THE EFFECTS OF LANGUAGE PROFICIENCY AND TASK TYPE ON EXECUTIVE FUNCTION AND WORKING MEMORY PERFORMANCE IN BILINGUAL ADULTS

by

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ABSTRACT

Research shows that bilingualism confers substantial cognitive benefits in children and the elderly. Bilingual advantages on nonverbal working memory, updating, shifting and inhibition tasks are widely reported. However, advantages are not always observed in young adults. These disparities may be due to varied proficiency levels and task types (verbal versus nonverbal) administered. This study sought to detect bilingual performance advantages on executive function and working memory tasks (verbal and nonverbal working memory, updating, shifting and inhibition tasks) between groups of 37 high and 37 low proficiency Spanish-English bilingual and 40 English monolingual young adults. Mixed MANCOVAs, using nonverbal intelligence scores as a covariate, identified no significant differences between language groups for performance on any task type or cognitive domain tested. Regression analyses showed nonverbal intelligence underlay performance on five of eight tasks. Young adulthood may represent a lull during which bilingualism does not confer cognitive advantages for functions examined.
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INTRODUCTION

The latest Census Bureau report on language use in the United States shows that bilinguals ages five and older account for over 19.9% of the population of the United States (U.S. Census Bureau; New York. Department of Labor, 2010). Of the nearly 20% of bilinguals, over 62% of U.S. bilinguals are Spanish-English bilinguals (U.S. Census Bureau; New York. Department of Labor, 2010). This population includes bilinguals who are highly proficient in both English and another language and bilinguals who are more proficient in one language than the other. These distinctions in proficiency become especially important when used for or against the argument that bilingualism offers cognitive advantages beyond expansion of the language system (Duncan and DeAvila, 1979).

While some studies have found cognitive benefits of bilingualism, such as advantages in conflict resolution (Costa, Herenandez, Sebastian-Galles, 2008), suppressing irrelevant information (Bialystok, Craik, Klien, & Vishwanathan, 2004; Bialystok, Craik, & Luk, 2008; Ransdell, Barbier & Niit 2006), shifting between mental sets (Garbin et al., 2010; Prior and MacWhinney, 2010), improving control of linguistic processes (Bialystok, 1987), and slowing the decline of executive functions in aging adults (Bialystok, 2007; Bialystok, 2010), these results are not consistently replicated, especially on verbal tasks. Bilingualism has been associated with detriments on tasks of verbal fluency (Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000), longer reaction
times for picture naming (Gollan, Montoya, Fennema-Notestine, & Morris, 2005), and more errors in picture naming (Roberts, Garcia, Desrochers & Hernandez, 2002). The present study was interested in finding whether these inconsistencies were rooted in the proficiency levels of bilinguals tested and the whether non-standardized assessment of proficiency have resulted in the incongruent results found in the literature thus far.

The American Council of Teaching Foreign Language (ACTFL) defines proficiency as functional language ability as it pertains to practicality in real-world situations. Differences in bilinguals’ second language functional ability are described as a continuum, which ranges from the highly articulate language user to the user with little to no functional ability by the ACTFL guidelines (ACTFL, 2012). Others define proficiency solely by tasks used to assess it for the experiment at hand, while other researchers do not specifically define proficiency, but define what it is not. Bialystok (1991) argues language proficiency is not just a skill, which is mastered, but also something, which alters cognition. The definition by the ACTFL was used for the purposes of this study, and proficiency was tested using the Bilingual Verbal Ability Tests (BVAT), which assesses multiple aspects of vocabulary to ensure that a bilingual could properly comprehend and communicate in the languages in which he or she claimed proficiency.

In earlier studies conducted on bilingual young adults, bilingual advantages on nonverbal tasks were observed when bilingual participants received multiple objective measures to verify language proficiency (Costa, Hernandez, & Sebastian-Galles, 2008). Costa et al. (2008) tested a sample of 200 young adults (100 monolinguals and 100 highly proficient Catalan-Spanish bilinguals) on an attentional network task (ANT). Participants were tested on reading, writing, comprehending, speaking and pronouncing one or both
languages and then administered the ANT. In the ANT, participants were to focus on the arrow cue in the middle of the screen and press specific response keys to indicate whether the arrow was pointing to the right or left. In neutral trials, participants were only shown one arrow to which they were to provide a response. In congruent and incongruent conditions, the central arrow cue was surrounded by arrows on both sides which were either facing in the same direction as the central cue (congruent condition) or facing in the opposite direction as the central cue (incongruent condition). It was found that bilinguals were faster at responding on both congruent and incongruent trials. Additionally, bilinguals incurred less shifting and inhibition costs. It was concluded that high proficiency bilinguals have more efficient executive control networks. The aim of the present study was to test whether the level of bilingual proficiency was the underlying reason for cognitive differences found between bilinguals and monolinguals.

