The Role of Foreign Language Experience on Executive Control

A project completed in partial fulfillment of the requirements for the Honors Program

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5/3/2016

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Abstract

Prior studies have shown that bilinguals enjoy certain cognitive advantages, particularly those related to executive control; but, there have also been some studies that did not report this advantage. This study sought to investigate the impact of foreign language experience on measures of executive control, as measured by a modified version of the Stroop task. It is important to note that "bilingual" here is defined in terms of foreign language exposure. Participants completed a bilingual vocabulary task and answered questions about extracurricular activities. The results are expected to show that priming participants foreign language knowledge reduces Stroop interference (i.e., improves executive control).
The Role of Foreign Language Experience on Executive Control

Knowledge of a foreign language brings certain cognitive advantages, particularly when it comes to executive control. Some studies (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Luk, 2008; Costa et al., 2008; Linck, Hoshino & Kroll, 2008) suggest that multilingual individuals have an advantage at tasks that require inhibitory control, but other studies did not report such an advantage (Carlson & Meltzoff, 2008; Morton & Harper, 2007). The constant competition for selection between two languages that bilinguals experience may lead to enhanced cognitive control that is domain-general (Green, 1998). This study will measure bilingual ability and its effect on executive functions, namely task-switching and inhibition control. Bilingual ability will be measured by self-reported proficiency and score on a bilingual code-switching task.

Executive Functioning

Executive functioning involves various control functions (such as working memory) that are employed when one needs to think and concentrate, and are helpful when acting upon initial impulse can be detrimental (Diamond, 2012). Executive functioning is multi-dimensional (Heidlmayr, Moutier, Hemforth, Courtin, Tanzmeister, & Isel, 2013), with one model proposing three dimensions of executive functioning: inhibition of dominant response; shifting of mental states; and monitoring and updating the information within working memory (Miyake et al., 2000). The researchers tested various models and found that having a three-faceted model best represents the data in their study; they do, however, note that the three functions mentioned above are the only executive functions (Miyake et al., 2000). Task-switching requires an individual to exhibit all three executive functions; preparing for the next task may exercise a top-down mechanism and require executive control according to a theory which proposes an
additional processing phase in between tasks (Baddeley, Chincotta, & Adlam, 2001; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). An example of task-switching would be engaging in a task with a certain set of directions, and then engage in the same task but the directions have switched. If a computer program requires a subject to press "q" to any vowels and "p" for any consonants, a switch in the task could involve pressing "q" to any consonants and "p" to any vowels. One must monitor and update the information about the task within working memory, while being sure to not let the initial priming phase interfere with the new set of directions in the current task. Response times increase and accuracies tend to decrease in the laboratory setting in the switch phase, compared to a task that is repeated with the same directions (Schmitz & Voss, 2014).

Inhibition control requires the inhibition of a dominant response, which bilinguals exhibit, in order to inhibit the dominant language and use their non-dominant language (Green, 1986*, 1998). More generally, inhibition allows one to control one's behavior, by overriding habitual or dominant responses and exhibiting self-control (Diamond, 2012). One way of measuring inhibition control is through the Stroop task (Wright, Waterman, Prescott, & Murdoch-Eaton, 2003). Part of the Stroop task involves presenting color words in a color that is congruent to the word itself, after which color words are presented in a color that is incongruent to the word itself. For example, in the trials which present a color-word in an ink that is incongruent to the word; the word "yellow" may appear in red ink. Moreover, many cognitive processes are being employed (such as attention, memory, and inhibition). These cognitive processes may be able to be trained by using them (Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015). Switching languages often could help enhance those cognitive
processes, since in order to communicate in a non-dominant/non-native language, the individual must inhibit the dominant/native language (Green, 1986*, 1998).

The dominant response in the incongruent phase of the Stroop task is to press the key that signifies the color yellow, but the individual must press the key that signifies the color in which the word appears, which is in this case red. The incongruent trials take participants longer than the congruent trials, because of the automaticity of reading; one must inhibit what the word is, and divert attention to the ink in which the word appears (Raz, 2006). The Stroop effect is measured by the difference in response times of the congruent and incongruent trials. There have been explanations of what contributes to the Stroop effect (Cohen, Dunbar & McClelland, 1990; Morton & Chambers, 1973; Zhang & Kornblum, 1998). The processing of information related to the response (identifying the color) is disrupted by processing other information in the stimulus (the lexical meaning of a word) (Cohen, Dunbar & McClelland, 1990). While the model by Zhang and Kornblum (1998) suggested that the relations between the two stimuli (the color of the ink and the word) and between the to-be-ignored stimulus and the response (the word and the color of the ink) interact and contribute to the Stroop effect.

