TESTING THE BILINGUAL ADVANTAGE HYPOTHESIS: AN INDIVIDUAL DIFFERENCES STUDY ON RATES OF MIND WANDERING

by

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The bilingual advantage hypothesis proposes that the experience of processing multiple languages affords an individual with mental resources that can extend beyond the domain of language, namely in executive control. Although various studies have found evidence in support of the bilingual advantage hypothesis, it is not without controversy, as there are also studies that provide evidence against such an advantage. This study explored a novel way of testing the bilingual advantage hypothesis, utilizing rates of mind wandering during an anti-saccade task as a measure of executive control. Although bilingual participants reported lower rates of mind wandering than monolingual participants, no bilingual advantage was found in anti-saccade task performance or working memory capacity measures. Bilingual group anti-saccade task performance was not affected by increased rates of mind wandering, suggesting that some difference in the executive control system exists, but developments in objective measures of mind wandering are required to further examine this possible difference.

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Introduction

Bilingual Advantage Hypothesis

Human beings have developed the ability to think and communicate in various languages. Some individuals are fluent in more than one of the many languages that exist throughout the world. The consequences of juggling two language systems in one brain are of great interest to research, because they can provide insight into processes of the brain. A controversial field of research examining differences between monolinguals and bilinguals has produced various studies that point to possible advantages in linguistic and non-linguistic domains for bilinguals.

The nature of these proposed advantages arises primarily from a mechanism of dual language processing. In theory, when a bilingual individual wishes to produce a language both languages are simultaneously activated, causing cognitive conflict. So in order to produce only the target language, inhibitory control is exercised to resolve the cognitive conflict. This model of language processing is known as the Inhibitory Control (IC) model and describes the process of language production as an active inhibition of non-target language lemmas when a desired lemma is produced (Green, 1998). This model of inhibition of conflicting information is analogous to the experience of an individual performing a Stroop task during an incongruent trial. A Stroop task asks participants who are shown a color name written in either the same color that it represents (e.g., green written in green ink) or a different color (e.g., green written in blue ink) to report only the ink color as quickly as possible. So in other words, the effects of reading the word “green” in blue letters is hypothesized to be the same as a Spanish-English bilingual saying “abuela” instead of “grandmother”. In both the case of a Stroop task and bilingual language production, there are two active representations in the mind but only one is relevant, necessitating inhibition of the irrelevant representation to produce the correct one. There is evidence that for fluent bilinguals who use both languages frequently, both languages are active and available when only one is being used (for review see Bialystok, 2009). The inhibition of the translation equivalent of the target word or phrase in the non-target language is required for a bilingual brain to produce a target word; thus bilingualism serves as frequent practice of these inhibitory cognitive processes.

It has been proposed that because a bilingual brain frequently uses inhibitory control to properly inhibit conflicting lexical activation then the resulting effect on an individual would be enhanced cognitive abilities in more than just the domain of language. Evidence for the possibility of frequently repeated experience changing the human brain has been seen as increased visuo-spatial ability in architects compared to non-architects (Salthouse & Mitchell, 1990), enlarged regions of the hippocampus responsible for spatial navigation in taxi drivers (Maguire et al. 2000), and even increased cortical representation of left hand fingers in professional string instrument musicians (Elbert et al. 1995). Evidence from other aspects of cognition illustrates the effect of experience on cognitive performance, and supports the hypothesis that bilingualism can afford an individual with cognitive advantages.

The posited mechanism the bilingual brain employs to perform the active inhibition during language processing is known as executive control. The primary tasks of the executive control system are inhibition, shifting of mental sets (task switching or cognitive flexibility) and updating information in working memory (Miyake et al.

2000). Because bilinguals may be continuously exercising their executive control in the process of language production, it was theorized that their executive control system would be enhanced, making it more robust for other, non-linguistic functions (Bialystok, 2009). Studies performed to investigate this claim tested kindergarten students' executive function with a battery of conflict and delay tasks. Conflict tasks tested the children's ability to inhibit a proponent response in order to produce the correct one, while delay tasks tested their ability to delay an action such as ringing a bell for a snack or resisting the urge to peek inside a gift box. The results of the studies showed that bilingual children outperformed monolinguals on tasks that require conflict monitoring, conflict resolution and inhibition but not on delay tasks (Bialystok and Majumder, 1998; Meltzoff & Carlson 2008). It is important to note that these studies controlled for the effects of other possible individual differences, e.g., in age, verbal ability and socioeconomic status (SES) that may have accounted for the difference in performance findings, because it demonstrates that bilinguals outperformed their monolingual peers on precisely the tasks that presented conflict for competing options that needed to be resolved to produce a correct response (Bialystok, 2009).

Although the evidence for a bilingual advantage in the studies previously mentioned was derived from child participants, the proposed advantage is not limited to only this age group. In some studies examining the bilingual advantage hypothesis, adult participants performed the Simon task (reviewed in Lu and Proctor, 1995), a task consisting of congruent trials where the response is in a relatively similar location as the stimulus and incongruent trials where the response is not located near the stimulus. Incongruent trials of the Simon task require inhibition of the irrelevant representation in order to produce low reaction times, a process which mimics the inhibition posited by the IC model of language processing. Bilinguals demonstrated faster reaction times and a higher ability to correctly perform the incongruent trials of a Simon task than monolinguals. Furthermore, evidence for a bilingual advantage in the Simon task has been found across age groups in children, young adults and older adults (for review see Bialystok, 2009). As previously discussed, it is argued that the conflict that arises in bilingual language processing is best demonstrated by the Stroop task (Green, 1998). Utilizing the most common example of a Stroop task, naming the ink color of a color word in black in for control trials and either congruent or incongruent ink colors for experimental trials, Bialystok and colleagues (2008) found that bilinguals demonstrated a smaller cost in naming the ink color for incongruent trials than did their monolingual peers.

While the results from the previously mentioned study hint at a bilingual advantage in executive control, there have been studies that report no significant advantage in measures of executive control (for review see Hilechy, 2011). Research within the field of the bilingual advantage hypothesis remains controversial, as results are conflicting and remain inconclusive. Unlike the studies performed by Bialystok & Majumder (1998) and Meltzoff & Carlson (2008), some earlier studies testing the bilingual advantage hypothesis did not control for SES, a powerful confound for measures of cognitive performance (for review see Morton & Harper, 2007). Failure to control for SES in a study could have significant effects on the results and potentially mask individual differences in cognitive performance. Adding to the controversy, a study analyzing conference abstracts of studies on executive control advantages in bilinguals found that there was a publication bias for studies that presented evidence for a bilingual advantage over those that found no difference (de Bruin et al., 2014). This study will use reported rates of mind wandering while performing a laboratory task to test the bilingual advantage hypothesis in a novel way, whilst controlling for confounds (e.g., SES) to contribute evidence to the continually growing field of research surrounding it.

Mind Wandering

The experience of having thoughts that are unrelated to the current environment or experience is one common to all humans. Until recently the research concerning these types of distracting thoughts was scarce and definitions for this phenomenon were varied. Smallwood and Schooler (2006) defined the phenomenon of mind wandering as “a shift of attention away from a primary task toward internal information” (p.946) in an effort to unify the existing body of research. To fully grasp the significance of mind wandering in the context of this study it is necessary understand what mind wandering is in the context of the human mind, the theoretical models posited to describe the experience, and the measurable effects this experience has on a person.