Kousaie and Phillips (2012a) argued that most previous studies reporting an advantage for bilinguals relative to monolinguals have used samples that vary in the socioeconomic status (immigrant/nonimmigrant) and in the level of proficiency of the second language. After testing for proficiency using an animacy judgment task, they found that when French/English bilinguals and monolinguals are matched by status of native/second language and socioeconomical variables the bilingual advantage disappeared on a task examining verbal inhibition (the Stroop task). However, Kousaie and Phillips (2012b) found that while high proficiency bilinguals do not outperform monolinguals on behavioral measures, event-related potentials (ERPs) showed differences between monolinguals and bilinguals on resource allocation, conflict monitoring, stimulus categorization, and error processing. Additionally, others have
found that language proficiency is linked to control over attention, which is handled by executive components, such as inhibition and shifting (Bialystok, 1991). Segalowitz and Frenkiel-Fishman (2005) had previously separated an English-French young adult bilingual group using the same animacy judgment task and found that degree of shifting significantly correlated with second language proficiency. The disparity between the results of these studies and those of Costa et al., (2008) and Kousaie and Phillips (2012b) may be due to the fact that both studies tested proficiency in both languages and only used high proficiency bilinguals.

Assuming this holds true in young adulthood, accounting for bilinguals’ combined language proficiency (ability to communicate in real-world situations in two languages) should correspond to the degree of advantages on working memory and executive function performance in nonverbal and nonverbal tasks when both high and low proficiency bilinguals are tested. Meaning that high proficiency bilinguals should outperform low proficiency bilinguals on nonverbal tasks. This study attempted to explore the impact of proficiency on task performance by examining cognitive differences between monolinguals and high and low proficiency bilinguals on an array of verbal and nonverbal working memory and executive function tasks. Executive functions are cognitive control mechanisms of the frontal cortex used to carry out high-level cognitive tasks (generally goal-directed behaviors) (Bialystok, 2007). The current study assessed participants on three executive functions: updating, shifting, and inhibition; these are higher-level cognitive functions used for achieving goals that sometimes counter automatic responses to the environment (Hernandez, Costa, Fuentes, Vivas, & Sebastian-Galles, 2010).
Updating is defined as the process of monitoring incoming information and replacing outdated, or irrelevant, information in working memory (Miyake & Friedman, 2012). In a social setting, this may entail picking a language based on the peer with which one is meeting, and perhaps switching to a new language on the arrival of a person who cannot understand the current language initially being spoken. Shifting is the mental flexibility to switch tasks, rules or mental states (Prior & Macwhinney, 2010). Bilinguals may shift between two different languages, or shift between rules in one language. An example of the later is the use of formal and informal commands in Spanish. When peers speak with one another, they may use the informal commands; however, once a senior enters the conversation, peers must remember to switch to formal terminology, requiring shifting from one set of rules to another. Inhibition measures the ability to tune out irrelevant information and suppress automatic responses (Friedman et al., 2006). This can be seen when a bilingual must forcibly tune out someone at a neighboring table who is speaking their native language to focus on the individual at his or her table, who is speaking the bilingual’s secondary language. Working memory has been identified as a factor, which is integrated in executive functions (Miyake & Shah, 1999). Working memory has been defined as a short-term storage area that retains information for a short period of time in the presence of other incoming information (Baddeley, 2003).

The goal of this study was to evaluate whether high and low Spanish and English proficiency, bilingual young (18-45) adults performed better on nonverbal tasks than their monolingual peers. Most studies assessing bilingual cognition have been conducted on children and the elderly, leaving a gap in the research of younger adults. Studying this group can answer the important question of whether the effects of bilingualism are
manifested before the brain starts to age (around 60), as suggested by Bialystok (Bialystok, 2007). Attempts to bridge this gap have produced mixed results.

