar tasks. As mentioned, McVay and Kane (2012b) used Stroop, SART, and antisaccade tasks. All three of these tasks have been used in bilingualism studies (Bialystok et al., 2006, 2008). Within the bilingualism literature the Stroop and antisaccade have served as measures of proactive control and the SART has been described as a measure of reactive control. Bilingualism studies have also commonly used other measures of proactive and reactive control as well as measures of updating and shifting. Table 2 lists commonly used tasks in both literatures along with predictions typically made by each literature regarding task performance.

It is clear that both literatures use similar tasks, with the general trend being that less mind wandering leads to better performance on tasks, and being BL leads to better performance on tasks. This raises the important question of whether BLs' advantage in tasks of cognitive control, when observed, is related to fewer occurrences of mind wandering. Based on the general trend that BLs outperform MLs and better cognitive performance is associated with fewer occurrences of mind wandering, one may predict that BLs experience less mind wandering than MLs; however it is important to note that a) there is slight disparity across the literature regarding reactive control, such that the bilingualism literature has reported mixed findings, and the mind wandering literature finds a negative relationship between performance on reactive control tasks and mind wandering and b) there is some uncharted territory in the mind wandering literature regarding the functions of updating and shifting. The purpose of the present study was to answer two questions. First, do BLs outperform MLs on all aspects of cognitive control discussed? Second, if BLs outperform MLs on these tasks, is it due in part to better attention regulation (i.e., less mind wandering)? The first question addresses the disparity in the literature, and the second asks a question that has not been explored before.

The Present Study and Hypotheses

To answer the question of whether BL cognitive control advantages are related to mind wandering, the present study examined mind wandering during a variety of cognitive tasks in people from varying language backgrounds ranging from MLs to BLs who are fluent in both of their languages. If high cognitive control reduces intrusions of off-task thoughts (McVay & Kane, 2012b), it was expected that for tasks in which BLs have an advantage, bilingualism would be related to reduced mind wandering (e.g., fewer off-task thoughts). To test this, participants completed cognitive tasks that are measures of working memory, inhibition, shifting, and updating. Because it has been suggested that inhibition is not unitary (Bialystok et al., 2008) and may consist of proactive and reactive components (Morales et al., 2013), two tasks of inhibition measuring these two components were used. To assess mind wandering, mind wandering probes were embedded into each of these tasks, such that participants were periodically interrupted and asked to report the contents of their thoughts. The following hypotheses were made about each task.

Working memory. Participants completed the Operation Span task (OSPAN). Based on research demonstrating that BLs tend to outperform MLs on working memory tasks, especially complex working memory tasks (Linck et al., 2013), it was hypothesized that BLs would demonstrate higher scores on the OSPAN. Because some mind wandering research demonstrates that higher working memory scores are associated with less mind wandering (e.g., McVay & Kane, 2012b), it was also hypothesized that BLs would mind wander less than MLs during the OSPAN.

Proactive control. There is some consistency in the literature that BLs outperform MLs on tasks requiring participants to maintain the goal response in order to prevent making the wrong, conflicting response (Bilaystok et al., 2008; Colzato et al., 2008; Morales et al., 2013). Some researchers in the mind wandering literature argue that it is this same cognitive mechanism that helps maintain on-task thoughts and prevent off-task thoughts, which increases performance on tasks (McVay & Kane, 2012b). Both literatures have used variations of the Stroop task to measure proactive control; therefore, the current study used a Numerical Stroop task. It was predicted that BLs would have better performance, which was measured by reaction times and errors made. Furthermore, it was predicted that if better proactive control leads to less mind wandering, BLs would report fewer TUTs during the Stroop task.

Reactive control. The current study utilized a commonly used task in both literatures, a numerical SART. There is some disagreement in the bilingualism literature about whether BLs have an advantage in reactive control. Evidence of MLs and BLs performing equally on tasks such as the SART suggest that BLs do not have an advantage for this component of inhibition (Bialystok et al., 2008), but Morales et al. (2013) argued that BLs have an advantage for both components of inhibition (i.e., proactive and reactive control). In the mind wandering literature, variation in mind wandering on the SART was found to be negatively correlated with working memory capacity (McVay & Kane, 2012b), suggesting that having better general cognitive control can be evident even for tasks such as the SART. With the discrepancy in the literatures, this remains an open question. We hypothesized that if the results of the present study are consistent with no BL advantage on task performance, there would not be a relationship between bilingualism and mind wandering for this task. Conversely, if bilingualism is positively related to task performance, we predicted that bilingualism and the occurrences of TUTs would be negatively related.

Shifting. The BL experience of language switching is believed to produce advantages in nonlinguistic task switching, and some evidence has favored this (Marzecová et al., 2013; Prior & MacWhinney, 2010); therefore, it was predicted that bilingualism would be positively related to task performance on the Color-Shape switching task as measured by reaction time and errors. To our knowledge, mind wandering has not been assessed during tasks measuring shifting, but it can be argued that like tasks used in the mind wandering literature, having TUTs would result in poorer performance; therefore better performance should be related to fewer TUTs. We predicted that if bilingualism is associated with better performance, it would also be associated with fewer number of TUTs.

Updating. Because little research has been conducted studying the relationship between bilingualism or mind wandering with performance on tasks specifically measuring the mechanism of updating, it is difficult to make a specific prediction about what the relationship will be between bilingualism and mind wandering for this task. However, both the bilingualism literature and mind wandering literature have used complex measures of working memory and found that bilingualism is associated with greater working memory capacity (Linck et al., 2013), and greater working memory capacity is associated with less mind wandering for working memory demanding tasks (McVay & Kane, 2012b; Smallwood, 2013). Based on these findings, it is plausible to predict that bilingualism would be positively related to performance on an updating task, the Letter Memory Task, and negatively related to occurrences of TUTs.

Method

Participants

All procedures and materials were approved by Western Kentucky University's Human Subjects Review Board (HSRB), and all participants were treated in accordance with their guidelines (see Appendix A for HSRB approval letter). A total of 68 MLs (44 females) and 58 BLs (28 females) participated. These participants were recruited from Western Kentucky University. Some participants were recruited through the university's study pool of students completing studies for partial course credit. In addition to course credit, these students received $5. Other participants were recruited by contacting various campus organizations and by posting flyers; these participants received $15. All participants were eligible for a chance to win a cash prize drawing of $150 at the end of data collection.

Participants completed basic demographic questions about their gender, age, and education as well as completed an adapted version of the Language History Questionnaire (see below and Appendix B; Li, Zhang, Tsai, & Puls, 2013) about their history and experiences with a second language. Participants were initially classified as being BL or ML based on their self-report of whether they spoke a second language or not. Then, participants were retained or excluded based on their average rating of their proficiency in a second language in reading, writing, speaking and listening that was on a 7-point scale in which the anchor for 1 was “Very Poor”, and the anchor for 7 was “Excellent.” MLs whose average proficiency ratings for their L2 were 4 (neutral) or higher, and BLs whose average proficiency ratings of their L2 were 4 or lower were excluded from all analyses. This resulted in the exclusion of seven MLs and six BLs. Two additional BLs were excluded due to one having had a recent traumatic brain injury and the other failing to follow task instructions. An additional seven MLs were excluded due to having a learning disability or taking medications that could affect attention, and two MLs were excluded due to technical difficulties that resulted in loss of data. This left a total of 52 MLs and 52 BLs that were included for analyses (see Table 3 for demographic information for the final sample).

In addition to English, other languages that BLs in the final sample reported speaking as one of their two most proficient languages included: Arabic (7), Bosnian (3), Chinese or Mandarin (3), Farsi (2), Haitian Creole (1), Korean (1), Portuguese (23), Spanish (9), Swahili (1), Swedish (1), Taiwanese (1), and Twi (1). Eighteen of these participants rated English as their most proficient language and 32 rated English as their second most proficient language. Two participants rated English as their third most proficient language, but their proficiency for English was rated high and above the criterion for exclusion. In addition to the diversity of languages spoken, BL participants also originated from a variety of different countries (see Figure 1 for a map of participants' countries of origin).

Materials

Thought probes. To assess mind wandering, we used the same technique used by other mind wandering researchers (e.g., McVay & Kane, 2012b; Mrazek et al., 2012). That is, while performing the cognitive tasks, participants were periodically presented with thought probes after a percentage of critical trials in each task. These thought probes were distributed pseudorandomly throughout each task, and they asked participants to assess whether they had just been mind wandering or not. The percentage of total trials on each task that were followed by a thought probe ranged from 6% - 17%, depending on the number of trials, duration, and nature of the task. Probes followed a bell sound, and for the Color-Shape, Numerical Stroop, and SART tasks, the probe instructed, "Please choose the one option below which best describes your experience with the task just now." For the OSPAN and Letter Memory task, the probe asked participants, "Can you describe what was going through your head while you were answering the set of problems you just completed, right before your most recent response?" and "Can you describe what was going through your head while you were rehearsing the list of letters you just completed, right before your most recent recall?" respectively. For each probe, participants indicated from the following options if they were thinking about: a) the task, b) task performance, that is, evaluating one's own performance, c) something else unrelated to the task, or d) when the next question like this one may occur. The first three options participants could choose from have been used in previous mind wandering studies (McVay & Kane, 2009, 2012a), and the last option was used to determine whether the frequency of mind wandering probes caused participants to become preoccupied with the probes. After selecting an option, participants were asked whether their thoughts were in a) English, b) a language other than English, c) in more than one language, or d) they were unsure.