In the laboratory, mind wandering has been defined as the experience of having task-unrelated thoughts while performing a task that requires that the participant hold some degree of sustained attention. In the context of daily life mind wandering can be understood as internal rumination or memory recollection. Experiences of mind wandering can be commonly referred to as “zoning out” or “daydreaming”. Thought sampling methods have been utilized in studies to capture the experience of mind wandering, either by self-report in the form of diary entries (Unsworth, 2012) and multiple daily prompted questionnaires (Kane et al., 2007), or as thought probes during laboratory tasks (McVay, Kane, & Kwapil, 2009). As a result of these thought samples it was consistently found that participants experience mind wandering in the laboratory and in daily life an average of 30% of the time (Kane et al., 2007; McVay, Kane, & Kwapil, 2009). One important example of real life mind wandering was that of undergraduate students while in educational contexts. One sample of students experienced lapses in attention due to mind wandering in class or while studying 76% of the time (Unsworth, 2012). As revealing as these findings are on the frequency of mind wandering, the methodology used does not allow for much specificity in determining the causes of the phenomenon.

Stawarczyk et al. (2011) performed a study utilizing a novel method of thought probes that discriminated between the possible distractions experienced by a participant during the experiment based on two dimensions: ‘stimulus-dependency’ and ‘task-relatedness’ (Stawarczyk et al., 2011). Based on these criteria, mind wandering is both stimulus-independent (i.e., not ambient noise) and task-unrelated (i.e., not related to the task at hand), a marked difference from task-related interference or external distractions. Stawarczyk and colleagues (2011) argue that the importance of differentiating between external distractions such as hunger, internal task-related thoughts such as when the experiment will be over, and mind wandering is that these experiences may have varied effects on the attention of the participant. They found that participants reported mind wandering 21.6%, task-related interference 30.34% and external distractions 20.78% of the time, suggesting that mind wandering occurs at a rate fairly similar to that of other distractions (Stawarczyk et al., 2011). These studies suggest that mind wandering is pervasive, and that it occurrence is independent of the surroundings (i.e., stimulus-independent), which raises the question: how exactly is it that the mind wanders?

To answer the question of how the mind wanders, two competing models have been proposed. Smallwood and Schooler (2006) argue that a shift of the executive component of attention towards internal goals/thoughts results in a superficial representation of the external environment (Smallwood & Schooler, 2006). In the case of a laboratory setting, the external environment is the task at hand, so changing the focus of attention from the task to internal thoughts would result in reduced perception of the stimulus required to correctly perform the task. This implies that mind wandering requires executive control resources to initiate and maintain it as the locus of attention. Following this logic, and given that executive control resources are limited, a participant who is mind wandering is trading off executive resources from the task at hand to mind wandering in a competition for these resources.

Evidence from a number of studies has demonstrated that mind wandering varies as a function of task difficulty, with rates decreasing as stimulus presentation, memory load, and cognitive resource requirements increase, whereas mind wandering rates increase as these measures of task difficulty decrease (McVay & Kane, 2010). Smallwood and Schooler (2006) interpret these data as evidence for their model of mind wandering as a drain on executive control resources (Smallwood & Schooler, 2006). That is, tasks that require a high degree of cognitive resources will not allow for mind wandering to occur, as the task will be the primary focus of these resources. In tasks that are low on cognitive resource demand, or practiced and thus more automated tasks, more resources are available for mind wandering, so this theoretical model predicts that its rate should increase. Furthermore, this model of mind wandering would predict that individuals with more cognitive resources, measured in the laboratory as working memory capacity, would mind wander more as they possess the excess resources to do so. Although Smallwood and Schooler's prediction on mind wandering rates increasing as a function of cognitive resource measures seems logical, this prediction goes against empirical evidence that has shown significantly higher rates of mind wandering in low-resource individuals than high-resource individuals when performing challenging tasks (McVay and Kane, 2012).

The opposing model to that proposed by Smallwood and Schooler, proposed by McVay and Kane (2010), is known as the executive failures model. This model argues that mind wandering does not consume executive resources; instead its occurrence is controlled or prevented by the executive control system. In line with this view, mind wandering is prevented when control is exerted either proactively, by actively maintaining task goals in mind, or by reactively initiating inhibition of task-unrelated thoughts as they arise (McVay and Kane, 2010). The evidence that mind wandering is negatively correlated with task demand, in terms of executive control resources, can now be interpreted as indication that more demanding tasks employ greater executive control to suppress mind wandering in order to correctly perform the task. Following this logic, mind wandering is then a failure of the executive control system to suppress the task-unrelated thoughts, thus leading to poorer performance on the task.

The executive failures model also better explains evidence of a relationship between individual differences in working memory capacity (WMC) and rates of mind wandering that Smallwood and Schooler's model does not. Studies show that people with high measures of WMC across various tasks (Engle & Kane, 2004) report less frequent mind wandering than do low WMC individuals during tasks that are attention demanding, both in and out of the laboratory (Kane et al., 2007; McVay & Kane, 2009;2011). Furthermore, Smallwood and Schooler's model would predict that high WMC individuals' performance on tasks would be less affected than that of low WMC, as they would have sufficient resources to allocate to simultaneous task performance and off-task thoughts. After reexamining data from a study on mind wandering and task performance (McVay and Kane, 2009) it was found that participants were less accurate on trials where they reported mind wandering, irrespective of WMC measures (McVay and Kane, 2010). These findings can be interpreted as evidence for the executive failures model of mind wandering, since the experience of mind wandering has shown to have negative effects on task performance in both high and low WMC participants even though Smallwood and Schooler's model predicts better task performance in high WMC participants experiencing mind wandering. Furthermore, because an experience of mind wandering can be modeled as a failure to exert executive control in order to prevent its occurrence, we can then predict that individuals who possess greater levels of executive control would be better at inhibiting these thoughts and thus mind wander less frequently.

These two opposing models make distinct predictions on the relationship between WMC and mind wandering rates, but recent research has shed new light on the dynamic nature of these predictions. New evidence from studies conducted within the last five years has suggested that the role of executive control on the occurrence of mind wandering varies depending on the context. Some studies have shown a positive correlation between WMC and mind wandering (Levinson et al. 2012; Rummel & Boywitt, 2014), providing evidence that contradicts the prediction of the executive failures model (McVay & Kane, 2010). Because existing pattern of data does not seem to fit neatly with either model, a compromise was proposed. The Context Regulation Hypothesis (Smallwood & Schooler, 2015) argues that according to existing data, the role of executive control in mind wandering changes depending on the relative demands of the external task. In tasks with low attention demands the executive resources model (Smallwood & Schooler, 2006) best describes the function of executive control, whereas in tasks with high relative attention demands the executive failures model (McVay & Kane, 2010) provides the most accurate predictions.

