Abstract

Previous research has suggested a bilingual advantage in executive function (EF) and creativity compared to monolinguals. It is theorized that bilinguals' EF advantage stems from their constant practice of selecting one language while inhibiting the other language in conversation, thus strengthening their EF, which may facilitate more complex problem solving such as creative tasks. Eighty-three participants recruited from the university community participated in the two-part study. Both computer and pencil-and-paper tasks were used to assess the five proposed components of EF, as well as creative performance. Contrary to our initial hypotheses, preliminary findings indicate a monolingual instead of bilingual advantage on EF and creativity. Our findings are consistent with the lack of bilingual advantage recently reported in other studies. These results suggest that the language effect may not be as robust as once thought, or that other factors need to be taken into account when evaluating findings across studies.

Keywords: executive function, creativity, bilingualism, language.

Introduction

The understanding of bilingualism's effects on cognition is a relatively uncharted area of cognitive science that has been gaining interest in recent decades. The effect of bilingualism on cognition has not been clear cut. Some of the earliest research suggested it may have detrimental effects on cognition and intelligence (Tucker & d’ Anglejan, as cited by Salvatierra & Rosselli, 2010). More recent research started compiling evidence that bilingualism provides advantages in a variety of domains,
such as executive function (EF) and creativity (Bialystok, Craik, Klein, & Viswanathanan, 2004; Bialystok & Craik 2010). It has been found that while bilinguals enjoy some cognitive benefits, they have also shown deficits in verbal tasks requiring rapid lexical access and retrieval, such as verbal-fluency tasks (Bialystok & Craik 2010). Beyond the immediate cognitive advantages, there is also evidence that lifelong bilingualism maintains cognitive functioning and delays the onset of dementia in old age. In a study of 184 patients from a memory clinic in Toronto, Bialystok, Craik, & Freedman (2007) found that on average, bilinguals showed symptoms of dementia 4 years later than monolinguals. However, despite recent studies finding cognitive advantages for bilinguals, these results have not been consistent. Other studies have found no such advantage or have been unable to replicate findings by Bialystok, so the topic remains controversial and in need of further investigation (Paap & Greenberg, 2013; Salvatierra & Rosselli, 2010).

If bilinguals do have a cognitive advantage over their monolingual peers, where does this advantage stem from? Previous research suggests that there is parallel activation of semantically linked items in both languages associated with a particular concept (Green, 1998). The bilingual has to inhibit one language while selecting for the appropriate language. It is believed that the demand to continually manage two languages strengthens the Supervisory Attentional System, a system that is hypothesized to be a broad cognitive conflict system, and that these advantages extend to non-linguistic tasks. This theory of competition between two semantic units may also explain why bilinguals perform less well on verbal tasks; for example, they may respond more slowly on picture-naming tasks, produce fewer words in verbal fluency tasks, and perform less well on lexical decision tasks (Hilchey & Klein, 2011).

The overarching brain mechanism that facilitates many instances of cognitive conflict and control is referred to as the executive control system. Executive functions (EFs) are fundamental cognitive mechanisms linked to the pre-frontal cortex that regulate and control our behavior and cognitive processes such as planning, working memory, attention, inhibition, task switching, and problem solving. Because EF is such a fundamental aspect of cognition, deficits in it can have detrimental consequences on people’s lives and well-being,
including such important aspects as children’s success in school, and people’s emotional/behavioral control or inhibition (Barkley, 1997; Biederman et al., 2004).

There currently is no agreed upon view of the exact elements of EF, as researchers vary in the ways they subdivide and categorize its components. There is however, much overlap in the various models that have been proposed. The current study combined aspects from two previously established theoretical frameworks used by Shimamura (selecting, maintaining, updating, and rerouting) (2000) and Miyake & Friedman (updating, shifting, and inhibition) (2012), to come up with five facets of EF: selecting, maintaining, inhibition, shifting, and updating. Selecting is the ability to focus attention on aspects of information processing, such as a stimulus or memory representations. Maintaining is the ability to maintain information in short-term memory after it has been selected. Inhibition is the deliberate overriding of a dominant or prepotent response. Shifting is the ability to switch flexibly between tasks or mental sets. Updating requires constant monitoring and coding of incoming information, and revision of items held in working memory by replacing no-longer-relevant information with new, more relevant information (Miyake & Friedman, 2012; Shimamura, 2000).