Some factors which affect how one performs on the Stroop task, namely how much inhibition control one can exhibit, include how often one plays video games (Bialystok, 2006) and sports (Diamond & Lee, 2011), musical ability (Bialystok & DePape, 2009), and foreign language ability (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Luk, 2008; Costa et al., 2008; Linck, Hoshino & Kroll, 2008). Furthermore, how balanced the bilingual is—often defined as how frequently one switches between languages and how fluent one is in the non-dominant language—affects executive control (Prior & Gollan, 2011); those who are balanced (switch between languages frequently and are regarded as fluent) and those who are
interpreters have a noticeable advantage over monolinguals and unbalanced bilinguals, while unbalanced bilinguals do not exhibit such an advantage in executive control when compared to monolinguals (Bialystok et al., 2006). Executive control can be enhanced by activities which require attention, memorization, and the control of complex processes (Diamond 2011).

**Bilingual Ability**

Those that are bilingual may exhibit certain advantages, particularly in regards to exhibiting inhibition control, when compared to those who are not bilingual; this applies particularly to balanced bilinguals, as unbalanced bilinguals do not exhibit an advantage in executive control when compared to monolinguals (Bialystok et al., 2006). Some studies (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Luk, 2008; Costa et al., 2008; Linck, Hoshino & Kroll, 2008) have shown that bilinguals are better able to exhibit inhibition control, but some studies did not show that bilinguals show more inhibition control than non-bilinguals (Carlson & Meltzoff, 2008; Morton & Harper, 2007). Another study (Heidlmayr, Moutier, Hemforth, Courtin, Tanzmeister, & Isel, 2013) that included bilingual individuals who know both French and German, and monolingual individuals who know only French, has shown that individuals who were bilingual showed less of the Stroop effect than those who are monolingual; some of the factors controlled for include when the other language, L2, was acquired, and how proficient the participant is in L2. The number of years of functional bilingualism can positively influence cognitive advantages, since bilingual cognitive advantages emerge over time. This is because of the cognitive demands of bilingual language processing. Also, how often the bilingual code-switches can influence cognitive advantages, for those who do so frequently have better task-switching abilities (Prior & Gollan 2011).
Bilinguals who are interpreters and balanced bilinguals perform better than unbalanced bilinguals on the Simon and Attention Network Test in regards to accuracy (Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015). Additionally, bilinguals have two languages that are activated simultaneously (Kroll, Bobb, & Wodniecka, 2006; Assche, Duyck, & Hartsuiker, 2012), and need a way to suppress one language and activate the other in certain cases. This competing of the two languages for selection may lead to enhanced cognitive control that is domain-general, as opposed to being language-specific (Green, 1998). It has also been found that bilinguals, even in experimental conditions, are rarely affected by context to the point that they unintentionally switch; hence, bilinguals are able to exhibit a certain amount of inhibition control (Green, 1998). Additionally, they display a certain amount of accuracy in selecting the correct language in lexical decision tasks, suggesting a plasticity in their cognitive control. Any switch in language use is considered code-switching (Hoff, 2005), but the type of code-switching that will be considered here is what occurs when a bilingual switches from using one language to another language. Myers-Scotton and Jake (2014) suggest code-switching can take many forms, even the instance of a bilingual switching languages in the same conversation or even the same clause constitutes code-switching. Code-switching is deemed time-consuming: bilinguals were found to read and comprehend more slowly sentences that used two languages, compared to sentences that utilized only one language (Heredia & Altarriba, 2001). This is because the bilingual must determine which lexicon will be on or off during language processing; a factor that impacts code-switching is the ratio of L1 and L2 words in the sentence. If there are more Spanish words than English words, or the structure is more similar to that of a Spanish than English sentence, the bilingual will access the Spanish words quicker. Producing speech, on the other hand, for a bilingual is a higher-order mechanism and is under the control of
the bilingual; language dominance is also a factor, as when someone who is speaking cannot think of the word in one language, the bilingual may say the word using the other language.

Code-switching and task-switching are not mutually exclusive; indeed both employ executive function, and both elements can appear in a single task, such as the language-switching task administered by Prior and Gollan (2011). In that particular study, those bilinguals who reported switching between languages frequently exhibited smaller switching costs in the task-switching portion of the task when compared to monolinguals; another set of bilinguals in the study who reported switching between languages less frequently did not exhibit any advantage in task-switching when compared to monolinguals. The researchers suggest that there is a link between language-switching and bilingual advantages in task-switching.