Given that mind wandering can be conceptualized as a failure of executive control in the context of relatively high attention demanding tasks, insight as to the effects of this experience on laboratory task performance and real life scenarios can provide a better understanding of the significance mind wandering has on the human experience. In studies measuring performance on laboratory tasks, mind wandering predicts lower accuracy as well as slower and more variable reaction times when responding to stimuli (Stawarczyk et al. 2011). These findings have led to the use of reaction times as an operational measurement of mind wandering. These slower reaction times, which would indicate an instance of mind wandering during the task, have been found to correlate with executive control measures of WMC, response inhibition and retrieval fluency because the highest rate of slow reaction times were found among individuals with low executive control abilities (Unsworth et al., 2010). In addition, Mrazek and colleagues (2012) have found that mind wandering negatively correlates with measures of WMC and scholastic aptitude. In this same study, data showed that participants reported mind wandering more often on trials with incorrect responses as compared to trials with the correct response, leading to the conclusion that mind wandering negatively affects performance (Mrazek et al. 2012). In a study that used the same method of thought probing developed by Stawarczyk and colleagues (2011), young adults reported task-unrelated thoughts 45% of the time, which also predicted poorer performance as measured by accuracy and reaction time (McVay, Meier & Kane, 2013).

Because there appears to be a relationship between WMC and mind wandering, performance on laboratory tests can predict rates of mind wandering during daily activities, as individuals with high measures of WMC report less mind wandering and being more on task regardless of concentration demands or effort required. The inverse (higher rates of mind wandering and reports of being less on task) is true for lower WMC individuals (Kane et al., 2007). Outside of the laboratory mind wandering plays a significant role, especially in the lives of students. Working memory and attentional control are predictors of mind wandering rates as well as external distractions that are frequent in the lives of students. For example, low WMC individuals report higher rates of mind wandering than high WMC individuals during challenging daily life tasks that require a higher level of concentration and effort (Kane et al, 2007). Tasks in an educational context are relatively challenging, so it can be argued that individual differences in WMC would affect a student's performance on such tasks. In addition to this high rate of occurrence, they also found that mind wandering is negatively correlated with intelligence as measured by a test of general aptitude (the SAT), so those who mind wander more tend to score lower (Unsworth et al., 2012). Furthermore, mind wandering has been found to affect reading comprehension as individuals who mind wander more while reading show higher rates of impaired comprehension (McVay and Kane, 2012). Because mind wandering has been shown to be a common experience that has deleterious effects on measures of cognitive processes and intelligence, particularly in educational contexts, it is of great importance to explore possible means of reducing the occurrence of this phenomenon of the mind.

Executive Control in Mind Wandering

If individual differences were what account for the variability of mind wandering rates, then it would be of great benefit to discover possible differences that minimize episodes of mind wandering. To do so, it is necessary to hone in on what cognitive processes are responsible for the occurrence of mind wandering. As was previously discussed, the executive failures model of mind wandering (McVay and Kane, 2010) can explain the relationship between mind wandering and working memory capacity. Because WMC measures have shown to correlate with rates of mind wandering, then perhaps the individual differences in WMC can account for this variability. Engle and Kane's (2004) two-factor theory of executive control posits that individual differences in working memory capacity are not differences in memory storage, but rather that they arise from differences in executive control. In this theory, the role of executive control in working memory is to "maintain goal-relevant information in a highly active, accessible state under conditions of interference or competition" (Kane & Engle, 2004). Evidence for this theory comes from studies that demonstrated that, compared to high WMC participants, individuals with low measures of WMC demonstrated impaired performance in tasks with distractors that generated interference, but showed no drop in performance when these distractors were absent (Conway & Engle, 1994; Rosen & Engle, 1998; Kane & Engle, 2000, as cited in Kane & Engle, 2004). Kane and Engle (2004) portray working memory as “a system consisting of domain-specific memory stores with associated rehearsal procedures and domain-general executive attention” (p.23) and the data provides evidence that individual differences in WMC are mostly explained by attentional control abilities.

Providing more evidence that executive control is a key component of the individual differences in WMC, high capacity individuals have demonstrated better performance than low capacity individuals on tasks that measure attentional control and not working memory capacity. An example of this type of task is the anti-saccade task, where on pro-saccade trials participants respond as quickly as possible to a stimulus presented in the location indicated by a cue (e.g., an arrow) whereas on anti-saccade trials the location of the stimulus is contrary to what the cue indicates. The nature of this task requires participants to exert attention control on anti-saccade trials to inhibit the interfering signal of the cue and instead saccade towards the target stimulus. Performance on pro-saccade trials was similar for high and low capacity individuals, but high capacity individuals had significantly better accuracy and faster response times in anti-saccade trials, leading to the conclusion that high WMC individuals have increased efficiency in attentional control (Kane et al., 2001).

In light of evidence that individual differences in working memory capacity are primarily differences in attention control, Kane and Engle (2004) argue that the two factors of executive control are keeping task relevant goals in mind for proper task performance while simultaneously resolving conflict by inhibition (i.e., inhibiting prepotent pro-saccade response in an anti-saccade trial). Utilizing the logic behind Kane and Engle's (2004) theory of executive control and McVay and Kane's (2010) model of mind wandering as a failure of executive control, it can be argued that bilinguals, who are theorized to possess a more efficient system of executive control (Bialystok, 2009), would experience the phenomenon of mind wandering less frequently than their monolingual peers. This study will test this hypothesis by examining whether bilinguals exhibit an advantage in executive control in the form of reduced rates of mind wandering.

The Present Study

To test our hypotheses it is necessary to measure participants' visual working memory capacity, executive control, and rates of mind wandering. Visual working memory capacity was measured by administering a visual change detection task (Luck & Vogel, 1997). Participants performed an anti-saccade task to measure their attention control, as this task has shown to be a good measure of executive control that correlates well with WMC (Kane et al., 2001; Unsworth, Shrock & Engle, 2004; Unsworth et al. 2012). To measure rates of mind wandering, thought sampling (for review of mind wandering assessment methods see Smallwood & Schooler, 2006) during the anti-saccade task will probe participants after a block of ten randomly chosen trials to describe their thoughts in the previous trial as on-task, task-related interference, task-unrelated thoughts, or other. We will use all of these measures to compare bilinguals to monolinguals in their working memory capacity measures, attention control, and rates of mind wandering. Previous studies testing facets of the bilingual advantage hypothesis have failed to control for SES in their statistical analyses. Previous research has provided evidence that low SES has a negative impact on cognitive skills (Hackman et al., 2010; Stevens & Neville, 2009), so in order to appropriately compare the behavioral measures of the monolingual and bilingual participant groups we must control for the potential effects of SES on the dependent measures.

We predict that because of the practice of inhibition by the executive control system in bilingual language processing (Green, 1998) bilinguals will show an advantage in executive control over monolinguals in the form lower reported rates of mind wandering, as well as greater accuracy in the anti-saccade task. Furthermore, because performance on the anti-saccade task is a measure of executive control, we predict that rates of mind wandering will negatively correlate with anti-saccade task accuracy. We also predict that participant WMC will positively correlate with their anti-saccade task accuracy and negatively correlate with mind wandering rate. If a significant bilingual advantage in suppression of mind wandering is found, then an argument can be made in favor of promoting bilingual education in youth, especially for the benefits in attentional control pertinent to students.

Method

Participants

A total of 95 participants were recruited from the University of Oregon and the surrounding community to participate in the study in exchange for monetary compensation. Participants were recruited as part of a larger study that included an ERP task in addition to a series of behavioral assessments. As present study focuses on the behavioral assessments, ERP results will not be discussed. All participants were right-handed individuals with normal or corrected-to-normal vision without any reported history of brain injury, disorder, or concurrent use of drugs that affect cognitive function. All participants had completed at least some level of a college education at the time of testing.