Cognitive control measures.

Working memory. Participants completed the Operation Span (OSPAN) as a measure of complex working memory. Participants were presented with a series of basic math equations (e.g., "(20 – 4) + 3 = 16") followed by a single letter (e.g., "R"). Each equation and paired letter were presented on the computer screen one at a time for 5 seconds. During those 5 seconds, participants were asked to verify whether the math equation was correct by hitting "Y" or "N" on the keyboard for "yes" and "no" respectively and to read the letter out loud. After a list of two to five math equations, participants were asked to recall and type the letters from that set in order. There were a total of 24 trials with six trials for each set size of letters to be recalled. Participants' scores were calculated as the proportion of correctly recalled letters. During the task, there were a total of four mind wandering probes, one for each set size, which was approximately 17% of the total sets. Mind wandering probes occurred after participants provided a response for the trial, and the question asked them to base their response on their thoughts during the trial leading up to their most recent response

Proactive control. Participants completed a Numerical Stroop task similar to the one in McVay & Kane (2012b). Participants developed a response mapping prior to the start of the task by indicating on the keyboard the number of boxes on the screen: two, three, or four. Following, participants were presented with two, three, or four identical numbers in a horizontal row. Participants' task was to indicate the number of digits presented. Each trial was preceded by a fixation crosshair presented for 1,000 ms, and the trial remained on the screen until the participant responded. Congruent trials occurred when the number of digits matched the digit presented on the screen (e.g., 333). There were a total of 360 congruent trials, which made up 75% of a total 480 trials. Incongruent trials occurred when the number of digits did not match the digit presented (e.g., 33). There were 120 incongruent trials, which made up 25% of all trials. Incongruent trials occurred at random intervals with the exception that two incongruent trials did not occur consecutively. Reaction time and accuracy was measured for both congruent and incongruent trials. Mind wandering probes occurred at random intervals on 36 of the incongruent trials, which is 7.5% of the total trials.

Reactive control. Participants completed a numerical Sustained Attention to Response Task (SART; Robertson et al., 1997). Digits 1-9 were presented in the center of the screen one at a time for 200 ms followed by a crosshair for 900 ms that served as a mask. The digit "3" was designated as a "no-go" trial and all other digits were designated as "go" trials. All digits were presented an equal number of times and occurred randomly with the exception that the digit "3" could not occur consecutively. Participants were instructed to press the space bar for all "go" trials and withhold their response whenever a "3" was presented. There were a total of 540 trials. The no-go, target trials occurred on 60 trials, approximately 11% of the time. Reaction time for go-trials was measured, and accuracy for go and no-go trials was measured. Mind wandering probes occurred at random intervals on 36 of no-go trials, which is 6.67% of total trials.

Shifting. Participants completed the Color-Shape task (Friedman et al., 2008). Each trial consisted of the presentation of a cue and a shape. The shape was either a red or green circle with a diameter of 4 cm or triangle with a height of 3.5 cm and sides that were 4.3 cm. The cue was either a "C" or an "S." The cue was presented 150 ms before the presentation of the shape, and it remained on the screen 1 cm above the shape until participants responded. The cue "C" informed participants that they should indicate the color of the shape, and "S" informed participants that they should indicate the shape. Participants completed 48 practice trials to learn a response mapping for responding to shapes or colors on the keyboard. Keys were labeled with the respective shape or color to facilitate response mapping. Participants then completed 200 trials in which 50% of the trials were "switch" trials. Switch and nonswitch trials occurred pseudorandomly with one exception: there could not be more than four consecutive switch trials. Reaction time and accuracy for both non-switch trials and switch trials were measured. Mind wandering probes occurred after 20 switch trials, which is 10% of the total trials. These probes occurred pseudorandomly with the exception that there was no more than one mind wandering probe within five consecutive switch trials to avoid consecutive mind wandering probes.

Updating. Participants completed the Letter Memory task (Friedman et al., 2008). Participants were presented with a set of either five, seven, or nine letters one letter at a time. Each letter appeared on the screen for 2,500 ms. Participants were instructed to say aloud the last three letters presented each time a new letter was presented. At the end of each set, participants recalled the last three letters. There were 18 trials with each set size occurring six times. The proportion of correctly recalled letters was calculated. Mind wandering probes occurred after 3 trials, one for each set size, which was 16.67% of the total sets, and they occurred after participants provided a response for the trial. The mind wandering probe asked them to base their response on their thoughts during the trial leading up to their most recent response.

Raven's Advanced Progressive Matrices. To check whether BLs and MLs were similar on nonverbal intelligence, we administered Set I of the Raven's Advanced Progressive Matrices (Raven, Court, & Raven, 1977). This included 12 matrices. The task involved participants determining which pattern among a set of eight options would come next and most logically complete the matrix (see Table 3 for the mean scores on this task for MLs and BLs, which were not significantly different from one another, $t(102) = .34$, $p > .05$).

Language questionnaire. Participants completed a questionnaire adapted from the Language History Questionnaire (see Appendix B; Li et al., 2013) that assessed their proficiency in reading, writing, speaking, and listening to another language. These questions were on a 7-point Likert scale where 1 is very poor and 7 is excellent. The questionnaire also contained general demographic questions and questions related to their language experience. Questions related to their language experience included questions about the frequency of their use of their second language, age of acquisition, immersion experiences, and language mixing. These questions were used to characterize the participants for descriptive purposes.

Procedure

After giving consent to participate, participants completed a brief vision test by using the Rosenbaum and Snellen vision charts. Following, participants were seated at the computer to complete the series of cognitive measures. The order in which participants completed the cognitive tasks was fully counterbalanced using a Latin square. While completing the cognitive tasks, participants were periodically interrupted with the thought probes. After completing the cognitive tasks, participants completed the Raven's task followed by the Language History Questionnaire. After completing all measures, participants were debriefed. The entire procedure lasted between 90 and 120 minutes.

Results

Design and Statistical Analyses

Prior to data analyses, the data were screened for outlying scores for each task. Any participants' data that was 2.5 *SD*s below or above the mean of the variable of interest were excluded for that analysis. This resulted in the exclusion of data from two MLs and two BLs for analysis of the OSPAN, one ML and one BL for the Numerical Stroop task, three MLs and three BLs for the SART, two MLs and one BL for the Color-Shape task, and two MLs and one BL for the Letter Memory task. All analyses were run both prior to excluding outliers and after, and the results were unchanged by excluding outliers. Therefore, below we report only the analyses in which outliers were excluded. Means and standard deviations for all measures can be found in Table 4.

OSPAN

Participants' letter recall was scored using the partial-credit unit scoring method (Conway et al., 2005). The score could range from 0 to 24. An independent samples *t*-test was used to compare the MLs' recall score to BLs' recall score. This analysis did not reveal a significant difference, $t(98) = .97$, $p > .05$.

Numerical Stroop

Both accuracy and reaction times (RTs) were analyzed for this task using a 2 (BL vs. ML) x 2 (congruent vs. incongruent) mixed ANOVA. For accuracy, there was a main effect of trial congruency such that participants were more accurate on congruent trials than incongruent trials, reflecting the expected Stroop effect, $F(1, 100) = 169.45$, $p < .001$, $\eta_p^2 = .63$. There was a marginal main effect of language group such that BLs tended to be slightly more accurate than MLs, $F(1, 100) = 3.10$, $p = .08$, $\eta_p^2 = .03$. There was not a significant interaction, $F(1, 100) = 2.64$, $p > .05$, $\eta_p^2 = .03$. Before conducting the analysis for RT, incorrect trials and trials with RTs 2.5 *SD*s above or below a participants' individual mean RT were removed for each participant. There was again the expected main effect of congruency such that participants were faster for congruent trials than for incongruent trials, $F(1, 100) = 600.55$, $p < .001$, $\eta_p^2 = .86$. There was also a main effect of language group, $F(1, 100) = 5.52$, $p = .02$, $\eta_p^2 = .05$. Contrary to the hypothesized results of BLs outperforming MLs, the direction of this main effect was such that BLs were slower than MLs (see Figure 2). There was not a significant interaction, $F(1, 100) = .09$, $p > .05$, $\eta_p^2 = .001$.