Prior and MacWhinney (2010) investigated whether the switching advantages displayed by bilingual children and older adults are also observable in bilingual young adults. The authors’ premise was that bilinguals have more experience in switching than monolinguals because, in bilinguals, both languages are active in the brain and constant switching between languages and their associated rules is required. To test whether the practical use of language switching would result in advantages on task switching, the authors tested a group of monolinguals and a group of heterogeneous bilinguals on a nonverbal task in which participants were to respond to either a shape presented on a screen, or to the color of shapes presented. One condition required participants to first respond to one type of cue (e.g., shape) and then switch to respond to the second cue (e.g., color). The authors found that the bilinguals were quicker to adapt to new rules for response, i.e. their reaction times (RTs) on switch trials were significantly smaller than those recorded for monolinguals.

While bilinguals have shown advantages on nonverbal tasks, they are usually outperformed by monolinguals on verbal tasks. Bialystok et al., (2008) found monolinguals performed significantly better at lexical retrieval tasks than bilinguals. However, bilingual proficiency was not tested. This relationship may have been stronger if proficiency were objectively tested in the sample. Since it has previously been found that high language proficiency in a bilingual’s first language facilitates higher proficiency in the second language (Mindt et al., 2008) high proficiency bilinguals are predicted to show more cognitive advantages than low proficiency bilinguals in nonverbal tasks and
the opposite pattern is predicted for verbal tasks. Language proficiency should have an inverted relationship to verbal task performance. Ivanova and Costa (2008) found that bilingual language proficiency resulted in slower word retrieval on a picture-naming task. Bilinguals self-reported proficiency, and highly proficient, primary language (L1) dominant bilinguals’ picture naming speeds were compared to monolinguals’ speeds. Bilinguals produced responses significantly more slowly than monolinguals in both their dominant (L1) and non-dominant (L2) languages. The results indicate a disadvantage for bilinguals on verbal tasks, or tasks requiring word generation for highly proficient bilinguals in comparison to monolinguals. However, this has not been tested with a sample of monolinguals and bilinguals who have been objectively tested for proficiency. These studies demonstrate both the importance of assessing bilingual proficiency and carefully selecting tasks to assess bilinguals on cognition.

In summary, few studies have compared verbal and nonverbal task performance with bilingual proficiency objectively measured. Studies that have tested for proficiency objectively have found bilingual advantages on shifting and inhibition nonverbal tasks and disadvantages on verbal tasks, indicating that task performance may be related to proficiency level. Studies in which proficiency level was self-reported have found no differences between language groups performance on executive function tasks in young adults (Bialystok et al., 2004; Bialystok, et al., 2008; Bialystok & Feng, 2009; Salvatierra & Rosselli, 2010). In order to thoroughly understand the role of proficiency on both tasks presented and task types used, proficiency should be tested using objective measures, and low proficiency bilinguals should be included to see group differences in bilingual performance on verbal and nonverbal measures. Additionally, while bilingual advantages
have been observed for performance on nonverbal tasks, bilingualism does not appear to show these same advantages on verbal tasks (Portocarrero, Burright & Donovick, 2007; Rosselli et al., 2000) This is believed to be a cost of dual language maintenance and can be measured in larger processing speeds on verbal tasks (Salvatierra & Rosselli, 2010).

The current study sought to objectively measure language proficiency prior to testing participants on both verbal and nonverbal tasks for a number of cognitive constructs (working memory, updating, shifting, and inhibition) with the goal of determining whether proficiency impacts bilingual performance on any of the cognitive constructs evaluated. The next section reviews the studies that have investigated bilingual performance on nonverbal tasks in each cognitive construct being explored in the current study.

**Bilingual Nonverbal Task Performance**

Bilingual advantages on nonverbal tasks result from the use of executive functions to manage their two languages without interference from language systems (Bialystok, 2009). Although it has been found that manipulation of two languages may cause disadvantages for bilinguals on verbal tasks (Gollan et al., 2008; Ivanova & Costa, 2008; Lehtonen & Laine, 2003; Nicoladis, Palmer & Marentette, 2007), more of the research has focused on bilingual advantages on nonverbal working memory and executive function task performance in comparison to monolinguals (Adesope, Lavin, Thompson, & Ungerleider, 2010; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; & Emmorey, Luk, Pyers, & Bialystok, 2008).