Of all participants, 48 were monolingual English speakers ranging in age from 18 to 32 (*M* age = 22 years, *SD* = 2.82) and 46 were bilingual Spanish/English speakers ranging in age from 18 to 35 (*M* = 20 years, *SD* = 0.71; see Table 2). All of the bilingual participants reported acquiring both languages before the age of 9 and equally frequent use of each language throughout their lifetime. In order to objectively measure their bilingualism, participants completed language proficiency measures to assess their proficiency in each language and to determine their language dominance, which are described below. All bilingual participants had Spanish proficiency scores within two standard deviations of the mean (*M* = 89.9, *SD* = 13.4) and English proficiency scores within three standard deviations of the mean (*M* = 101, *SD* = 9.39). Bilingual participants' Spanish proficiency scores ranged from 63.3 – 111.7 and English proficiency scores ranged from 68 – 120.6.

Procedure

After giving written informed consent, participants underwent a color blindness screening. They were then asked to complete a brief demographic questionnaire to confirm eligibility to participate in the study. Before beginning the tasks, participants were fitted with an elastic EEG cap for the ERP task, which was completed first inside an electrically shielded booth. After completion of the ERP paradigm, they completed two behavioral tasks in the following order: first a change detection task to measure visual working memory capacity (Luck & Vogel, 1997) and second, an anti-saccade task to measure attentional control (Kane, Engle & colleagues, 2001). During the anti-saccade task, mind wandering rates were measured using the thought probing technique (Smallwood & Schooler 2006;2015) by asking participants to report the content of their thoughts during randomly selected trials. After completing the behavioral tasks in the booth, participants entered a testing room where language proficiency tests were administered, in both Spanish and English for bilinguals and only in English for monolinguals. Finally, participants completed a questionnaire to gather information about their basic demographics and the SES of the family in which they were raised. Bilingual participants completed an additional questionnaire to assess their language acquisition history and language usage.

Measures

Language Proficiency Measures. Language proficiency was measured using the Woodcock-Muñoz Language Survey (Riverside Publishing, 2005 – Revised Normative

Update, 2010) and the Speaking Grammar subtest from the Test of Adolescent and Adult Language – 3(TOAL-3, Hammil, Brown, Larsen & Wiederhold, 1994). There is no Spanish version of the Speaking Grammar subtest, so a Spanish-English bilingual graduate student translated the items in English while preserving the grammatical structure of each item. A composite score was calculated by averaging the scores from the three measures.

Working Memory Capacity. A visual change detection task (illustrated in Figure 1a) that has been shown to be a valid measure of working memory capacity was administered (Luck & Vogel, 1997). Participants sat in front of a computer screen and were flashed sets of 2, 4 and 8 colored-squares in a randomly distributed array on a grey background for 150ms. After a delay period of 1000ms, they were presented a test array in which a single colored-square reappeared in the same location where it had first flashed, and were asked to indicate if the test square had changed colors from the original presentation or not by way of pressing a button. The task consisted of 240 trials, with 80 trials per set size (2, 4, and 8) that were presented at random. The target square changed colors in half of the trials. Working memory capacity (k) was calculated by multiplying the difference between correct rate and incorrect rate by set size, *k = set size x (hit rate – false alarm rate)* (Cowan, 2001).

Anti-Saccade Task. An anti-saccade task (illustrated in Figure 1b) that has been shown to be a valid measure of attentional control (Kane, Engle et al., 2001; Unsworth et al., 2012) was administered. In this task, participants were instructed to stare at a fixation point on a screen where a cue ("=") was flashed once either to the right or left of the fixation point for 100ms. After this initial cue, the target stimulus (the letter B, P or R) appeared on the opposite side of the screen for 100ms, was then masked by an H for 50ms, and finally replaced by an 8 until a response was given. The flashing cue indicated that the target stimulus would appear on the opposite side of the screen, so in order to perceive the target stimulus, participants must disengage their attention from the initial cue and saccade to the opposite side of the screen. The participant's task was to identify the target letter by pressing the corresponding key as quickly and accurately as possible. The task began with 10 practice trials in which the cue and target both flashed in the center, 15 practice pro-saccade trials in which both the cue and target flashed on the same side of the display, and 20 practice anti-saccade trials in which the cue and target flashed on opposite sides of the display. The real trials consisted of 60 anti-saccade trials. The proportion of correct trials out of the 60 is the dependent measure.

Mind Wandering Measure. During the anti-saccade task trials, participants were probed on their current conscious experience using the thought probe technique (illustrated in Figure 2), which is a commonly used way to assess mind wandering in the laboratory (Smallwood & Schooler 2006; 2015). Immediately after 10 randomly selected trials participants reported their current content of their thoughts under one of four categories: on-task (OT), task-related interference (TRI), task-unrelated thoughts (TUT), or other (Stawarczyk, 2011). Proportions of each response were calculated, and because in the literature mind wandering is commonly defined as task-unrelated stimulus-independent thoughts, TUT proportion was used as a measure of mind wandering rate. TRI proportions were utilized as a dependent variable to contrast any possible difference in mind wandering rate with this other category of distracting thoughts. Additionally, OT proportions were also used as a dependent variable.

Socioeconomic Status. Participants' childhood socioeconomic status was measured using the Hollingshead Four-Factor Index of Socioeconomic Status (Hollingshead, 1975). This survey measures the childhood socioeconomic status of an individual based on parental educational attainment, and occupational prestige. The education level is rated on a 7-point scale that ranges from graduate/professional training as the highest score to less than 7th grade as the lowest score. The occupational level is rated on a 9-point scale for which the Hollingshead manuscript provides a detailed list of occupations and their point value. A socioeconomic score is then calculated based on these scores. Bilingual participants reported a significantly lower average SES measure (M = 36.8, SD = 17.4) than monolinguals (M = 47.1, SD = 11.4), $t(92)= 3.415$, $p < 0.01$. To control for SES in between-group analyses an our analyses an analysis of covariance (ANCOVA) was conducted, using SES score as the covariate.

Design

This study tested two primary sets of hypotheses: 1) that bilingual experience will positively affect behavioral task performance and rates of mind wandering and 2) that behavioral task measures will positively correlate with off task thoughts. To test the first set of hypotheses on the effects of bilingual experience, we conducted ANCOVAs, with SES as the covariate, on the measures of WMC, anti-saccade task performance, as well as reported on and off task thought proportions. We predicted that the bilingual group would have better performance, respective to the monolingual group, on all measures.

To test our set of hypotheses on the correlations of behavioral measures we conducted multiple bivariate correlational analyses on the following pairs of measures: WMC with anti-saccade task accuracy, WMC with TUT proportion, TUT proportion with anti-saccade task accuracy, TRI proportion with anti-saccade task accuracy, and OT proportion with anti-saccade task accuracy. All correlational analyses were done separately for the monolingual and bilingual groups to test for possible group differences on the correlations.