Conclusion

Bilinguals tend to exhibit cognitive advantages when compared to monolinguals, but this depends on factors such as how fluent one is in the L2 and how frequent one switches between languages. This study will help to show how bilinguals, compare to monolinguals on various tasks. How much experience they have with the L2 and how frequently they switch between languages should be relevant. Based on previous research, what is expected is that bilinguals exhibit more cognitive advantages compared to monolinguals, thereby displaying some benefits of learning another language.

What is predicted is that those who are bilingual will in fact exhibit less of the Stroop effect on the baseline Stroop when compared to monolinguals; this will be moderated by certain factors, such as how frequently one uses the L2. Furthermore, bilinguals who take the Stroop task after the bilingual code-switching task, which will activate the L2 of the bilinguals, should exhibit less of the Stroop effect when compared to their baseline Stroop. The results of the
bilingual code-switching tasks should correlate with the results of the task-switching, based on the study by Prior and Gollan (2011). Those who are more bilingual should exhibit less switching costs, as the study by Prior and Gollan (2011) found. All of the Stroop tasks will be administered in the same testing session, and there are two reasons for this: 1) the Stroop task will be modified (so all of the neutral, congruent, and incongruent trials are mixed together into one phase) to reduce or eliminate any practice effects that may occur with the congruent and/or neutral trials; 2) the Stroop effect is difficult to reduce by practice (Raz, 2006).

**Method**

**Participants**

Participants (college students) were recruited in the following way: a flyer detailing a brief overview of the study was posted just outside the Psychology Lab at a Midwestern liberal arts institution, with a sign-up sheet. Upon the sign-up sheet, participants wrote their name and their e-mail address. Most subjects were students whose participation counted toward fulfilling a research requirement for an introductory psychology course.

Fifteen subjects participated, all of whom reported some degree of experience with a foreign language; hence, there was no monolingual group in this study. Subjects had to both self-report their language ability, and also take a bilingual code-switching task. An independent t-test was run to determine if there was any significant difference in the bilingual code-switching task scores between those who reported to be beginners in regards to their L2, versus those who reported to be intermediate. There was no significant difference between the beginner group (N = 9, M = 31.22, SD = 2.59), and the intermediate group (N = 6, M = 32.00, SD = 3.74), t(13) = - .479, p > .05. As a result, this study cannot claim to be comparing students with differing bilingual abilities. All subjects were analyzed as a single group for the remainder of the analyses.
A few variables, such as playing a sport, an instrument, or gaming, could potentially be covariates. Subjects were consequently divided into whether or not they reported playing a sport/physical activity. An independent t-test was run, comparing the first Stroop scores of these two groups. There was not a significant difference between those who played a sport or physical activity (N = 4, M = 260.25, SD = 190.18), and those who do not (N = 11, M = 260.45, SD = 184.28), \( t(13) = -.002, p > .05 \).

Subjects were then divided into whether or not they reported playing an instrument; another independent t-test was run. Again, there was not a significant difference between those who reported playing an instrument (N = 4, M = 224.50, SD = 205.57), and those who do not (N = 11, M = 273.45, SD = 177.28), \( t(13) = .455, p > .05 \).

Next, subjects were divided into whether they had experience with more than one foreign language, or just one foreign language. There was not a significant difference between those who had experience with just one foreign language (N = 12, M = 225.92, SD = 159.24), and those who had experience with more than one foreign language (N = 3, M = 398.33, SD = 221.13), \( t = -1.569, p > .05 \).

Finally, subjects were divided into whether they played games fewer than 20 hours per week (N = 9, M = 281.11, SD = 191.24), or more than 20 hours per week (N = 6, M = 229.33, SD = 170.80). There was not a significant difference between these two groups, \( t = .535, p > .05 \). Given the lack of a significant difference between these groups, none of these variables were used as covariates.

**Procedure**

An overview of the methodology is provided, as Figure 1. Participants were first given a questionnaire (named the Experience Questionnaire), which asked questions about how many
hours the participant plays video games (anything played on a tablet, phone, etc. were also counted) on a weekly basis, if the participant plays any sports and for how long he/she has played each sport, and how much skill the participant has with musical instruments (which were included as potential covariates). The participant was then asked to list which language(s) (if any) the participant has knowledge of, and how well the participant knows each language, along with how frequently the participant uses those languages. For the Stroop Task and the Task-Switching task, Direct RT programs were constructed so that response times and accuracy for each trial were able to be measured.