Previous studies on bilingualism have not investigated individual aspects of EF, but look at “executive control”, or “executive processes” in general, as measured by one, or a few commonly used tasks. To measure this effect studies have commonly employed a Flankers task, the standard Simon task, or the arrow Simon task, which is considered to be more difficult, and is the task that was used in this study. This task was included as an extra EF task because it has been used frequently in the bilingual literature. We wanted to see if our Simon results were in line with previous findings. There are congruent trials, where the target stimulus aligns with the same side as the correct button response, and incongruent, in which the stimulus is on the opposite side of the correct button. Reaction times (RTs) are often faster when the target location and button response location are congruent. The difference between the congruent RT and the incongruent RT is referred to as the “Simon effect.” Having a smaller Simon effect, or interference effect, is indicative of an advantage in inhibitory control. This effect has received
much attention as earlier findings in the literature supported a bilingual advantage (Bialystok et al., 2004). More recent studies however, including a meta-analysis, have found that this effect is not very reliable or robust in younger adults (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Hilchey & Klein, 2011). Although the bilingual effects in older populations are understudied at this point, there is mounting evidence that the effect becomes much more salient in older bilinguals compared to monolinguals. A bilingual advantage that has been found to be more robust across age groups is the “global advantage”, or overall RT advantage, in which bilinguals respond quicker than monolinguals on all trial types (Bialystok et al., 2004; Costa et al., 2009).

Creativity is a hard concept for researchers to define or measure, but it can be thought of as higher level processing of complex novel problem solving. Previous research has found a bilingual advantage in children on divergent thinking tasks, on measures of fluency, flexibility, elaboration, and originality (Kharkurin, 2011; Lee et al., 2011). Many of the studies on bilingualism and creativity focus on the additional cultural experiences a bilingual has had, as the catalyst of their enhanced creativity. In this study we are interested in assessing whether the fundamental aspects of cognition (EFs) enhance creative potential. That is, if bilinguals experience an advantage in EFs, will this translate into an advantage in creativity as well? Previous research by Kharkhurin (2011) found that among a group of bilingual students, selective attention had a moderate effect on the difference in creative performance. In another study, which consisted only of bilinguals, a positive correlation was found between individual’s degree of bilingualism and their creativity performance as measured by the Torrance Test of Creative Thinking (TTCT) (Lee & Kim, 2011).

Because previous research has focused narrowly on inhibition, or broadly on “executive processes”, the current study sought to systematically examine the bilingual EF advantage by pairing specific EF tasks to the aspects of EF proposed by Miyake and Friedman (2012) and Shimamura (2000). We hypothesized that bilinguals will show an advantage in EFs (as shown by quicker reaction times, and higher accuracy rates on tasks), which may translate into an advantage in creative performance. We are measuring five facets of EF to see if we can
find a specific realm of EF bilinguals excel in.

**Methods**

**Participants**

Eighty-three students (26 male, 57 female) from the University of Minnesota community participated in this study. There were 37 monolinguals (13 male, 24 female) with a mean age of 20.7, and 46 bilinguals (13 males, 33 females) with a mean age of 21.3. Monolinguals were defined as having no second language until high school, and bilinguals were defined as acquiring 2 or more languages by the age of 8. Participants were balanced across demographics except for education, in which bilinguals had significantly more years of education (15.2) than monolinguals (14.3). This was due to there being more graduate students in the bilingual group. Participants were recruited through a screening survey, and compensated with REP points or money ($10 per hour).

**Tasks and Procedure**

The tasks and procedure from this study are a subset of tasks taken from a larger study which entailed approximately five hours of computer and paper-and-pencil tasks broken up into two experimental sessions approximately a week apart. The EF tasks used in this study come from session one of the experiment, and the creativity (TTCT) task comes from session two. In all computer tasks the keyboard and monitor were set at identical distances for each participant, making sure proximity to the monitor/keyboard was not a factor in performance.

**EF Tasks**

**Selecting** - Flankers task. In this task subjects were to determine which direction an arrow was pointing by pressing a left key with their left finger or a right key with their right finger. Subjects were presented with a fixation point (+), and then one of three stimulus types was presented (congruent, incongruent, neutral). Participants responded as quickly as they could, indicating which direction the target arrow (shown in red) was facing. In congruent trials the target stimulus was flanked by congruent arrows, the incongruent trial had the target arrow flanked by arrows facing the opposite direction, and the neutral trial had the arrow flanked by diamonds.
Maintaining - Spatial-Delayed Response. In this task participants were required to maintain information in their working memory of a selected stimulus. The sequence of this task goes as follows: (a) participants focus on a fixation point in the center of the screen (+), (b) a target stimulus of a circle is presented on the screen, (c) the target stimulus disappears for a delayed amount of time depending on the condition (5, 15, or 30 seconds), during which time distracter shapes appear on the screen (such as triangle, square, diamond) and the participant is instructed to press the space bar anytime they see a diamond, (d) after the delay sequence the subject is asked to point to where the target stimulus was, and then a mouse was used to click this point. Accuracy is measured by the subject’s mean pixel distance away from where the target actually was.