Sustained Attention to Response Task

To begin comparing the groups on SART performance, a 2 (BL vs. ML) x 2 (go vs. no-go) mixed ANOVA was conducted with accuracy as the dependent variable. There was a main effect of trial type such that accuracy was higher for go trials than no-go trials, which is typical for this task, $F(1, 96) = 561.49$, $p < .001$, $\eta_p^2 = .85$. There was not a main effect of language group, $F(1, 96) = .82$, $p > .05$, $\eta_p^2 = .01$ or a significant interaction, $F(1, 96) = .35$, $p > .05$, $\eta_p^2 = .004$. We also compared MLs and BLs on RTs for correct responses to go-trials. An independent samples *t*-test revealed that BLs were slower to respond than MLs, $t(96) = 2.37$, $p = .02$ (see Figure 2).

Color-Shape Task

Both accuracy and RTs were analyzed for this task using a 2 (BL vs. ML) x 2 (nonswitch vs. switch) mixed ANOVA. For accuracy there was a main effect of trial type such that accuracy was greater for nonswitch trials than switch trials, $F(1, 100) = 11.92$, $p = .001$, $\eta_p^2 = .11$. There was not a significant main effect of language group nor a significant interaction, $F(1, 100) = .02$, $p > .05$, $\eta_p^2 = .00$ and $F(1, 100) = .09$, $p > .05$, $\eta_p^2 = .001$, respectively. Before conducting the analysis for RT, incorrect trials and trials with RTs 2.5 *SD*s above or below a participants' individual mean RT were removed for each participant. There was a significant main effect of trial type such that RTs were longer for switch trials than nonswitch trials, $F(1, 99) = 607.14$, $p < .001$, $\eta_p^2 = .86$. There was also a significant main effect of language group, $F(1, 99) = 12.94$, $p = .001$, $\eta_p^2 = .12$. Similar to the Numerical Stroop task, BLs had slower RTs than MLs (see Figure 2). The interaction was marginally significant, $F(1, 99) = 3.31$, $p = .07$, $\eta_p^2 = .03$. Also consistent with a BL disadvantage, this marginal trend suggested that although the difference between nonswitch and switch trial RTs were significant for both MLs, $t(49) = -19.63$, $p < .001$, and BLs, $t(50) = -16.34$, $p < .001$, the difference was somewhat larger for BLs (mean difference for MLs was 203.77, $SD = 73.39$ and the mean difference for BLs was 236.26, $SD = 103.27$).

Letter Memory Task

Accuracy was calculated by finding the proportion of letters correctly recalled; therefore scores could range from 0 to 1. An independent samples *t*-test revealed no significant differences between MLs and BLs, $t(99) = 1.07$, $p > .05$.

Mind Wandering

In addition to determining whether there were any group differences in performance on the different cognitive tasks, we were also interested in determining whether performance of the two language groups could be related to mind wandering tendencies. To begin addressing this question, the proportion of each mind wandering probe response was calculated for each participant for each task. Overall, across all participants, the tendency to mind wander was high: on-task thoughts were reported only 50%-60% of the time. The most common sub-type of mind wandering was thinking about task performance, which was reported 19%-38% of the time. Having completely task-unrelated thoughts was reported between 6%-24% of the time, and thinking about the next probe was reported 4%-9% of the time (see Figure 3 for depiction of means for probe responses for each task).We then compared BLs and MLs on each of these mind wandering probe responses. In order to determine whether these tendencies were different for BLs and MLs, independent samples *t*-tests were conducted for each mind wandering option. The results showed that there were no significant differences between BLs and MLs in the tendency to be on-task, nor for any of the subtypes of off-task mind wandering, all *p*s > .05 (see Table 5 for means and standard deviations). Because there were no significant differences in mind wandering tendencies between MLs and BLs, it is unlikely that any differences between ML and BL performance on any of the tasks were being driven by differences in mind wandering; therefore, no additional analyses were performed.

To summarize the results presented thus far, we found no differences between MLs and BLs for the OSPAN or Letter Memory Task. We also found no significant differences between MLs and BLs on accuracy for the Numerical Stroop, SART, and Color-Shape tasks, but there was a BL disadvantage in RTs for these three tasks. The differences in performance on these tasks in not likely the result of differences in mind wandering tendencies between BLs and MLs as the comparisons of two groups on mind wandering revealed no differences. Because the overall results revealed no BL advantages, we conducted additional analyses to determine whether these results were being driven by certain characteristics of the BLs, namely age of acquisition and the similarity of BLs' languages.

Comparison of Early Bilinguals, Late Bilinguals, and Monolinguals

To examine the effects of age of acquisition on our results, BLs were categorized as early BLs if they had begun acquiring their L2 at six years or younger. They were categorized as late BLs if they had begun acquiring their L2 when they were older than six years. This criterion was based on studies finding BL advantages in cognitive control for early BLs who had begun acquiring their L2 before the age of six years (Bialystok et al., 2008; Morales et al., 2013). This resulted in samples of 13 early BLs and 39 late BLs (see Table 6 for means and standard deviations). Because the sample size for early bilinguals is small and because the group sizes are uneven, the following results should be interpreted with caution.

OSPAN. A one-way ANOVA was conducted to compare early BLs, late BLs, and MLs on OSPAN accuracy. There was a significant effect of language group, $F(2, 99) = 3.52$, $p < .05$. Post hoc comparisons using the Bonferroni correction indicated that early BLs ($M = 22.02$, $SD = 1.07$) had significantly higher accuracy than MLs ($M = 21.00$, $SD = 2.24$, $p < .05$. All comparisons with late BLs ($M = 20.04$, $SD = 2.91$) were nonsignificant.

Numerical Stroop. A 3 (early vs. late vs. ML) x 2 (congruent vs. incongruent) ANOVA was conducted for accuracy and RTs. For accuracy there was a main effect of congruency, $F(1, 99) = 117.28$, $p < .001$, $\eta_p^2 = .54$, with higher accuracy for congruent trials than for incongruent trials. There was not a main effect of language group, $F(2, 99) = 2.05$, $p > .05$, $\eta_p^2 = .04$, or a significant interaction, $F\ (2, 99) = 1.52$, $p > .05$, $\eta_p^2 = .03$. For RTs, there was a main effect of congruency, $F(1, 99) = 419.94$, $p < .001$, $\eta_p^2 = .81$, such that RTs for incongruent trials were greater than congruent trials. There was a marginal main effect of language group, $F(2, 99) = 3.16$, $p = .05$, $\eta_p^2 = .06$ (see Figure 4). Pairwise comparisons revealed a marginal difference between MLs and late BLs (MLs tended to be faster, $p = .07$), and a significant difference between MLs and early BLs such that MLs had faster RTs, $p = .03$. The difference between early and late BLs was not significant, $p > .05$. The interaction was not significant, $F(2, 99) = .27$, $p > .05$, $\eta_p^2 = .01$.

Sustained Attention to Response Task. A 3 (early vs. late vs. ML) x 2 (go vs. no-go) mixed ANOVA was conducted with accuracy as the dependent variable. There was a significant main effect of trial type, $F(1, 95) = 359.14$, $p < .001$, $\eta_p^2 = .79$; as expected, participants were more accurate on go trials than no-go trials. There was no effect of language group, $F(2, 95) = .42$, $p > .05$, $\eta_p^2 = .01$, and no interaction, $F(2, 95) =$

.90, $p > .05$, $\eta_p^2 = .02$. To compare groups on RTs, a one-way ANOVA was conducted. There was a significant effect of language group, $F(2, 95) = 4.43$, $p < .05$ (see Figure 4). Post hoc comparisons using the Bonferroni correction indicated that early BLs had slower RTs than MLs, $p < .05$.

Color-Shape Task. A 3 (early vs. late vs. ML) x 2 (nonswitch vs. switch) ANOVA was conducted for accuracy and RTs. For accuracy there was a significant main effect of trial type such that participants were more accurate for nonswitch trials than switch trials, $F(1, 99) = 10.77$, $p < .01$, $\eta_p^2 = .10$. There was no effect of language group, $F(2, 99) = .33$, $p > .05$, $\eta_p^2 = .01$, nor an interaction, $F(2, 99) = .57$, $p > .05$, $\eta_p^2 = .01$. For RTs there was a significant main effect of trial type such that participants were slower for switch trials than nonswitch trials, $F(1, 98) = 436.59$, $p < .001$, $\eta_p^2 = .82$. There was also a significant main effect of language group, $F(2, 98) = 7.60$, $p < .01$, $\eta_p^2 = .13$ (see Figure 4). Pairwise comparisons indicated that this was driven by a difference between late BLs and MLs such that late BLs had slower RTs than MLs, $p < .001$. However, there was also a significant interaction, $F(2, 98) = 3.68$, $p < .05$, $\eta_p^2 = .07$. Simple effect analyses indicated that although each language group had significantly slower RTs for switch trials than nonswitch trials (all $p < .05$), this difference was greatest for late BLs with a mean difference of 250.64 ms. The mean difference for MLs and early BLs was 203.77 ms and 194.23 ms, respectively.