**Stroop Task**

A Stroop task was then administered, which had two phases, with 25 trials in each phase. The task was administered as follows: participants were first told to look at the color on the screen (which was in the form of a rectangle), and press the key that corresponds to that particular color; participants were also told to complete this task as quickly as possible; accuracy was also emphasized. Each of the keys (c, v, b, n) that were used were marked as "red", "green", "blue", and "yellow" respectively for easy reference. After that task was completed, the participant read the computer screen which gave instructions about the next task; the participant then was instructed to press the space bar to continue to the next task when ready. The next phase consisted of congruent, incongruent, and neutral trials that were randomized across subjects. The congruent trials consisted of being presented color words (e.g. "Yellow") that appeared in their respective color ("Yellow" appeared as yellow). The incongruent trials consisted of being presented color words that appeared in an incongruent color ("Yellow" could appear as any color in the test except for yellow). The neutral trials consisted of being presented a random word ("lot", "ship", knife", and "flower"), the text of which appeared as a random
color. In each task, the participant pressed the key that corresponded to the ink in which the word or block appeared. The first phase helped the participant get used to the keys involved; no words were presented. The second phase involved all of the different trials aforementioned, and the order in which each trial was presented was randomized for each subject.

As soon as subjects pressed a key, Direct RT displayed the next trial; and only one color block or word appeared in each trial. The time in between each phase was dependent upon how long the participant took to read the instructions and press the space bar, and the viewing distance between the participant and the computer screen was a distance comfortable for the participant. In each phase, the color block or word appeared against a white background, and each word was capitalized. The sequence of trials that occurred in each phase was randomized across subjects. Response time and correct/incorrect were recorded for each trial.

A bilingual vocabulary task to activate the participant's native and foreign language or task-switching task was then administered (the order in which these two tasks were administered was counterbalanced across participants). This Stroop served as a baseline.

**Task-Switching**

The next part consisted of a task-switching task (which was a Direct RT program) and another Stroop task (either the task-switching task or code-switching task was administered; this order was counter-balanced), which allowed for analysis of the Stroop effect after the task-switching task had been administered to see if administering this task before a Stroop has any effect compared to the participant's baseline Stroop. The task-switching task was similar to the ones administered in the studies conducted by Schmitz and Voss (2014) and Rogers and Monsell (1995). A stimulus was presented that was either a letter or a number: the letters used were the vowels A, I, E, U, and the consonants G, K, M, R; the numbers were an integer from 1 to 9. The
participant was asked to label the stimulus as "odd" or "even" for numbers, and "vowel" or "consonant" for letters. Each letter or number in the set was presented once for the first trial, and the order in which each appeared was randomized. The next trial consisted of the same directions, and was called the "repeat" trial. The next trial was similar, but called the "switch" trial, as the key presses which allow the participant to denote the stimulus as "odd", "even", "vowel" or "consonant" were switched. In the first two trials, the key Z on the keyboard designated "odd", M for "even", Q for "vowel" and P for "consonant. In the switch trial, P designated "odd", Q for "even", M for "vowel", and Z for "consonant".

**Bilingual Code-Switching**

This next part, which involved a bilingual code-switching task (to activate the L2) and then another Stroop (or the task-switching task if the participant has already had the bilingual code-switching task). The bilingual code-switching task was administered as a worksheet for the subject to complete. All the questions were in multiple choice format; a word in either the L1 or L2 was presented, and the subject chose one word from four that best matches the target word provided. The first section presented 10 L2 words; the second section 10 L1 words; and the third section 10 L1 and 10 L2 words, which were mixed together.

**Scoring and Analysis**

The data were analyzed using SPSS 17 with alpha set at .05. Self-rated proficiency in the L2 used was compared to how many words the subject correctly identified on the bilingual code-switching task. Since subjects claimed to either be a beginner or intermediate with respect to their L2 experience, an independent t-test was run between those two groups. Potential covariates (gaming, playing sports or other physical activities, playing instruments) divided the subjects into two groups (i.e. those who play sports and those do not), at which point an independent t-test was run comparing the two groups' first Stroop score. A repeated measures
ANOVA was run to compare the Stroop scores on both reaction time and accuracy across all three trials. Finally, a 2 order x 3 Stroop mixed ANOVA was run to determine if taking either the bilingual code-switching task or the TS task had any impact on Stroop interference scores, for both reaction time and accuracy.