Inhibition- Anti-Saccade task. In this task subjects had to inhibit their natural response to look at a distractor stimulus in order to identify the briefly shown target stimulus. Subjects (a) fixated on a fixation point, (b) a distractor stimulus (a small square) would appear on the left or right side for 225 ms, (c) the target stimulus (an arrow pointing left, right, or up) would briefly appear on the opposite side of the distractor stimulus for 150 ms, (d) subjects responded accordingly using the keyboards up, left, right arrows. There were 90 trials composed of nine different durations ranging from 1500 – 3500 ms.
Shifting- Number – Letter (NL). In this task participants were presented with a square subdivided into four smaller quadrants. In each quadrant a letter and a number would appear one at a time. For the first part of this task participants were tasked with pressing “V” whenever the number was even, and “M” whenever the number was odd. For the second part of this task participants focused only on the letter and pressed “V” whenever the letter was a consonant, and “M” whenever the letter was a vowel. For the third part of the task a number letter pair was presented in a quadrant one at a time in a clockwise order. Participants had to respond to the number being even or odd in the top two quadrants, and if the letter was a vowel or consonant in the bottom two quadrants. Participants were required to continually shift between number and letter responses.

Updating - Tone-Monitoring. For this task participants were presented with a sequence of different pitched tones (high, medium, low) via computer speakers. They were instructed to keep track of the number of times each tone sounds, and to press the spacebar every time a tone repeated four times.

Arrow Simon – In this task participants (a) focus on a fixation point, (b) are presented with an arrow on either the left or
right side of the screen, and the arrow is pointing either left or right, (c) the participants respond with the left button (Z) if the arrow is facing left, or right button (/) if it is facing right. There are congruent trials (e.g., arrow on left side facing left) and incongruent trials (e.g., arrow on left side facing right).

Creativity Tasks

To quantify creative ability this study used the Torrance Test of Creative Thinking (TTCT). Both the figural and verbal portions of the test were administered in the larger study, but only the results from the verbal portion of the test have been analyzed for this portion of study. The verbal TTCT comprises three different tasks that are all scored on three different dimensions (fluency, originality, flexibility). Fluency is scored as the number of acceptable responses a participant writes down. Originality is the amount of original responses written down. Responses are original if they are not on the normed word list. Normed word lists are responses that have been found to be common for a given task. Flexibility is a score of how many different categories of responses the participant gives on a task. Two raters scored the tasks independently, yielding a high inter-rater reliability of .98 (fluency), .95 (originality), and .91 (flexibility).

Results

Independent sample t-tests were conducted between monolinguals and bilinguals on the EF tasks and the TTCT. No significant bilingual advantages were found in any of the tasks, but advantages were trending in favor of monolinguals, with some significant advantages. Analyses showed that monolinguals (M = 980.56, SD = 241.71) had significantly smaller mean pixel distance to the target in Spatial – Delayed Response than bilinguals (M = 1105.73, SD = 243.04), t(82) = -2.35, p = .02. Additionally, monolinguals (M = 21.51, SD = 5.21) scored significantly higher in flexibility on the TTCT than did bilinguals (M = 19.31, SD = 4.98), t(82) = 1.97, p = .05. This difference is illustrated in Figure 5. Analyses showed that monolinguals (M = 39.44, SD = 11.76) scored moderately higher in fluency than bilinguals (M = 35.7, SD = 10.45), t(82) = 1.74, p = .09. This difference is also illustrated in Figure 5.
Discussion