Letter Memory Task. A one-way ANOVA was conducted to compare early BLs, late BLs, and MLs on Letter Memory accuracy. This analysis indicated that there was no significant effect of language group, $F(2, 98) = 1.33$, $p > .05$.

Comparison of Same-Script and Different-Script Bilinguals and Monolinguals

There has been some suggestion that BLs with two different script languages may experience less linguistic competition and thus would not develop as much of a BL advantage as those BLs who speak languages that are similar (Linck et al., 2008). However, there is also evidence that even BLs who have dissimilar languages also experience cross-linguistic activation (Jouravlev & Jared, 2013); therefore, the degree to which script can influence cognitive control remains an open question. Although exploring this question was not a primary purpose of the present study, we divided our BL participants into groups that spoke languages that shared a Latin script and those that did not share the Latin script of English. Because Bosnian can use either a Latin or Cyrillic script, and because it is uncertain what these Bosnian participants used, they were excluded from these analyses. That left 36 who spoke a language other than English that also used a Latin script and 12 participants who spoke one language that did not use a Latin script (see Table 7 for means and standard deviations). As with the analyses involving age of acquisition, the small sample size for different-script BLs and the uneven group sizes are cause for interpreting the results of the analyses with caution.

OSPAN. A one-way ANOVA was conducted to compare same-script BLs, different-script BLs, and MLs on OSPAN accuracy. This analysis indicated that there were no differences between the groups, $F(2, 96) = .76$, $p > .05$.

Numerical Stroop. A 3 (same script vs. different script vs. ML) x 2 (congruent vs. incongruent) ANOVA was conducted for accuracy and RT. For accuracy, there was a significant main effect of trial congruency, $F(1, 95) = 81.92$, $p < .001$, $\eta_p^2 = .46$, such that participants were more accurate for congruent trials than incongruent trials. There was a marginal main effect of language group, $F(2, 95) = 2.62$, $p = .08$, $\eta_p^2 = .05$. Pairwise comparisons showed that different-script BLs tended to be more accurate than MLs, $p = .03$, but all other comparisons were nonsignificant, $p > .05$. The marginal effect of language group was better explained by a marginally significant interaction of language group and trial congruency, $F(2, 95) = 2.74$, $p = .07$, $\eta_p^2 = .06$. Post-hoc analyses showed that this interaction was characterized by different-script BLs having higher accuracy than MLs on the incongruent trials only, $p < .05$. All other comparisons were not significant, all *p's* > .05. For RT, there was a significant main effect for congruency, $F(1, 95) = 358.21$, $p < .001$, $\eta_p^2 = .79$; RTs were slower for incongruent trials than congruent trials. There was a marginal main effect of language group, $F(2, 95) = 2.51$, $p = .09$, $\eta_p^2 = .05$ (see Figure 5). Pairwise comparisons revealed that same-script BLs had slower RTs than MLs, $p = .03$. All other comparisons were nonsignificant. There was not a significant interaction, $F(2, 95) = 1.58$, $p > .05$, $\eta_p^2 = .03$.

Sustained Attention to Response Task. A 3 (same script vs. different script vs. ML) x 2 (go vs. no-go) mixed ANOVA was conducted with accuracy as the dependent variable. There was a significant main effect of trial type, $F(1, 91) = 349.60$, $p < .001$, $\eta_p^2 = .79$. Participants were more accurate on go trials than no-go trials. There was no effect of language group, $F(2, 91) = 1.25$, $p > .05$, $\eta_p^2 = .03$, nor was there an interaction, $F(2, 91) = 1.65$, $p > .05$, $\eta_p^2 = .04$. To compare groups on RTs, a one-way ANOVA was conducted. There was a significant effect of language group, $F(2, 91) = 3.29$, $p < .05$ (see Figure 5). Post hoc comparisons using the Bonferroni correction indicated that MLs tended to have faster RTs than same-script BLs, $p = .08$. All other comparisons were nonsignificant.

Color-Shape Task. A 3 (same script vs. different script vs. ML) x 2 (nonswitch vs. switch) ANOVA was conducted for accuracy and RTs. There was a significant main effect of trial type such that participants were more accurate for nonswitch trials than switch trials, $F(1, 95) = 7.22$, $p < .01$, $\eta_p^2 = .07$. There was no effect of language group, $F(2, 95) = .62$, $p > .05$, $\eta_p^2 = .01$, nor an interaction, $F(2, 95) = .15$, $p > .05$, $\eta_p^2 = .003$. For RT, there was a significant main effect of trial type such that participants were slower on switch trials than nonswitch trials, $F(1, 94) = 427.59$, $p < .001$, $\eta_p^2 = .82$. There was also a significant main effect of language group, $F(2, 94) = 6.70$, $p < .01$, $\eta_p^2 = .13$ (see Figure 5). Pairwise comparisons indicated that MLs had faster RTs than both same-script BLs and different-script BLs, both *p*s < .01, but there was not a significant difference between the two BL groups, $p > .05$. There was not a significant interaction, $F(2, 94) = 2.30$, $p > .05$, $\eta_p^2 = .05$.

Letter Memory Task. A one-way ANOVA was conducted to compare same-script BLs, different-script BLs, and MLs on Letter Memory accuracy. This analysis indicated that there was no effect of language group, $F(2, 95) = .84$, $p > .05$.

In summary, the secondary analyses of both the age of acquisition and similarity of languages were overall consistent with the primary analyses. Any significant difference between groups was consistent with MLs outperforming at least one of the BL groups, or there was a difference between the BL groups. There was one exception, however. Early BLs did achieve higher accuracy on the OSPAN than MLs. This is an isolated finding, and as mentioned, there were only 13 early BLs, and the group sizes were uneven; therefore the overall findings of these secondary analyses are in line with the initial finding of no BL advantage.

Discussion

The purpose of this study was to address disparate findings in bilingualism research on cognitive control by answering whether BLs in our study would outperform MLs on four aspects of cognitive control (i.e., working memory, inhibition, shifting, and updating). We also asked the novel question of whether BLs had better attention regulation as measured by mind wandering tendencies that may in turn be related to any advantages in performance. Based on the published research, we hypothesized that BLs would outperform MLs on a working memory task, an inhibitory task that tapped into proactive control, and a shifting task. There was less certainty about whether we would see a BL advantage for inhibitory tasks tapping into reactive control and on updating tasks, but based on literature that has found a BL advantage for reactive control (Morales et al., 2013) and the positive relationship between bilingualism and working memory (Linck et al., 2013), we hypothesized that we should see a BL advantage.

We recruited a large sample of BLs with very diverse linguistic backgrounds, making the generalizability of our data strong. Furthermore, BLs were similar to MLs in age, education, and non-verbal intelligence, thus minimizing those potential confounds. However, contrary to what some studies have reported in the published literature, the results of our cognitive tasks did not support a BL advantage for cognitive control. The results were quite consistent across tasks: BLs did not outperform MLs on any tasks. Usually, ML and BL performance was equal; however, on the three tasks that measured reaction times (i.e., Stroop, SART, and Color-Shape tasks), there was a BL disadvantage such that BLs had slower reaction times. Interestingly, these results are quite similar to those of Paap and Greenberg (2013) and Paap and Sawi (2014). Like the current study, Paap and Greenberg and Paap and Sawi also compared MLs and BLs on a several cognitive control measures and failed to replicate a BL advantage and found some instances of a BL disadvantage. For example, Paap and Sawi, found a ML advantage for antisaccade RT, Simon interference effect, and global Simon RT. As with the current study, the reasons for those ML advantage findings are not well understood.

In addition to cognitive control performance, we were also interested in mind wandering tendencies of MLs and BLs. This question would have been of particular interest if BLs had shown superior performance. Nonetheless, we compared MLs and BLs on mind wandering responses, and the results indicated that there were no significant differences between the groups in the tendency to be on-task, or for any of the types of mind wandering they could have reported (i.e., thinking about task performance, the occurrence of the next probe, or something task-unrelated). Because there were no differences in mind wandering tendencies, we concluded that differences in task performance, when they occurred, were not related to differences in mind wandering tendencies. Although this was a preliminary study on the relationship between bilingualism and mind wandering and more research is needed, it is nonetheless interesting to note that our data suggest that mind wandering is a common occurrence regardless of one's linguistic experience. Indeed, the data were quite consistent with previously published reports of people spending as much as 30% - 50% of daily awake thoughts mind wandering (Kane et al., 2007; Killingsworth & Gilbert, 2010). Participants in the current study reported being off-task as much as 50% of the time, regardless of whether they were MLs or BLs.