**Results**

This study investigated if foreign language ability had any effect on a subject's Stroop score, and did so by having subjects report languages with which the subject is familiar, then having subjects complete a bilingual code-switching task on the foreign language with which the subject is most familiar. Subjects also completed a TS (task-switching) task, as prior research has indicated that good language switchers are good task switchers. The TS presented a letter or number, and the subject pressed a key for odd, even, consonant, or vowel. The first two trials were the same, but the third trial switched the key presses so the subject had to exercise inhibition.

A repeated measures ANOVA was run, to see if subjects improved across their Stroops; specifically, the data used for this were subjects' Stroop interference scores for their first, second, and third Stroops (see Figure 2). Stroop interference score was calculated by subtracting the congruent Stroop reaction time from the incongruent (mimicking how Raz, Kirsch, Pollard, and Nitkin-Kaner (2006) calculated it). There was a significant difference between trials, $F(2,28) = 8.632, p < .05$. Specifically, Stroop interference times for the second trial ($M = 123.53$, $SD = 119.74$) were significantly lower than that of the first trial ($M = 260.40$, $SD = 178.90$), $p < .05$; likewise for the third trial ($M = 112.27$, $SD = 83.77$) compared to the first trial, $p < .05$. This means that subjects' incongruent reaction times were closer to their congruent RTs for their second and third Stroops compared to their first Stroop; this also suggests significant
improvement in inhibition control and overall executive functioning from their first Stroop to their second and third Stroops. There was no significant difference between Stroop scores for the second and third trials, \( p > .05 \).

![Figure 2. Stroop interference (RT) for all three Stroops.](image)

Another repeated measures ANOVA was run, investigating whether or not subjects improved in their Stroop interference accuracy score across Stroop trials (see Figure 3). This was calculated by subtracting congruent accuracy from incongruent accuracy, so a negative score shows that the subject got more congruent trials correct than incongruent trials; the closer this score is to zero, the less interference occurred, and the more executive functioning the subject exhibited. There was a significant difference between trials, \( F(2,28) = 8.176, p < .05 \).

Specifically, subjects significantly improved in their second Stroop (M = -.0111, SD = .0509) compared to baseline (M = -.1083 SD = .1133), \( p < .05 \); but, not in their third Stroop (M = -
.0278, SD = .0582) compared to baseline, $p > .05$. There was also no difference between subjects' second and third Stroops, $p > .05$.

![Stroop Interference Graph](image)

**Figure 3.** Stroop interference for accuracy across all three Stroops.

Next, a 2 order x 3 Stroop mixed ANOVA was run, investigating impact on the Stroop interference score as a result of taking the bilingual code-switching task. The pre-task Stroop used was the baseline Stroop score; the post-task Stroop score for the bilingual code-switching task was the Stroop immediately after the task in question was taken. The main effect was significant for Stroop, $F(2,26) = 9.452, p < .05$. A post-hoc using the Bonferroni adjustment revealed that Stroop interference was significantly lower after taking the bilingual code-switching (M = 99.26, SD = 93.95) task compared to baseline (M = 260.40, SD = 178.90), $p < .05$. Figure 4 below illustrates this.
Another 2 order x 3 Stroop mixed ANOVA was run, investigating the impact of the bilingual code-switching task on Stroop accuracy interference score. The pre-task Stroop accuracy score was taken from the subject's baseline Stroop; and, the post-task score was taken from the Stroop that immediately followed the task administered. Subjects exhibited significantly more executive functioning following a task, $F(2, 26) = 8.919$, $p < .05$. A post-hoc using the Bonferroni adjustment revealed that Stroop interference was significantly lower following the bilingual code-switching task ($M = -.0306, SD = .048$) compared to baseline ($M = -.1083, SD = .1133$), $p < .05$. This, along with the post-hoc reported in the preceding, suggests that taking the bilingual code-switching task helps improve executive function, in terms of both RT and accuracy. Figure 5 below illustrates this.
Next, the impact of the TS task was evaluated in the same way that the bilingual code-switching task was. As mentioned above, the main effect for both 2 x 3 ANOVAs were significant. In terms of RT, a post-hoc using the Bonferroni adjustment revealed that Stroop interference was significantly lower following the TS task (M = 136.53, SD = 108.87) compared to baseline (M = 260.40, SD = 178.90), p < .05; see Figure 6 for a visual representation. In terms of accuracy, a post-hoc using the Bonferroni adjustment revealed that Stroop interference was significantly lower following the TS task (M = -.0083, SD = .059) compared to baseline (M = -.1083, SD = .1133), p < .05; see Figure 7.
The findings were not just an order effect. In the first 2 x 3 ANOVA (which looked at Stroop interference as it concerns RT), order main effect was not significant, $F(1, 13) = 1.347, p$
In the second 2 x 3 ANOVA, which looked at accuracy, order main effect was also not significant, $F(1, 13) = 3.978, p > .05$.