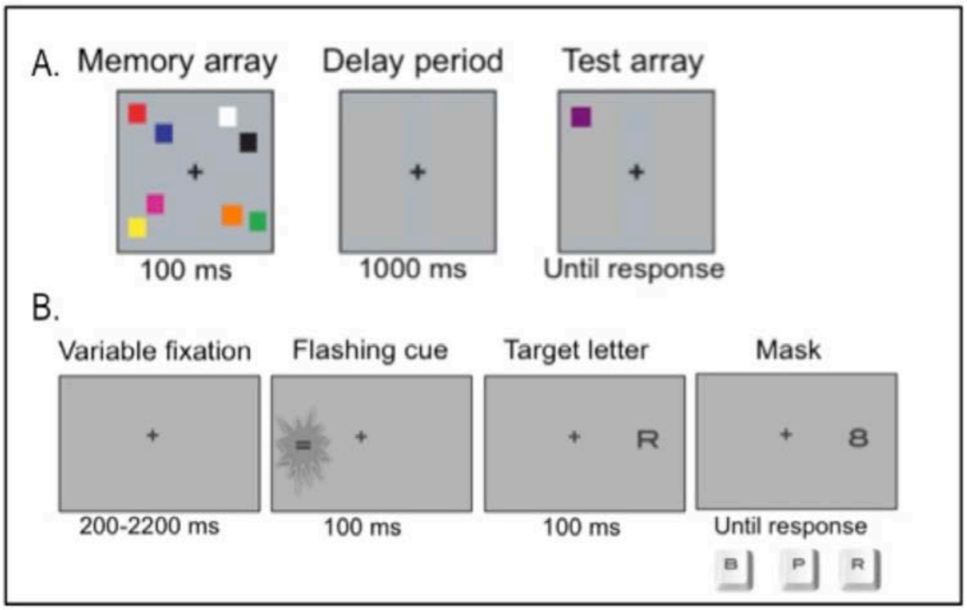

Figure 1: Illustration of A) WMC Change Detection Task and B) Anti-Saccade task.

Please characterize your current conscious experience:

1.I am totally focused on the current task

2. I am thinking about my performance on the task or how long it is taking

3. I am zoning out/my mind is wandering

4. Other

Figure 2: Illustration of Thought Probe

Results

To examine our central research question, we tested for a group difference in rates of mind wandering, operationalized as self-reports of on and off task thought during the anti-saccade task. Reported TUT proportion was the measure of mind wandering rate, so we predicted that the bilingual group would report lower TUT proportions than the monolingual group. Our test revealed a significant group difference on TUT proportion when controlling for SES, $F(1, 92) = 5.82$, $p = .018$, $\eta_p^2 = .059$, with bilinguals reporting a significantly lower TUT proportion ($M = 0.064$, $SD = 0.096$) than monolinguals ($M = 0.13$, $SD = 0.16$). Reported TRI proportion was a separate measure of off-task thought different from mind wandering, because although they are both stimulus-independent thoughts, mind wandering thoughts are task-unrelated. With this in mind, we predicted no group difference in TRI proportion. Our test revealed no significant group effect on TRI proportion when controlling for SES, $F(1, 92) = .82$, $p = .367$, $\eta_p^2 = .009$. Given that there was a significant group difference in TUT proportion we also tested for a group difference in reports of on-task thought (OT), predicting that the bilingual group would report higher OT proportions due to lower TUT proportions. Our test revealed no significant group effect on OT thought proportion, $F(1,92) = 1.17$, $p = .28$, $\eta_p^2 = .013$.

We then examined whether there was a group difference in WMC, because the two-factor theory of executive control (Engle & Kane, 2001) predicts that individual differences in WMC are actually individual differences in executive control. Following this logic, we hypothesized the bilingual group would have significantly higher K scores on the visual change detection task, compared to the monolingual group. This hypothesis was not supported, as no significant group difference was revealed on K score when controlling for SES, $F(1,92) = .012$, $p = .915$. We then tested if there was a group difference in anti-saccade task performance. We predicted the bilingual group would have significantly higher accuracy on the task relative to the monolingual group. However, our test revealed no significant group effect on anti-saccade task accuracy when controlling for SES, $F(1,92) = 2.45$, $p = .12$, $\eta_p^2 = .026$. Additionally, we tested whether the relationship between WMC (K) and anti-saccade task accuracy differed by group. Based on previous findings (Kane et al. 2001) we did not predict any group difference in the correlation of these variables, predicting it to be significant and positive for both groups. A bivariate correlational analysis revealed that for the bilingual group, WMC (K) correlated significantly with anti-saccade task accuracy, $r(47) = .40$, $p = .005$, $r^2 = .16$, and did not in the monolingual group, $r(4) = .12$, $p = .41$. As bilingual participants' WMC increased, so did their performance on the anti-saccade task, but for monolingual participants there was no relationship between these variables (see Figures 3a and 3b).

We also tested for group differences in the relationships between rates of mind wandering and task performance. First we examined the relationship between TUT proportion and WMC by group. Although thought probes were not applied during the visual change detection task, because previous findings have suggested a relationship between WMC and TUT rates (McVay & Kane, 2010; McVay & Kane, 2012), we expected a negative correlation for both groups. Our analysis revealed a marginally significant correlation between WMC (K) and TUT proportion for the bilingual group, $r(47) = .28$, $p = .06$, $r^2 = .023$, but no relationship for the monolingual group $r(48) =$ -

.15, *p* = .32. Next we examined the relationship between TUT proportion and anti-saccade task performance by group. We predicted a negative correlation between these variables for both groups. Our analysis revealed that TUT proportion significantly correlated with anti-saccade task accuracy in the monolingual group, *r*(48) = -.34, *p* = .019, r^2 = .11, but did not in the bilingual group, *r*(47) = .12, *p* = .44. As monolingual participants TUT proportion increased, accuracy on the anti-saccade task decreased (Figure 4b), but for bilingual participants there was no relationship between these two variables (Figure 4a).

Additionally, we examined the relationships between TRI proportion and anti-saccade task performance by group. Because TRI thoughts are considered to be different from mind wandering (Stawarczyk et al., 2011;Unsworth and McMillan 2014) and thus not conceptualized as a failure of executive control (McVay & Kane, 2010), we predicted that there would be no correlation between the two variables. Our analysis revealed that TRI proportion did not significantly correlate with anti-saccade task accuracy for either the monolingual group, *r*(48) = -.11. *p* = .46, or the bilingual group, *r*(47) = -.02, *p* = .89. Finally, we examined the relationships between OT proportion and anti-saccade task performance by group. We expected that OT proportions would positively correlate with anti-saccade task accuracy, as OT thoughts are representative of attention being focused on the task, with no group difference in the relationship between these variables. Our analysis revealed a significant correlation between OT proportion and anti-saccade task accuracy for the monolingual group, *r*(48) = .307, *p* = .034, r^2 = .094, but no relationship for the bilingual group, *r*(47) = .004, *p* = .97. As monolingual participants' OT proportion increased, accuracy on the anti-saccade task increased (Figure 5b), but for bilingual participants there was no relationship between the two variables (Figure 5a).