Limitations and Future Directions

Because the planned analyses did not yield any findings in support of the BL advantage, we ran additional analyses to see whether certain characteristics related to the BLs' language profile could help us gain insight into why no BL advantages were found. As noted previously, bilingualism is a multifaceted variable (Luk & Bialystok, 2013) consisting of many other variables such as proficiency, age of acquisition, similarity in languages, language usage, and other characteristics. For this study, we were particularly interested in age of acquisition and the similarity of the BLs' languages (i.e., whether they were the same script or not). Many of the reviewed studies that found BL advantages included participants who had acquired both of their languages early in life, usually before age six (e.g., Bialystok et al., 2004, 2006, 2008; Colzato et al., 2008; Morales et al., 2013). One could argue that learning a second language early while the brain is still developing in addition to the added time of managing the two languages may be a critical component for creating a BL advantage; therefore, we divided participants into groups of early BLs, late BLs, and MLs. Although our number of early BLs was relatively small, we still found that MLs were performing equal to or better than early and late BLs on all the tasks with one exception: early BLs did achieve higher accuracy on the OSPAN than MLs (but again, due to the low sample size, this should be interpreted with caution).

Another variable in addition to age of L2 acquisition was the similarity of languages. It has been proposed that the more similar the languages are the more likely they are to create interference and require more inhibition, and this could potentially lead to greater cognitive control (Linck et al., 2008). Although cross-linguistic activation has been demonstrated even for BLs whose languages are of a different script (e.g., Jouravlev

& Jared, 2013) thus creating interference, we wanted to examine whether differences or similarities in script would have any effect on our results. As with age of acquisition, our sample size of different-script BLs was somewhat small; however, here too we again found that MLs still performed similar to or better than BLs. For the Stroop, SART, and Color-Shape task, same-script BLs had slower RTs than MLs, whereas different-script BLs did not. This is not consistent with the hypothesis that same-script BLs should have the greatest cognitive control benefits, but, again, due to the small sample size, this finding should be interpreted with caution. In any case, it should also be noted that neither same-script nor different-script BLs had performance means in the direction of a BL advantage. Thus, although these data are suggestive regarding the factors of age of acquisition and language script similarity, the results in no way support a BL advantage, making the results largely consistent with the comparisons of MLs and our entire sample of BLs.

Although the findings of this study consistently indicated that there was no BL advantage, there are additional reasons why the current study may have not found a BL advantage. One possible confound is that there was not strict control over L2 proficiency, nor was there an objective measure of proficiency used in this study. It could be argued that because the majority of the BL sample consisted of late BLs, they may have not yet achieved fluency in their L2; however, this seems unlikely. These participants' mean ratings for their own L2 proficiency was a 5.38 on the seven point scale which is between the anchors of "Good" and "Very Good." A potential argument, however, is that the cut-off score of 4 on the proficiency scale could have allowed for some BLs with lower proficiency to affect the results. Although this argument cannot be ruled out, it should be noted that Paap and Greenberg (2013), who also used a 7-point scale with 4 as a criterion for categorizing BLs and MLs, completed follow-up analyses in which they exerted stricter criteria for proficiency and included only BLs whose proficiency was rated 6 or higher and MLs whose proficiency was rated as 1 or lower, and the results of their analyses revealed the same pattern of no BL advantage. A final argument about the method of categorizing participants as BLs or MLs is that it was based on self-report ratings. This method, however, is common, and subjective measures of proficiency have been noted to correlate well with objective measures of proficiency (Marian, Blumenfeld, Kaushanskaya, 2007). Nevertheless, without an objective measure, we cannot fully rule out effects of proficiency.

Other possible factors affecting the results of the current study in addition to proficiency include frequency of use of the L1 and L2, and the context in which they learned their L2 (e.g., through immersion or through taking classes). It is important to note, however, that these are common limitations in bilingualism research because controlling for all factors contributing to bilingualism proficiency in a single study would be difficult, if not impossible. Nevertheless, if bilingualism does indeed have consequences for cognitive control, future research will need to identify which individual differences in bilingualism contribute to those consequences.

In addition to the various uncontrolled factors related to bilingualism, there is the possibility that the current study did not replicate a BL advantage because of the age of the participants. It has been suggested that BL advantages may be difficult to observe in younger adults because they are at the peak of their cognitive ability, but can be more readily observed in older adults (Bialystok et al., 2004, 2005, 2008). It could potentially be argued that the reason BL advantages were not observed in the current study was because all the participants were younger adults. Although this argument cannot be completely ruled out, it is helpful to note that there have been several studies that have found BL advantages in younger adults (e.g., Colzato et al., 2008; Linck et al., 2008; Morales et al., 2013), giving credence to the rationale of using younger adults in the current study. Furthermore, some researchers have disagreed with the explanation that BL advantages are easier to observe in older adults by stating that a failure to replicate advantages in younger adults is inconsistent with claims that bilingualism produces better inhibitory control (i.e., the BICA hypothesis; Hilchey & Klein, 2011). Future research will need to address these disparate claims.

Although there are likely factors related to the language background or current age of the participant that may affect whether BL advantages are observed or not, there are also potential limitations with the tasks used. Our results are consistent with Paap and Sawi (2014) in that neither study found a BL advantage. It is worth mentioning that those authors' view of published studies is that when BL advantages do occur, the findings are isolated to specific tasks, suggesting that the BL advantage is task-specific. Furthermore, they found that in their own study, there was little convergent validity among tasks that are supposed to be measures of the same cognitive control mechanism. Paap and Sawi believe that this further supports the idea that BL advantages are task-specific and that it undermines the claim that bilingualism affects cognitive control constructs such as inhibition, shifting, and updating more globally. In other words, if there is no convergent validity among similar tasks, then we cannot accurately know what our tasks are actually measuring, and thus claiming a BL advantage for cognitive control when it is found only for a particular task may be invalid. Relating this idea to the current study, it is possible that we did not find a BL advantage because a) there may not be a BL advantage for cognitive control in the way of traditional thinking (i.e., inhibition, updating, and shifting), and b) our tasks may not have tapped into those unknown, task-specific elements for which some studies have found a BL advantage. This conundrum certainly highlights the need for future research to understand what may be driving BL advantages when they do occur, and as Paap and Sawi pointed out, there is need to develop and use measures with better construct validity.

Another important point for future research to address is the directionality of cognitive consequences of bilingualism. Although comparing MLs and BLs provide a quasi-experimental design in which differences may be inferred to mean that acquiring a second language *produced* said differences, the quasi-experimental nature of this type of design does not allow us to infer causality with complete certainty, despite how it may appear in many published studies. Some research has demonstrated that among BLs, those who have better cognitive control also have better language control (Festman, Rodríguez-Fornells, & Münte, 2010). The question derived from this study was whether having acquired better language control affected those BLs' cognitive control, or whether having better cognitive control affected their language control. In other words, does bilingualism produce better cognitive control, or does better cognitive control produce better bilingualism? Perhaps, if there is an effect, it is bidirectional. This is something that future research should attempt to solve. Because bilingualism is a quasi-independent variable, causality is hard to address. One possible method for future research to utilize is longitudinal studies. Collecting baseline cognitive control measures before L2 acquisition could potentially be beneficial.

Conclusion

In conclusion, this study sought to determine whether BLs would outperform MLs on a variety of cognitive control tasks and whether there were differences in mind wandering tendencies between the two groups. Our results failed to replicate a BL advantage for cognitive control which is consistent with other recent studies (Paap & Greenberg, 2013; Paap & Sawi, 2014). Although accumulating evidence disfavoring a BL advantage certainly does raise the importance of questioning the well-favored BL advantage claims, an effect of bilingualism on cognition cannot be ruled out entirely. In discussing the publication bias, de Bruin et al. (2014) noted that there may be BL advantages, but they may be small. Furthermore, as stated previously, BL advantages may be task-specific. There are also many factors of bilingualism (e.g., proficiency, age of acquisition, etc.) that are not well understood yet in terms of how they affect cognition. The current study resonates well with these latter statements in that it provided further evidence that the cognitive consequences of bilingualism are still not well understood and that broad sweeping statements of bilingualism creating cognitive control advantages should be curtailed until future research can provide additional insight.