**Working memory.** A bilingual advantage has previously been shown on nonverbal working memory tasks, such as the backwards Corsi block task (Bialystok &
Feng, 2009; Feng, 2008; Milner, 1971). In this task, Bialystok and Feng (n.d.) presented monolingual and bilingual participants with a spread out array of 25, highlighted blocks arranged in a 5x5 pattern. The number of blocks that were highlighted changed between trials in order to increase the difficulty of the task. Participants were initially asked to click on the blocks in the order in which they were highlighted (simple condition) and then, in the most difficult condition, asked to click on the blocks by an ordering rule (such as top to bottom along each column). While participants performed equally well in the simple condition, bilinguals outperformed monolinguals on the difficult (backwards) conditions, which placed greater executive control demands on working memory. The authors argue these advantages were not due solely to advantages on working memory. Rather, they claim, the tools needed to outperform on such tasks are the result of bilingual advantages in executive functions such as updating (Hernandez et al., 2010) and inhibition (Bialystok & Feng, 2009).

**Updating.** While updating has not been tested directly (in children or adults), it has been measured concurrently with shifting and inhibition using dual-modality monitoring in young and old bilingual adults (Bialystok, Craik, & Ruocco, 2006). The dual-modality paradigm is believed to parallel the actual processes used to manage two languages. Bilinguals use updating, shifting and inhibition in unison to have constant verification that the language in use is the best choice (updating for surroundings) and, they determine that it is not, the bilingual must switch to the appropriate language (shifting) and inhibit the language not in use. In the dual task paradigm, participants are initially given a classification task in which they classify stimuli as letters or numbers (LN) in one condition and animals and musical instruments (AM) in a second condition.
In the dual-task condition, the stimuli can be congruent (as in both auditory and visual would both derive from either LN or AM) or unrelated (one stimulus from the AM and the other from the LN or vice versa). The unrelated condition is believed to be the more difficult condition, requiring updating to give a response and shifting between rules. Both in the young and old adult samples (consisting of monolinguals, balanced bilinguals, and unbalanced bilinguals,) bilinguals performed significantly better than monolinguals in the divided attention tasks when the stimuli presented clashed (requiring additional updating and shifting resources). Results for the unbalanced group did not differ from those seen in the balanced bilingual group.

The results show bilingual advantages on nonverbal updating tasks, but the authors do not explain the role of proficiency. The bilingual advantage on experimental tasks is believed to be a byproduct of the practical ways in which bilinguals use updating, shifting, and inhibition to switch between two languages in various environments. Updating is not the only executive function to be tested in conjunction with other executive functions; shifting and inhibition are also tested using tasks that require the help of other functions (Miyake & Friedman, 2012).

**Shifting.** Nonverbal tasks measuring shifting have been measured using the local-global task and tasks similar to the Simon task. Prior and Macwhinney (2010) compared the many ways in which task switching parallels language switching in bilinguals. They hypothesized that bilinguals would perform better on switching tasks affording two competing responses. To test this, the authors compared 44 bilinguals of mixed languages to 44 monolinguals on a task switching paradigm using cued task switching in which participants had to provide button press responses to either color or shape stimuli. The
experimenters used a sandwich design in which participants were given single-task blocks (they were only to respond to either shape or color stimuli (shifting)), followed by mixed-task blocks (participants were shown both shapes and colors and asked to respond to one, depending on the cue (which required inhibition)), and finally, single-task blocks again. Overall, it was found that bilinguals incurred less shifting costs than monolinguals (measured by RTs), but did not outperform them on mixed-task blocks. Along with showing bilingual advantages on speed of nonverbal shifting tasks, these results indicate that bilingual advantages in shifting abilities may underlie bilingual inhibition abilities.