Table 1: Descriptive Statistics by Group

	Monolinguals (N = 48)	Bilinguals (N = 47)
Age (years)	21.3 (2.84)	22.3 (3.78)
Gender (females)	.55	.63
Hollingshead SES Score	47.1 (11.4)	36.9** (17.3)
WMC (K)	2.29 (.65)	2.33 (.56)
Anti-Saccade Accuracy	.41 (.12)	.44 (.12)
On Task Proportion	.42 (.33)	.51 (.32)
TUT Proportion	.13 (.16)	.063** (.095)
TRI Proportion	.37 (.25)	.33 (.28)
Other Proportion	.063 (.13)	.094 (.20)

Note. Gender values are proportion of female participants per group. ** $p < .05$

Table 2: Correlations of Behavioral Measures

	Correlation	
Behavioral Measures Pair	*Monolingual* (N = 48)	*Bilingual* (N = 47)
1. WMC – Anti-Saccade Accuracy	.12	.40**
2. WMC – TUT	-.15	.28
3. TUT – Anti-Saccade Accuracy	-.34**	.12
4. TRI – Anti-Saccade Accuracy	-.11	-.02
5. OT – Anti-Saccade Accuracy	.307**	.004

Note. **p < .05

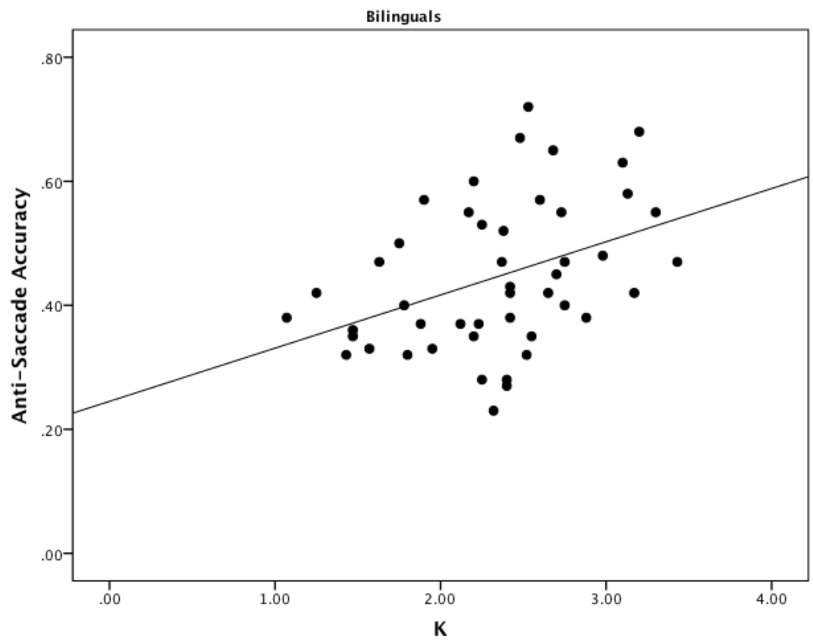

Figure 3a: Scatterplot of bilingual group anti-saccade accuracy versus K score.

R^2 = .16

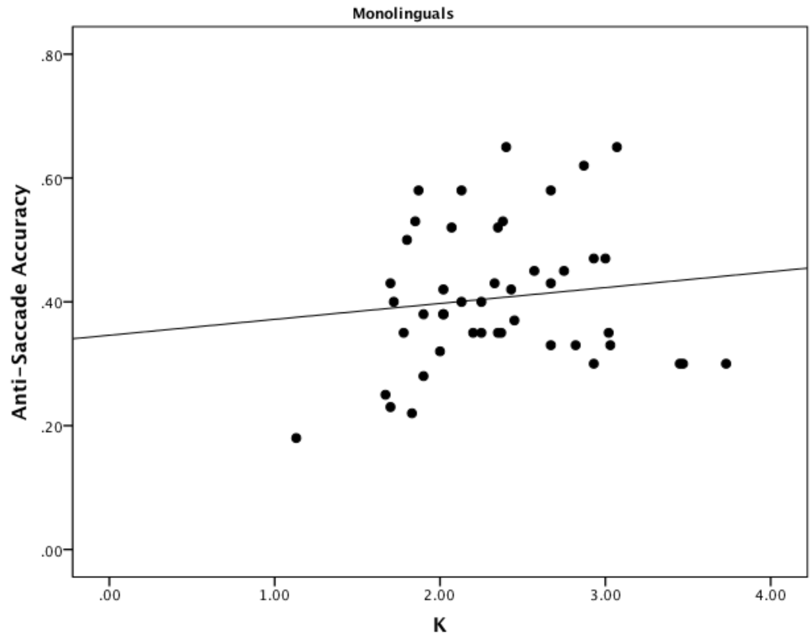

Figure 3b: Scatterplot of monolingual group anti-saccade accuracy versus K score.

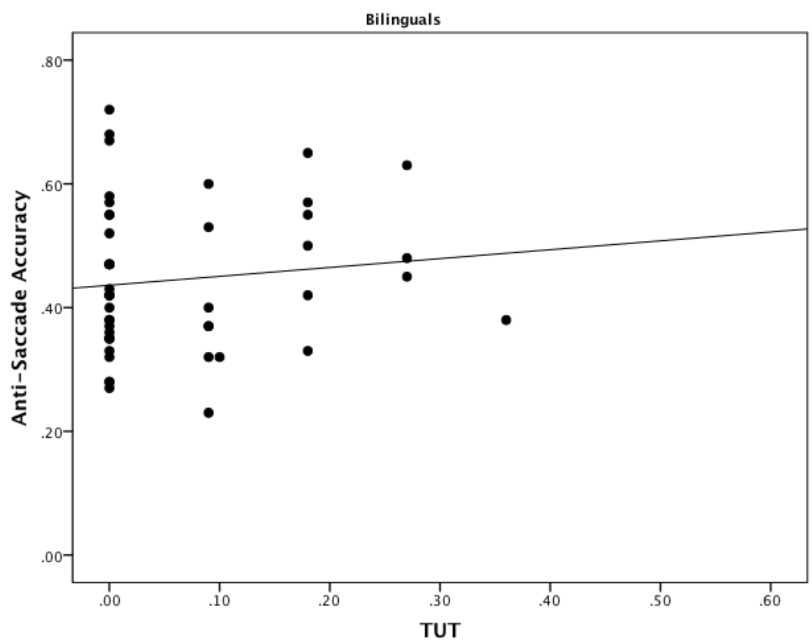

Figure 4a: Scatterplot of bilingual group anti-saccade accuracy versus TUT proportion.

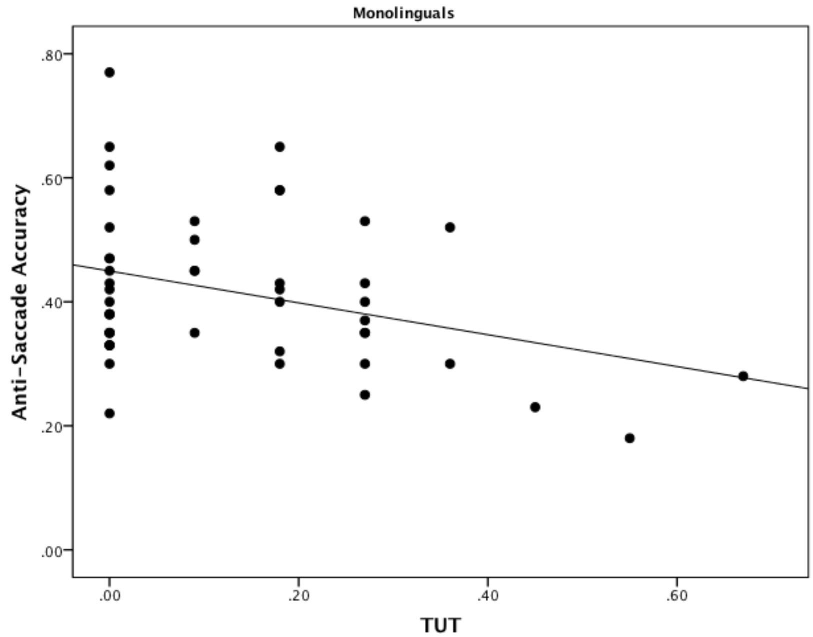

Figure 4b: Scatterplot of monolingual group anti-saccade accuracy versus TUT proportion.