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Table 1

Description of Terms Used to Describe Aspects of Inhibition and the Tasks Used to Measure Inhibition in Bilinguals

Paper	Term	Description of Term	Tasks
Bialystok et al. (2008)	Interference Suppression[a]	"Executive control is required to monitor attention to the relevant feature so that the response is chosen on the correct basis, even when the irrelevant feature indicates the opposite response" (p. 869).	*Simon Task:* indicate direction of arrows while ignoring location; *Stroop Task*: indicate color of word while ignoring word.
	Response Inhibition[b]	"This type of executive control is required to replace a habitual response with a nonsalient one, or to avoid executing a highly cued response" (p. 869).	*Sustained Attention to Response Task*: press a key on digits 1-9, but withhold the response on the digit "3".
Colzato et al. (2008)	Reactive Inhibition[a]	"Maintaining the task goal, so as to provide stronger support for target representations" (p. 303).	*Inhibition of Return:* Measures amount of time participants experience inhibition of looking at cued location; *Attentional Blink*: Measures the number of rapidly presented letters between target letters that it takes for participants to notice both target letters.
	Active Inhibition[b]	Active inhibition is a process that directly "hampers the noise" and "is not due to local inhibitory connections but to the intervention of a separate, central inhibitory system" (p. 303).	*Stop Signal*: stop a prepotent response when cued.

(Table continues)

Table 1 *(continued)*

Morales et al. (2013)	Proactive Control	Proactive control processes “reduce interference before it occurs” and “means that goal representations are triggered in preparation for the task and maintained during periods in which they are required” (p. 2).	*AX-CPT*: Respond “yes” to “X” following an “A”. Proactive control required on trials where “A” is followed by a non-X letter.
	Reactive Control	Reactive control is “the ability to react to competition and suppress irrelevant competing information” where “conflict detection mechanisms are required to signal when inhibitory control is needed” (p. 2, 4).	*AX-CPT*: Respond “yes” to “X” following an “A”. Reactive control is required on trials where a non-A letter is followed by “X”.

[a]Referred to as proactive control in the text’s body
[b]Referred to as reactive control in the text’s body.

Table 2

Comparison of Cognitive Control Mechanisms and Predictions in the Bilingualism and Mind Wandering Literature

Cognitive mechanism	Measure in bilingualism studies	Measure in mind wandering studies	Predictions in bilingualism literature	Predictions in mind wandering literature
Working Memory	Corsi Block, Digit Span Task, Backwards Digit Recall, Word Span	Operation Span, Reading Span, Spatial Span	Bilinguals outperform monolinguals	Greater working memory capacity results in less mind wandering
Proactive Control	Stroop, Simon Arrow Task, Antisaccade, Attentional Blink	Stroop, Antisaccade	Bilinguals outperform monolinguals	Better proactive control results in less mind wandering
Reactive Control	SART, Stop Signal Task, Simple Antisaccade	SART	Bilinguals and monolinguals perform equally or bilinguals outperform monolinguals	Better performance on SART is associated with less mind wandering
Updating	Spatial N-back	No previous updating tasks given	Bilinguals outperform monolinguals	No predictions in the literature
Shifting	Color-Shape Task, Letter-Number Task	No previous shifting tasks given	Bilinguals outperform monolinguals	No predictions in the literature

Table 3

Participant Characteristics

Measure	Monolinguals (n = 52) *M*	*SD*	Bilinguals (n = 52) *M*	*SD*
Age*	20.12	2.18	21.33	1.89
Education*	13.42	1.60	14.25	1.45
Raven's Advanced Progressive Matrices	7.96	1.66	8.08	1.85
Semesters of L2 instruction[a]**	3.19	1.60	6.71	3.56
L1 Proficiency*	6.56	.54	6.76	.37
L2 Proficiency**	1.99	.75	5.38	.63

[a]Total number of semesters of L2 instruction in high school and university.

*p < .05. **p < .001

Table 4

Means and Stand Deviations for Cognitive Control Task Performance

Measure	Monolinguals		Bilinguals	
	M	*SD*	*M*	*SD*
OSPAN (Accuracy)	21.00	2.24	20.52	2.71
Stroop Accuracy (Congruent)	.98	.02	.98	.02
Stroop Accuracy (Incongruent)	.88	.08	.91	.07
Stroop RT (Congruent)	537.82	74.81	580.88	96.65
Stroop RT (Incongruent)	627.44	94.12	672.66	116.68
SART Accuracy (Go Trial)	.90	.12	.92	.08
SART Accuracy (No-Go Trial)	.56	.13	.56	.16
SART RT (Correct Go Trials)	324.62	49.11	353.33	69.10
Color-Shape Accuracy (Nonswitch)	.94	.04	.94	.04
Color-Shape Accuracy (Switch)	.93	.05	.93	.05
Color-Shape RT (Nonswitch)	753.82	129.89	870.37	198.64
Color-Shape RT (Switch)	957.59	152.64	1106.63	255.75
Letter Memory (Accuracy)	.93	.07	.91	.07

Table 5

Means and Standard Deviations for Mind Wandering Tendencies

		Monolinguals		Bilinguals	
Task	Mind Wandering Option	*M*	*SD*	*M*	*SD*
OSPAN	On-Task	.50	.39	.55	.38
	Task Performance	.43	.38	.34	.36
	Off-task thoughts	.05	.13	.08	.19
	Next Probe	.03	.08	.05	.11
Numerical Stroop	On-Task	.48	.27	.51	.27
	Task Performance	.19	.17	.18	.23
	Off-task thoughts	.26	.23	.23	.22
	Next Probe	.07	.13	.08	.14
SART	On-Task	.52	.27	.49	.27
	Task Performance	.26	.22	.25	.25
	Off-task thoughts	.14	.13	.18	.14
	Next Probe	.09	.18	.09	.18
Color-Shape	On-Task	.61	.28	.62	.32
	Task Performance	.25	.20	.27	.30
	Off-task thoughts	.08	.13	.07	.11
	Next Probe	.04	.09	.04	.08
Letter Memory	On-Task	.51	.37	.54	.36
	Task Performance	.36	.38	.33	.34
	Off-task thoughts	.06	.13	.08	.20
	Next Probe	.07	.16	.05	.18

Table 6

Means and Standard Deviations for Early and Late Bilingual and Monolingual Cognitive Control Task Performance

	Monolinguals		Late Bilinguals		Early Bilinguals	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
OSPAN (Accuracy)	21.00	2.24	20.04	2.91	22.02	1.07
Stroop Accuracy (Congruent)	.98	.02	.98	.02	.98	.03
Stroop Accuracy (Incongruent)	.88	.08	.91	.06	.89	.10
Stroop RT (Congruent)	537.81	74.81	572.87	94.19	604.30	103.78
Stroop RT (Incongruent)	627.44	94.12	666.71	117.72	690.06	116.42
SART Accuracy (Go Trial)	.90	.12	.93	.07	.91	.12
SART Accuracy (No-Go Trial)	.56	.13	.56	.15	.60	.20
SART RT (Correct Go Trials)	324.62	49.11	345.30	52.88	381.07	107.13
Color-Shape Accuracy (Nonswitch)	.94	.04	.94	.04	.96	.03
Color-Shape Accuracy (Switch)	.93	.05	.93	.05	.93	.04
Color-Shape RT (Nonswitch)	753.81	129.89	885.18	205.83	827.09	176.22
Color-Shape RT (Switch)	957.59	152.64	1135.82	266.87	1021.31	205.81
Letter Memory (Accuracy)	.93	.07	.91	.07	.94	.06

Table 7

Means and Standard Deviations for Same- and Different-Script Bilingual and Monolingual Cognitive Control Task Performance

Measure	Monolinguals		Different-Script Bilinguals		Same-Script Bilinguals	
	M	*SD*	*M*	*SD*	*M*	*SD*
OSPAN (Accuracy)	21.00	2.24	20.22	3.63	20.44	2.44
Stroop Accuracy (Congruent)	.98	.02	.98	.02	.98	.02
Stroop Accuracy (Incongruent)	.87	.08	.94	.05	.90	.08
Stroop RT (Congruent)	537.82	74.81	573.01	113.19	580.36	93.36
Stroop RT (Incongruent)	627.44	94.11	647.34	124.54	677.16	116.94
SART Accuracy (Go Trial)	.90	.12	.92	.08	.93	.07
SART Accuracy (No-Go Trial)	.56	.13	.63	.21	.56	.14
SART RT (Correct Go Trials)	324.62	49.11	362.14	58.65	354.77	75.32
Color-Shape Accuracy (Nonswitch)	.94	.04	.95	.04	.93	.04
Color-Shape Accuracy (Switch)	.94	.04	.95	.03	.94	.04
Color-Shape RT (Nonswitch)	753.82	129.89	925.70	211.21	851.20	201.47
Color-Shape RT (Switch)	957.59	152.64	1162.73	243.38	1095.06	265.15
Letter Memory (Accuracy)	.93	.07	.90	.09	.91	.07

Figure 1. A map of participant country of origin which demonstrates the diversity of the sample of participants. Map was generated using an online tool found at traveltip.org.