**Discussion**

**Implications**

Prior research has indicated that engaging in certain physical activities and playing an instrument or video games helps improve executive functioning, but this finding was not found in this study. When, for instance, baseline Stroop interference scores (congruent reaction time subtracted from incongruent RT) were compared between those who engage in a physical activity and those who do not, there was no significant difference. Hence, these variables (and also whether the subject reported experience in more than one foreign language) were not used as covariates.

Prior research has also indicated that bilinguals perform better on executive functioning tasks compared to monolinguals. There were not any monolinguals in this study, based on the definition used; rather, all subjects had at least some experience with a foreign language. Hence, what was compared was Stroop interference scores prior to taking a task that activated the subject's L2 or should exercise executive functioning and after taking such a task. Both tasks, whether the bilingual code-switching (a 40-question vocabulary) task, or the task-switching (TS) task, significantly lowered Stroop interference score compared to subjects' baseline Stroop interference score. Both these tasks exercised executive functioning, the benefits of which are shown by the resulting (post-task) Stroop interference score as it concerns RT.

This same type of analysis was utilized, but investigated accuracy differences between congruent and incongruent trials. Just like the previous analysis concerning Stroop interference score as it concerns RT differences, subjects exhibited significantly more executive control
following either the bilingual code-switching task or the TS task. Such tasks do seem to activate executive functioning, resulting in decreased discrepancy between congruent and incongruent trials.

Subjects Both the bilingual code-switching and TS tasks helped subjects to exhibit more executive control, as evidenced by the significant decrease in Stroop interference following either task. The order in which these two tasks were administered did not play a role, as order main effect was not significant in both 2 order x 3 Stroop mixed ANOVAs.

This study originally sought to investigate the role of foreign language experience on executive functioning. Prior research on this topic has been mixed, with some studies reporting that bilinguals enjoy cognitive advantages (Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, Craik & Luk, 2008; Costa et al., 2008; Linck, Hoshino & Kroll, 2008), while others reporting that bilinguals do not enjoy such advantages when compared to monolinguals (Carlson & Meltzoff, 2008; Morton & Harper, 2007). Blumenfield and Marian (2013) give a list of various instances in which the latter has been supported; these cognitive advantages extend to task-switching, for instance (Prior & MacWhinney, 2010). All subjects reported some experience with one or more foreign languages, so this finding could not be replicated either way; but, none reported being advanced or fluent in any foreign language. This amount of foreign language experience was enough to, when the L2 was activated by the bilingual code-switching (a 40-question vocabulary task), enable the subject to exhibit more executive functioning such that the interference Stroop scores on both the RT and accuracy for post-task were significantly lower compared to baseline.

Limitations
Even though participants had to complete a bilingual worksheet, to obtain a measure of their proficiency with the language, only lexical knowledge was accessed. Other information about a participant's knowledge of another language, such as syntax, was not measured. Additionally, any sort of experience with a second language was defined here as bilingual to some degree, which eliminated the number of monolingual participants who would otherwise be conventionally defined as monolingual. Overall, there were not very many participants, so any conclusions would need more data in order to be more generalizable.

Future Research

Avenues for future research could include more extensive measures of knowledge of the L2: not only lexicon, but also syntax, for example. Additionally, one could divide bilinguals (as it is defined in this study) into two separate groups: those who have only had a class on the L2, and those who have used the L2 for any job- or professional-related purpose, which would include tutoring the language, translating documents, or teaching the language. Another line of research could compare bilinguals who have studied the language formally, versus those who have lived in a country where that language is spoken.
References


Figure 1: Flow chart showing the series of tasks run in the experiment.

All subjects:

Consent form → Experience Questionnaire → Baseline Modified Stroop Task

Subject placed into one of two groups: bilingual or monolingual

Bilingual

Task-switching task or code-switching task (counter-balanced) → Modified Stroop task → Code-switching task or task-switching task (counter-balanced) → Modified Stroop task

Monolingual

Task-switching task → Modified Stroop Task