**Inhibition.** One of the most common nonverbal inhibition tasks used to assess bilingual advantages is the Simon task (Simon & Rudell, 1967). In this task, participants are given specific response keys, which they are instructed to press in response to stimuli presented on either congruent side of the response key or on the incongruent side of the response key. Bilinguals have been shown to provide more rapid responses to congruent and incongruent stimuli in comparison to monolinguals on measures of inhibition (Bialystok et al., 2004; Bialystok, Craik, & Ryan, 2006; Costa, Hernández, & Sebastián-Gallés, 2008). Both Bialystok et al., 2004 and Salvatierra and Rosselli (2010) found bilingual advantages on a nonverbal inhibition task, the simple condition of the Simon task. Bialystok et al., (2004) used samples of monolingual and Tamil-English bilingual, young and old adults. Salvatierra and Rosselli (2010) tested monolingual and Spanish-English bilingual, young and old adults. Both studies found that older bilinguals showed smaller Simon effects on the simple version of this nonverbal task than monolinguals (i.e., were better at responding to incongruent stimuli presented on the opposite side of the response key). The findings for young adults align with Kousaie and Phillips’ (2012b)
who also found no significant differences on performance between monolinguals and highly proficient bilingual young adults on behavioral measures of inhibition.

Bialystok, Craik, and Ryan (2006) tested controlled attention and inhibition in 48 monolingual and bilingual college students using anti-saccade tasks with two conditions. In such tasks, participants are asked to focus attention on a target cue followed by a response cue. Participants must inhibit automatic responses in antisaccade conditions. Prosaccade conditions are ones in which the flashing cue and response are located on the same side of the screen. Whereas in antisaccade conditions, an indicator alerts participants that the response must be contrary to the side in which the flashing cue was presented. The saccade tasks used a simulated face on the computer screen to guide responses. Green eyes indicated a prosaccade condition, in which participants were to press the response button located on the same side as the flashing asterisk presented. The cue was presented 30 seconds after the change of eye color. Red eyes indicated the trial was an antisaccade condition, and participants were to press the response key on the opposite side of the cue (flashing asterisk).

To evaluate the gaze shift condition, the eyes of the simulated face also moved. This served as a third cue that would put additional pressure on executive resources. For example, in this task, it was possible to observe a combination of green eyes, a gaze to the left and a flashing cue on the right. Despite the fact that the gaze shift condition was more difficult, as it required suppression of two cues at once, bilingual participants responded significantly faster on antisaccade conditions in both the saccade and gaze shift tasks. However, it was found that overall performance (correct answers provided) was roughly equal between groups. These disparities in reaction times were predicted to
be amplified once bilinguals were sorted by proficiency, with high proficiency bilinguals predicted to experience the smallest inhibition costs.

**Bilingual Verbal Task Performance**

Jared & Kroll (2001) found that proficient bilinguals show constant activation of both languages and that some processes are slowed down by this mental juggling act. Specifically, bilinguals demonstrate weaker lexical access and smaller vocabularies than monolinguals (Bialystok & Craik, 2010). It has also been shown that attempting to process the language less frequently heard requires more of a bilingual’s working memory resources (Service, Simola, Metsanhelmo & Maury, 2002). This is usually evident in processing speeds and reaction times on verbal tasks, particularly on word generation tasks when bilinguals are forced to work in only one of their two languages (Sandoval, Gollan, Ferreira, & Salmon, 2010).

For example, Sandoval et al. (2010) found that young bilinguals perform worse on verbal fluency tasks than monolinguals. This may be a result of the brain requiring more time to produce a desired word due to infrequent use of a language for low frequency word generation (Ivanova & Costa, 2008; Ransdell & Fischler, 1987). One theory is that bilinguals perform poorly on verbal fluency tasks because their proficiency in two languages causes them to experience interference when they are forced to work in only one of the two languages. Assuming these findings hold true, bilinguals should be outperformed by monolinguals on all verbal tasks not given in their native language. The next section will explore whether this theory is true for verbal working memory tasks.

**Working memory.** While no study has directly explored the impact of bilingual proficiency on verbal working memory span in young adults using monolingual controls,
Service et al. (2002) explored how sentence comprehension influenced working memory span in 30 Finnish-English bilinguals using a complex span task in Finnish and English. Of this sample, 15 were in the English Majors (EM) group (high proficiency group for both languages) and 15 participants were in the Psychology Majors (PM) group, or the equivalence of a low proficiency group. Proficiency was measured using an English-as-a-foreign-language exam and the English majors group scored significantly higher than the Psychology majors group. The researchers hypothesized that, if bilinguals were less exposed to a language (in this case English) more working memory resources would be utilized to process information in that language and bilinguals would have lower recall spans.