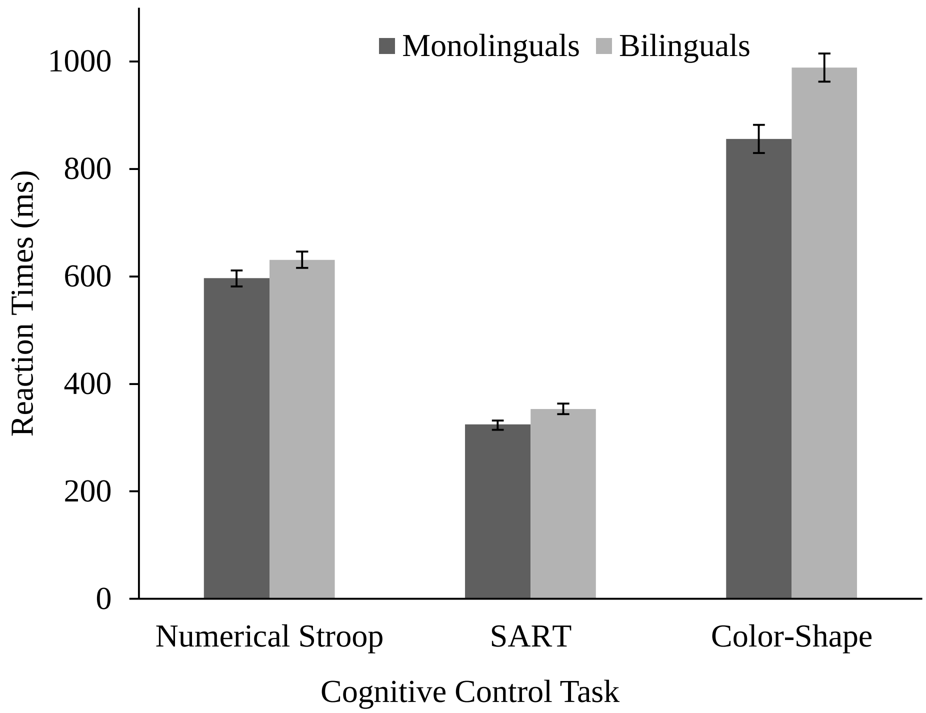

Figure 2. Mean reaction times in ms for bilinguals and monolinguals on the Numerical Stroop, SART, and Color-Shape tasks. Error bars denote standard error around the mean. Bilingual reaction times were significantly slower than monolingual reaction times for all three tasks, *p*s < .05.

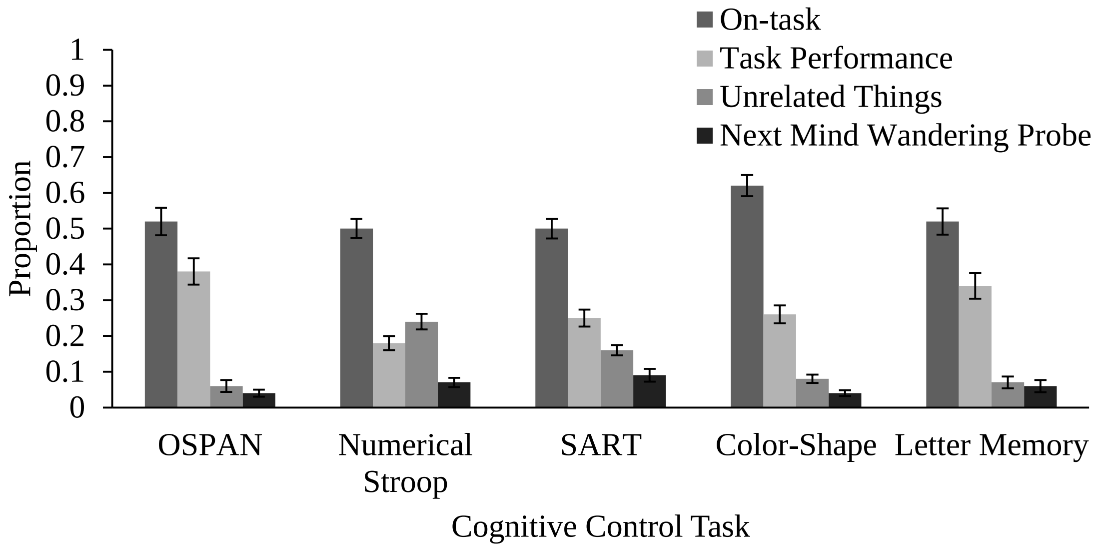

Figure 3. Mean proportion of the four mind wandering probe response options. Means depicted represent the proportion of the responses collapsed across bilinguals and monolinguals. Error bars denote standard error around the mean.

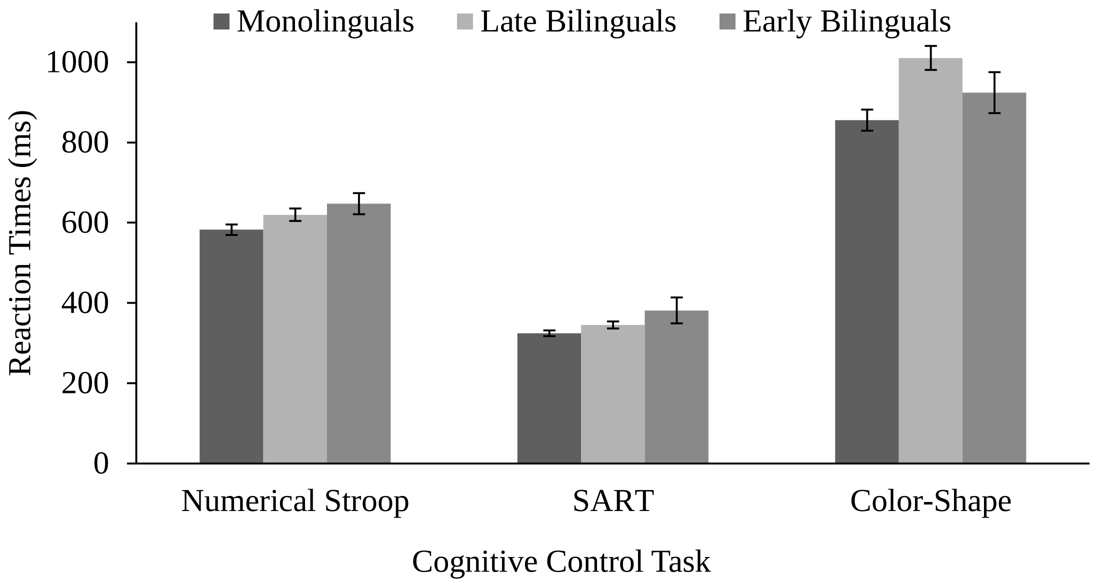

Figure 4. Mean reaction times in ms for early and late bilinguals (BLs) and monolinguals (MLs) on the Numerical Stroop, SART, and Color-Shape tasks. Error bars denote standard error around the mean. MLs tended be faster than late BLs, $p = .07$, and were faster than early BLs, $p < .05$ on the Numerical Stroop. MLs were also faster than early BLs on the SART, $p < .05$. MLs were faster than late BLs on the Color-Shape task, $p < .001$.

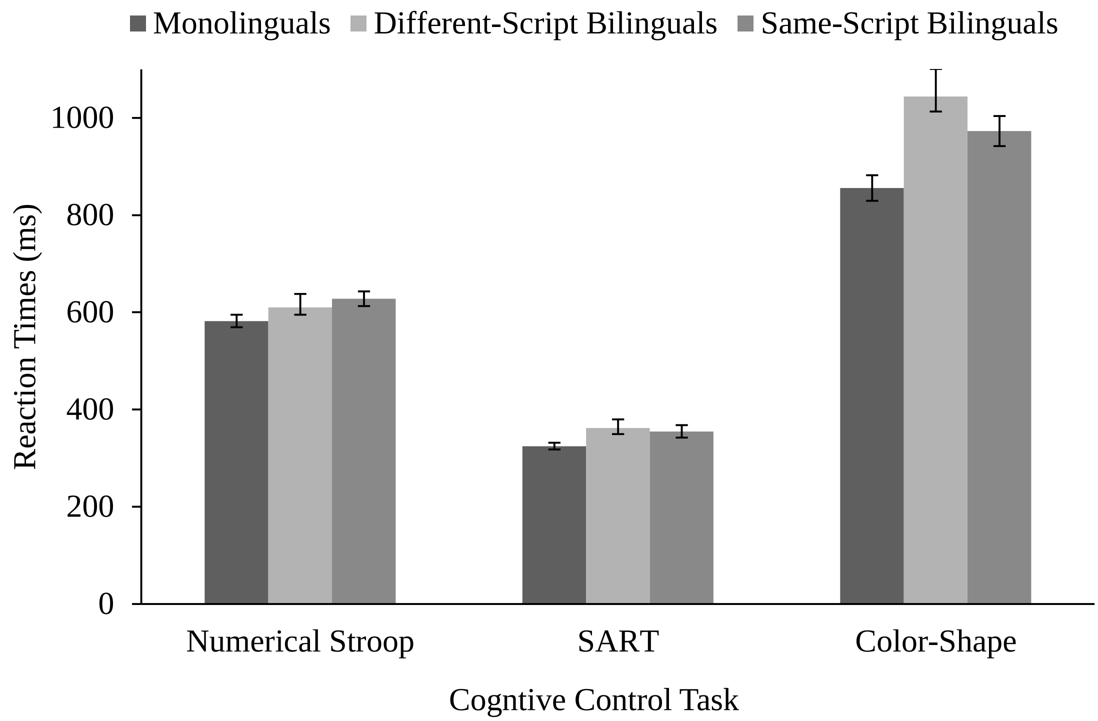

Figure 5. Mean reaction times in ms for same- and different-script bilinguals (BLs) and monolinguals (MLs) on the Numerical Stroop, SART, and Color-Shape tasks. Error bars denote standard error around the mean. MLs were faster than same-script BLs on the Numerical Stroop, $p < .05$ and on the SART, $p = .08$. MLs were faster than both same-script and different-script BLs on the Color-Shape task, *p*s < .01