R^2 = .11

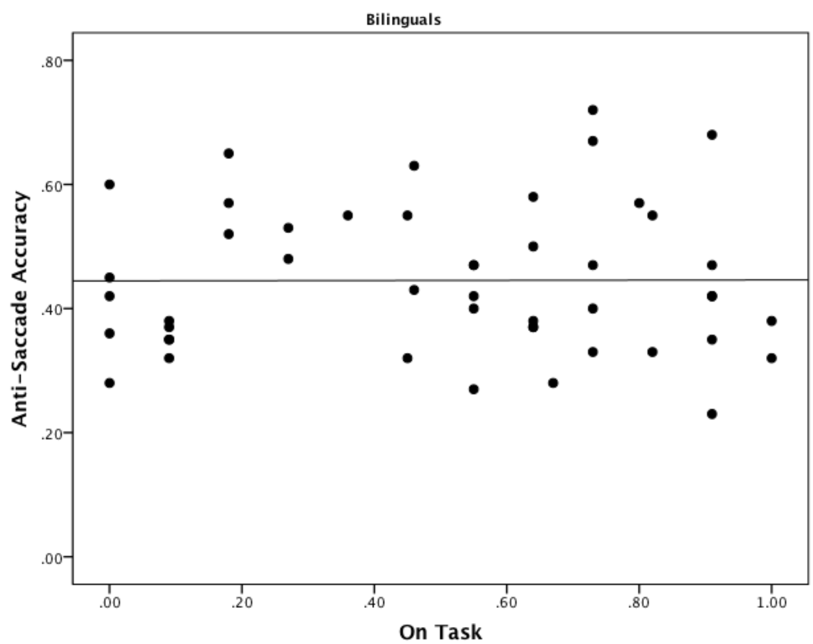

Figure 5a: Scatterplot of bilingual group anti-saccade accuracy versus OT proportion.

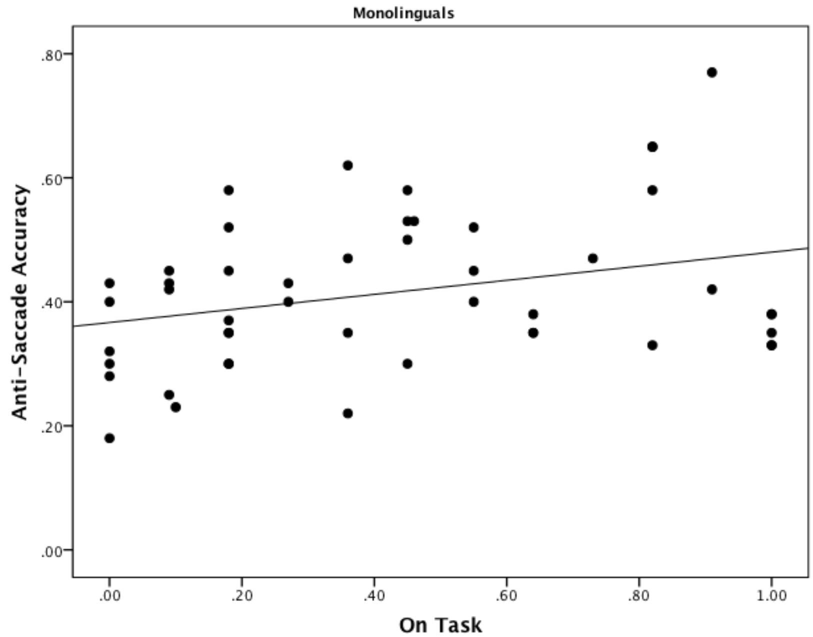

Figure 5b: Scatterplot of monolingual group anti-saccade accuracy versus OT proportion.

Discussion

According to the logic of the Inhibitory Control Model of bilingual language processing (Green, 1998), bilingual individuals posses an advantage in executive control from their continuous management of two languages. This model predicts that bilingual individuals will outperform their monolingual peers in laboratory tasks that measure executive control. However, previous research testing this hypothesis has yielded inconsistent results. Our study's aim was to test the bilingual advantage hypothesis in a novel way, utilizing rates of mind wandering as a measure of participants' executive control. An additional novel aspect of our study was that we also examined potential between-group differences in executive control and working memory capacity between the monolingual and bilingual participant groups while controlling for the confounding effect of childhood SES (Hackman et al., 2010). Not all of the previous studies that have tested the bilingual advantage hypothesis controlled for childhood SES, increasing their possibility of spurious results. For example, it has been argued that the not controlling for childhood SES can in part explain the inconsistent findings of research examining the bilingual advantage hypothesis (Hilchey & Klein, 2011) Therefore, our methodology is testing the bilingual advantage hypothesis in a novel and more controlled way.

For the purposes of our study, we conceptualized the experience of mind wandering as a failure of executive control to inhibit the onset of task-unrelated thoughts, in line with the executive failures model of mind wandering (McVay & Kane, 2010). Our reasoning for following this model instead of the executive resources model proposed by Smallwood & Schooler (2006) is driven by the context regulation which predicts that in high attention demanding contexts the experience of mind wandering is best explained by the existing evidence as a failure of executive control (Smallwood & Schooler, 2015). In the present study, we measured participants' mind wandering rates by probing the content of their thoughts during the anti-saccade task, which places relatively high attention demands on the participant. Therefore, because the context of our experiment was consistently attention demanding, we expected that the experience of mind wandering in this circumstance would fit with the executive failures model (McVay & Kane, 2010). Most importantly, this theoretical assumption is what led us to make the prediction that individuals with better executive control, which we hypothesized to be those in the bilingual group, would report less frequent episodes of mind wandering than their monolingual peers.

To test our primary research question we utilized probed reports of task-unrelated thoughts (TUTs) as a subjective measure of mind wandering rates. We found that bilingual participants reported lower rates of mind wandering than monolingual participants. This evidence supports our hypothesis that bilinguals would exhibit an advantage in executive control as measured by mind wandering rates. To support the argument that less frequent mind wandering for the bilingual group was due to an advantage in executive control, we compared the TRI proportions of the bilingual and monolingual groups, as this type of distracting thoughts are not argued to affect task performance when measuring executive control (Stawarczyk et al., 2011; Unsworth & McMillan, 2014). Our findings showed no difference in task-related interference (TRI) proportion between the two groups. Additionally, we also compared the two groups' on-task (OT) proportions and found no significant group difference. The only category of probed thought proportion in which there was a significant group difference was TUTs, suggesting that the lower rates of mind wandering reported by the bilingual group are due to individual differences in executive control. Given that our measure of mind wandering was based on self-report, this finding could also suggest that the bilingual participants in our study were just less likely to report instances of mind wandering, relative to their monolingual counterparts. We discuss this alternative below.