The results from the current study have generated more questions than they have answered, and it is hard to reconcile finding not only no bilingual advantage, but actually finding some monolingual advantages. Faced with these results, further scrutiny of the literature was necessary, and upon further investigation, many possible explanations for the disparity between findings across studies emerged. Recently, Paap and Greenberg (2013) did a study very similar to ours in the tasks used and the population tested (a mixed bilingual population), and they found very similar results. They found no bilingual advantage in any of the tasks, and actually found a few monolingual advantages. When reconciling the reports of significant bilingual advantages with findings unable to replicate this advantage Paap and Greenberg proposed two general perspectives: 1. The “bilingual advantages are real perspective,” according to which the failure to replicate findings is due to methodological differences between studies such as: the tasks used, differences between tasks (number of trials, ratio of congruent to incongruent trials), the type of bilinguals used (mixed, homogenous, high/low language switching), and the cultural context the study is taking place in. 2. The “bilingual advantages are artifacts perspective,” which states that when performance advantages do occur, they are due to factors other than bilingualism, such as hidden demographic factors that were not matched for, or cultural factors that contribute to the
One of the most salient variables that potentially plays a role in bilingualism and EF is age. There is not a breadth of studies done on older populations, but some studies that have not found advantages in young populations (or found smaller advantages), have seen significant advantages in the older populations (Bialystok et al., 2004; Gold et al., 2013; Salvatierra & Rosselli, 2010). Gold et al. did a study comparing young and old bilinguals to monolinguals on a switching task. They found that there were no significant differences among the young age group, but in the older age group bilinguals were found to have a lower switch cost RT, and less of a BOLD (Blood-oxygen-level dependent) activation in three brain areas of interest, indicating that the older bilinguals were processing the tasks more efficiently than the monolinguals. As mentioned earlier, Bialystok et al. (2007) found that bilingualism offset age related decline as measured by bilinguals experiencing symptoms of dementia 4 years later than monolinguals. Paap and Greenberg postulate that it is possible that the commonly tested populations (young adult college students) are already at the peak of their predetermined cognitive control capacity. Young adults fill their days with a range of normal activities that tax the EF system by attending to relevant information, planning, ignoring distractions, switching tasks, and monitoring their performance. These activities may be enough by themselves to max out this predetermined cognitive limit, if such a ceiling exists. It is only in aging that we begin to slowly see a decline in cognitive capacities, and this is when bilingualism could play a role in preserving cognitive abilities. If we assume that as age increases so does the bilingual advantage, then we can look at studies with differing results and see if it could be a product of age differences across studies. When Salvatierra (2010) tried to replicate Bialystok et al.’s (2004) findings of a bilingual advantage in the Simon task for complex and simple conditions, they only partially replicated the results. The study found only an advantage in the simple condition, and not the complex condition. Bialystok had a significantly smaller N, and lower mean age for age groups. The younger bilinguals (N=32) had a mean age of 42.6 years, and the older bilinguals (N=15) had a mean age of 70.3 years, while in Salvatierra’s study both groups were larger and had younger ages, young group (N=67) had
a mean age of 26.7, and the older group (N=58) mean age of 64.1. The smaller sample size and higher age for “young adults” likely played a role in the strength of the advantage found in Bialystok’s study.

Another important aspect that researchers need to be cognizant of is the prevalent entanglement between culture and language in bilinguals. Bilinguals can be bicultural as well, and this effect on EF is often not separated from language, or understood in its consequences. A study by Carlson and Choi (2009) dramatically demonstrates this entanglement between culture and bilingualism. In this study they found that bilingual Korean Americans showed a significant advantage over monolingual Americans using six different EF measures. When these bilingual Korean Americans were compared to Korean monolinguals however, the results for the two groups were undistinguishable. This leads us to believe that the EF advantages experienced were most likely not due to bilingualism, and that some cultural difference was influential in EF performance.

There is also the broader cultural context in which the study occurs, and the demographics within the bilingual sample itself that vary greatly across studies. Some studies are conducted in monolingual cultures (such as America), and some are conducted in bilingual cultures (such as Canada or India). Studies also vary in their bilingual population, some having a homogenous population (all Spanish, or all Mandarin bilinguals for example), and some studies having a mixed sample (many different types of bilinguals). It is worth mentioning that the current study, as well as that of Paap and Greenberg (2013), were both conducted in a monolingual culture (California, US, and Minnesota, US), with a mixed population of bilinguals, and with similar EF tasks, and both found no bilingual advantage, while also finding a few monolingual advantages. In contrast, the study of Bialystok et al. (2004) that found significant bilingual advantages used a monolingual group of native Canadian residents, and a bilingual group of Southern India residents. This eclectic participant selection raises questions of lurking cultural confounds.