Appendix A

Human Subjects Review Board Approval Letter

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	August 25, 2014
TO:	Leah Shulley
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[648701-1] The Relationship between Language Experience, Cognition, and Mind Wandering
REFERENCE #:	IRB 15-033
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	August 25, 2014
EXPIRATION DATE:	May 15, 2015
REVIEW TYPE:	Expedited Review

Thank you for your submission of New Project materials for this project. The Western Kentucky University (WKU) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a *signed* consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of May 15, 2015.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Paul Mooney at (270) 745-2129 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.

Appendix B

Language History Questionnaire

(Version 2.0, 2012)

Participant ID # _______

1. Age in years__________

2. Gender ______Male _______Female

3. Please select your race

_____White _____Black/African-American _____Hawaiian/Pacific Islander

_____Asian _____Native American/Alaskan _____Mult _____Other

4. Are you Hispanic
_____Yes

_____No

5. Please select the highest level of education that you have completed

_____High school (12)

_____Freshman

_____Sophomore

_____Junior

_____Senior (16)

_____Master's degree or equivalent

_____Professional degree (20)

6. Have you ever been diagnosed with a learning disability or language impairment?
   _____Yes

   _____No

7. Are you currently taking any medications that may affect things like learning, reading or attention?
   _____Yes

   _____No

8. Are you right- or left-handed?
   _____Right

   _____Left

9. After completing a quick vision test, the researcher will record the results below
   _____Snellen

   _____Rosenbaum

The following questions are about your experience and history with different language(s).

1. Do you speak more than one language?
   _____Yes

   _____No

2. Are you currently enrolled in a foreign language class?
   _____Yes

   _____No

3. Have you ever taken a foreign language class in high school?
   _____Yes

   _____No

   If you answered “Yes,” please indicate the number of semesters you *completed* in high school _________

4. Have you ever taken a foreign language class in college/university?
   _____Yes

   _____No

   If you answered “Yes,” please indicate the number of semesters you have *completed* in college/university_______

5. Have you ever taken a foreign language course outside of high school (e.g. Rosetta Stone)?
   _____Yes

   _____No

   If you answered “Yes,” please indicate the amount of time involved with that course in months _______

*If you answered “No” to questions 1-6, you may stop here. If you answered “Yes” to any of the above questions, please continue.

6. Please write in the box below the languages you know or are acquiring (or have attempted to acquire in the past). List the languages in order of proficiency (most proficient first).

Languages

7. a. Your country of origin (i.e., in which country were you born): ___________________

   b. Your country of current residence: ___________________

8. If 7(a) and 7(b) are the same, skip to question 9. If 7(a) and 7(b) are different, how long have you been in the country of your current residence? ______(years) _________months

9. If you have lived or travelled in other countries for more than three months, please indicate the name(s) of the countries, your length of stay, the language(s) you learned or tried to learn, and the frequency of your use of the language while in that country according to the following scale (circle the number in the table):

   1-Never

   2-Rarely

   3-Occassionally

   4-Sometimes

   5-Frequently

   6-Very Frequently

   7-Always

Country	Length of Stay (cumulative)	Language	Frequency of Use
			1 2 3 4 5 6 7
			1 2 3 4 5 6 7
			1 2 3 4 5 6 7

10. Rate your language learning abilities. In other words, how good in general do you feel you are at learning new languages (e.g., relative to friends or people you know)?

Very Poor	*Poor*	*Fair*	*Neutral*	*Good*	*Very Good*	*Excellent*
1_____	2_____	3_____	4_____	5_____	6_____	7_____

11. Please write in the box the age at which you first learned **each** language in terms of speaking, reading, and writing, and the number of years you have spent learning each language.

Language	Age first learned the language			Number of years spent learning (cumulative)
	Speaking	Reading	Writing	

12. Please write in the box the age at which you started to learn **each** language in any or all of the following situations (if only one situation is relevant for one language, provide age information for only that situation).

Language	At home	At school	After immigrating to the country where spoken	At informal settings (e.g., from nannies or friends	Through software (e.g., Rosetta Stone)	Other (specify): _______

13. Please rate your current ability on reading, writing, speaking, and listening for all languages you know, are currently acquiring, or have studied previously according to the following scale (circle the number in the table):

1-*Very Poor*

2-Poor

3-Fair

4-Neutral

5- Good

6- *Very Good*

7-Excellent

Language	Reading	Writing	Speaking	Listening
	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7
	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6 7

14. If you have taken a standardized language proficiency test in you non-native language (e.g., TOEFL), please indicate the name of the test, the language assessed, and the scores you received for each. (If you don't remember, write down a guess in the appropriate column. If you remember only a percentile of your score, write it in place of the score).

Test	Language	Actual Score	Guessed Score

15. Do you have a foreign accent in the languages you speak? Please rate how strong your accent is according to the following scale (circle the number in the table):

1-None

2-Little

3-Some

4-Intermediate

5-Strong

6-Very Strong

7-Extremely Strong

Language	Strength of Accent						
	1	2	3	4	5	6	7
	1	2	3	4	5	6	7
	1	2	3	4	5	6	7
	1	2	3	4	5	6	7

16. Estimate, in terms of hours per day, how often you are currently engaged in the following activities for each language you know (write the name of the language). If you are not currently engaged in an activity using that language, write down "0".

Activities	Language: ____________	Language: ____________	Language: ____________
Listen to Radio/ Watching TV:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for fun:	_______(hrs)	_______(hrs)	_________(hrs)
Reading for work/school:	_______(hrs)	_______(hrs)	_________(hrs)
Reading on the Internet:	_______(hrs)	_______(hrs)	_________(hrs)
Writing emails to friends:	_______(hrs)	_______(hrs)	_________(hrs)
Writing articles/papers:	_______(hrs)	_______(hrs)	_________(hrs)
Other (specify):_______	_______(hrs)	_______(hrs)	_________(hrs)

17. Estimate in terms of hours per day, how often you speak your languages currently with the following people.

Language	Family Members	Friends	Classmates	Co-workers

18. Do you mix words or sentences from two languages in your own speech (e.g., saying a sentence in one language but use a word or phrase from another language in the middle of the sentence)?

_____Yes

_____No

If you answered “No”, skip to question 19. If you answered “Yes”, list the two or more languages that you mix with different people, and estimate the frequency of mixing in normal conversation according to the following scale (circle the number in the table):

1-Never

2-Rarely

3-Occassionally

4-Sometimes

5-Frequently

6-Very Frequently

7-Always

Languages mixed	Relationship	Frequency of mixing						
	Family members	1	2	3	4	5	6	7
	Friends	1	2	3	4	5	6	7
	Classmates	1	2	3	4	5	6	7
	Co-workers	1	2	3	4	5	6	7

19. In which language (among your two best languages) do you feel you usually do better or feel more comfortable? Write the name of the language under each condition.

	At home	At work/school	At party or other social context
Speaking	____________	____________	________________
Writing	____________	____________	________________
Reading	____________	____________	________________

20. How often do you use your languages for the following activities? Circle the number in the table according to the scale below?

1-Never

2-Rarely

3-Occassionally

4-Sometimes

5-Frequently

6-Very Frequently

7-Always

Language	Arithmetic (e.g., count, add, multiply)	Remember numbers (e.g., student ID, telephone)	Dream	Think	Talk to yourself	Express anger or affection
	1234567	1234567	1234567	1234567	1234567	1234567
	1234567	1234567	1234567	1234567	1234567	1234567
	1234567	1234567	1234567	1234567	1234567	1234567
	1234567	1234567	1234567	1234567	1234567	1234567