We also predicted that bilingual participants would outperform their monolingual peers on the anti-saccade task, specifically showing higher accuracy on the task, as this is an operational measure of executive control. However, our results revealed no significant difference between monolingual and bilingual participants on anti-saccade task accuracy. Since anti-saccade accuracy and mind wandering rates were the direct measures of executive control in our study, we predicted that the bilingual group would demonstrate relatively better performance in both of these measures. The results only support the mind wandering rate portion of our hypotheses. Given that anti-saccade performance is an objective measure of executive control, whereas mind wandering is only a subjective measure, these findings can be interpreted as evidence against the bilingual advantage. However, when we analyzed the relationship between TUTs and anti-saccade task performance, we found that they correlated negatively only for the monolingual group. According to the executive failures model of mind wandering (McVay & Kane, 2010) higher rates of mind wandering are conceptualized as higher rates of executive control failures, and would thus decrease accuracy on executive control tasks. Therefore, we expected that anti-saccade task performance would decrease as frequency of mind wandering increased, regardless of bilingual experience. The lack of a relationship between TUTs and anti-saccade task performance in the bilingual group suggests that bilingual participants' performance on this executive control task was not negatively affected by higher rates of mind wandering.

In order to further examine the possibility of a bilingual advantage we turned to our measure of WMC. The two-factor theory of executive control (Kane & Engle, 2004) argues that individual differences in WMC are actually differences in executive control. Since we predicted that bilinguals would have an advantage in executive control, we also expected that this advantage would extend to our WMC measure. However, our results showed no group difference in WMC. We then further tested the hypothesis of a bilingual advantage in WMC by examining the relationship between WMC and TUTs. The executive failures model of mind wandering (McVay & Kane, 2010) predicts a negative correlation between WMC and TUTs, as higher WMC would allow for more efficient suppression of TUTs, leading fewer instances of mind wandering. Our findings showed that these variables were not correlated for the monolingual group but correlated positively for the bilingual group, albeit marginally. These results would serve as evidence in favor of the executive resources model (Smallwood & Schooler, 2006), because according to this model, individuals with higher WMC will have more resources at their disposal to engage in mind wandering. However, this model predicts that the correlation between these variables will be positive, regardless of bilingual experience. It is important to note that the thought probes measuring TUT frequency were not administered during the WMC task, which may account for the lack of a strong relationship between these variables. Future research should apply thought probes during the WMC tasks for to gain further insight as to the relationship between WMC and mind wandering.

Due to the fact that our results showed no group difference in either WMC or anti-saccade accuracy, when we hypothesized that bilinguals would obtain higher marks on both, we examined the relationship between these variables in order to explore other alternative possibilities. Our findings revealed that WMC and anti-saccade task accuracy correlated positively for the bilingual group, but showed no relationship for the monolingual group. This is a puzzling result, which does not align with previous findings that showed a strong correlation between WMC and attention control (e.g., anti-saccade, Stroop, SART tasks) measures (Unsworth et al., 2012; 2014). Although the previously mentioned studies were not examining the relationship of these measures with bilingual experience as a group factor, we did not predict any group difference in this relationship. We do not interpret this group difference as evidence for a bilingual advantage, instead we argue that one possible explanation for the lack of a correlation between WMC and anti-saccade task accuracy for the monolingual group arises from a limitation of our visual change detection task (Luck & Vogel, 1997). Specifically, the task we utilized to measure WMC is a simpler design than those used in the previously mentioned studies, where multiple operation, reading and symmetry span tasks (see Unsworth, Shrock, & Engle, 2005; Unsworth, Redick, Heitz, Broadway & Engle, 2009) were used to obtain a more complete measure of WMC. We argue that a more thorough measurement of participant WMC could better elucidate the relationship between WMC and executive control, and suggest that further research implement a multiple task approach to measure WMC.

Although our results do not fit neatly with the predictions of a bilingual advantage in executive control, we propose that the lack of a relationship between our measure of executive control and mind wandering rates in the bilingual group hints at a difference in the executive control system of this group. With this in mind, and due to the fact that when performing a relatively demanding task, bilingual participants' performance was unaffected by increased rates of mind wandering, we argue that perhaps bilinguals advantage in executive control is in their ability to efficiently shift attention back to the task at hand on trials in which they are experiencing mind wandering. If this is the case, experimental evidence of this form of a bilingual advantage is necessary to test our prediction. We predict that evidence for our proposed bilingual advantage would be shorter reaction times and greater accuracy on the anti-saccade task trials in which participants experienced mind wandering. This experimental procedure would require a method of measuring rates of mind wandering objectively and without the awareness of the participant, as well as reaction times of each individual trial.

The experimental procedure we propose also addresses the main limitation of our study, the lack of an objective measure of mind wandering. Mind wandering rates were measured using a self report method, which is a subjective measure. Although the thought probe method is a validated and widely used method of measuring mind wandering (Smallwood & Schooler, 2015), it is susceptible to self-report bias, as evidenced by many participants of this study reporting no form of off-task thought. Limiting the effect of self-report bias is key for furthering the validity of measuring mind wandering and allowing for more substantial conclusions to be drawn in future research. Currently there are a number of experimental and analytical methods being developed in search of an indirect objective measure of mind wandering that can be used, either in concert with subjective reports as a means of verification, or by itself, in order to measure mind wandering in a non-invasive manner. Such methods include electroencephalography (EEG) data (Kam et al., 2011) and pupilometry (Smallwood et al., 2011b). By combining thought probes and EEG data, Kam and colleagues found that the amplitude of the P3 event-related potential is reduced in the periods where participants reported off task thought while performing a sustained-attention-to-response task (SART; 2011). Smallwood and colleagues measured pupil dilation (PD) and found that PD was unchanged in response to external stimuli and had higher baseline activity prior to trials with errors and slow responses in a WMC task (2011b). The use of these nonintrusive techniques can serve to obtain a more complete picture of thought content during experimental procedures, and provide a measure of mind wandering that is not subject to any reporting bias. Future research using rates of mind wandering as a measure to test the bilingual advantage hypothesis must consider using these new methods in addition to thought probes to obtain a clear and accurate measurement of mind wandering.

In conclusion, although we found that bilingual participants reported lower rates of mind wandering while in the laboratory we cannot conclude that this difference alone is sufficient evidence in support of the bilingual advantage hypothesis. Advances in the methods of measuring mind wandering are necessary to further examine the possibility of a bilingual advantage in suppression of task-unrelated thoughts, as thought probes do not provide an objective measure of mind wandering. The development of said methods will enable further research in the field of mind wandering, such as our proposed experiment examining reaction times and accuracy in individual anti-saccade task trials in which participants' minds wandered, to properly test these hypotheses. In addition to testing the bilingual advantage hypothesis, we sought to explore the possibility of bilingual experience as a means of reducing the occurrence of mind wandering, due to the significant rates of mind wandering reported by students in educational contexts (Unsworth et al., 2012). Much research remains to be conducted before we can convincingly argue for the advantage of bilingualism as a method of increasing students' attention control.

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