A previously unexplored variable among bilinguals is the language they speak, and that language’s distance from English. A study done comparing French bilinguals, Cantonese bilinguals, and English monolinguals found that French bilinguals...
and Cantonese bilinguals showed similar patterns of brain activation in relation to faster RT on an EF task. They showed increased activation of the ACC, superior frontal, and inferior frontal regions situated in the left hemisphere. Monolinguals showed increased activation of the middle frontal area of the left hemisphere. However, even though the French and Cantonese bilinguals showed similar activation patterns, only the Cantonese bilinguals showed an EF RT advantage, over both the English monolinguals and French bilinguals (Hilchey & Klein, 2011). This suggests that something other than being a bilingual was responsible for the advantage. It is possible that languages further away from English syntactically can provide more robust advantages. For example, the differences that a Cantonese-English bilingual (hard bilingual) faces are greater than those that a Spanish-English bilingual (soft bilingual) confronts, and this additional difficulty the EF system is faced with may confer measurable advantages in “hard bilinguals.” The author is not familiar with any bilingual studies which measure this factor, and suggests that future studies employ a quantitative measure of the distance between English and second languages to see if language distance has an operative effect on EF. One such measure has been established by Chiswick (2004).

Another important component that varies across studies, and that has been shown to affect the presence of the bilingual advantage is the methodology of the tasks in the study. Two main points regarding this concern the number of trials in a task, and the ratio of incongruent to congruent trials used. A possible limitation of the current study is the amount of trials used in each task. For the Simon task the current study used 8 blocks of 40 and 8 blocks of 10 trials (400 total trials). Bialystok et al. (2004) used 10 blocks of 24 trials (240 trials total). They found that bilinguals started out faster than monolinguals and remained so until block 7, in which the two groups converged. This would be roughly around trial 168, and similar results have been found throughout the literature; bilingual advantages disappearing with practice, so it is conceivable that our bilinguals’ advantage got washed out in the many trials. We did however analyze the first few blocks of the Simon task, and found no such advantage, but further inspection into the other tasks is still needed. Concerning the ratio of congruent to incongruent trials Costa et al. (2009) did a series of systematic experiments varying the ratio...
of trials and they found that it was a critical variable to finding a bilingual advantage in the Flanker task (a more balanced ratio extinguished the bilingual difference advantage, but increased the bilingual global RT advantage).

A final point that is worth discussing concerns environmental factors that may be unaccounted for, but which can affect EF performance such as socioeconomic status (SES), high computer use, video game play, and expertise in music, which all co-vary with EF performance (Hilchey & Klein, 2011). Failure to control SES is the most widespread unanswered criticism in studies of bilingual cognitive differences. Occasionally studies try to control for SES by asking the highest achieved level of formal education, or by selecting from middle class neighborhoods, but these methods are criticized as being relatively indirect. When Morton and Harper controlled for SES directly and replicated the Simon task they found no bilingual advantage, and found that monolinguals experienced a global RT advantage. However, this experiment was done on children only, and their interpretation is considered somewhat controversial (Hilchey & Klein, 2011). In the current study we took SES into account by asking participants to rate their SES on a scale of 1 to 5 before the age of 12 and after the age of 12. This measure is a relatively indirect measure of SES, and it is suggested that future research use a more sensitive and direct measure. Many previous studies have failed to take into account the factors of computer use, video game play, and musical expertise. In our demographics we included questions asking what video games the participants play and how many average hours a week they play them. We also asked about what instruments they play, and how many hours a week they play them. This data still needs to analyzed and inspected to see if it had an effect on EFs.

**Conclusion**

Studies investigating the bilingual advantage vary immensely in a wide array of factors such as methodology, cultural context, homogeneity of the language sample, and demographics (such as age and SES). Findings across studies for a bilingual advantage have been inconsistent and fickle, which suggests that the effect may not be as robust as we thought, in young adults at least. Although fewer studies have been done on older populations, there is evidence that the bilingual advantage
becomes more pronounced with age, and further research into these populations is needed to be conclusive. Further investigation into the differences among studies with conflicting findings is needed, and future research on the bilingual advantage should be mindful of the factors discussed in this study (SES, age, culture versus language entanglement, etc.). Future research could also include a language distance scale such as that discussed earlier to see if language distance has an effect on EF. In conclusion, either bilingual advantages are real but more likely more limited than previously thought, and failure to replicate them is due to methodological differences between studies, or bilingual advantages are artifacts, and the EF advantage stems from other lurking variables. With the current available evidence it is premature to conclude one way or another; additional research on bilingualism is needed to understand the possible cognitive advantages it presents.

References


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