In order to test this hypothesis, participants were given a complex span task in Finnish and English in which they were shown a picture while listening to a sentence and were asked to give a button response to indicate whether the presented sentence matched the picture. At the same time, participants were instructed to remember the last word of every sentence. It was predicted (and found) that the PM group had lower spans (probably due to less working memory resources) than the EM group. The PM group also made significantly more errors in English than in Finnish. The current study explored whether verbal memory span would be smaller (i.e. for participants testing as low proficiency bilinguals than high proficiency bilinguals) in a much larger sample of bilingual participants.

 Updating. Updating entails monitoring incoming information and replacing outdated, or irrelevant, information in working memory (Miyake & Friedman, 2012). Bilinguals are believed to use updating to evaluate their environment and determine
which language is best used in that environment; however, an experimental method which specifically tests updating in bilinguals has not been published. Much of the difficulty in examining updating stems from the fact that it is sometimes considered synonymous with working memory and monitoring. For example, studies have investigated updating via proactive interference. In such tasks, participants are presented with several lists, each of which has words of the same category as a previous list. After each list is presented, participants are asked to recall the most recent list heard. It is expected that after a certain number of lists, participants will correctly recall less words that were on the most recent list and more likely recall words of the same category from a previous list. Another similar task used to assess updating is the letter-memory task, (described below) (Miyake et al. 2000).

Bialystok and Feng (2009) used a proactive interference task to assess the effects of language proficiency on cognitive control. They tested 55 English monolingual and 54 mixed bilingual young adults. Proficiency was established by using a self-report of how often the second language was used in various scenarios and age of acquisition. Each participant was administered four lists of 10 words, given a filler task after each list, and then tested on word recall for each list. While the overall performance between groups was roughly the same, there were differences attributed to vocabulary and proficiency that should have been further explored. Separating bilinguals by proficiency is predicted to show an inversed relationship between combined language proficiency and verbal updating.

**Shifting.** Shifting is the mental flexibility to switch tasks, rules or mental states (Prior & Macwhinney, 2010). Shifting in bilinguals is shown in situations in which two
peers may choose to converse in a native language until a third (non-native language speaking) friend enters the conversation. In this scenario, the two friends would switch from the language they were using to the language familiar to all three friends. In labs, shifting can be measured by asking bilinguals to switch between their two languages on a task, requiring them to actively inhibiting the language not in use (Meuter & Allport, 1999,) or by asking participants to shift between two sets of rules they used to respond. The latter is especially used when one of the groups being tested is monolingual. While shifting has been measured using nonverbal tasks, a direct comparison of monolingual and bilingual performance on verbal shifting tasks has not previously been made. However, the importance of separating bilingual groups by proficiency for tasks has been shown using a shifting task.

Segalowitz and Frenkel-Fishman (2005) assessed whether proficiency in a second language (L2) related to degree of control on verbal shifting tasks requiring controlled attention with gramaticized words. Participants were screened to test proficiency in L2 using the lexical access (animacy judgment) task. Sixteen English-French bilingual undergraduates between 19 and 44 years of age were asked to speedily categorize nouns presented on a screen as either animate or inanimate objects using button responses. In the attention-shifting task, participants had to correctly assign the appropriate causal conjunction (but, also, and) or time adverbial (now, tomorrow, later) to two-part sentences in L1 (baseline) and L2. Higher proficiency bilinguals were expected to be faster at shifting (in this case, understanding the proper uses for the four choices given in order to best select which word best fits the sentence in L2) in comparison to participants with lower L2 proficiency and a correlation analysis confirmed this to be the
case. Additionally, hierarchical linear modeling found that the unique variance of bilingual proficiency in L2 could be explained by their speed of attention control in that language, showing that attention control in L2 plays a role in L2 proficiency. This result suggests that it is important to divide bilingual groups by language proficiency as level of proficiency in a language may have a direct relationship to the degree of executive advantages and disadvantages.

The current study tested whether Segalowitz and Frenkel-Fishman’s (2005) verbal shifting advantages could be replicated in a large sample, with high and low proficiency bilinguals groups divided and compared to monolinguals. Many of the tasks used to assess shifting require the use of inhibition, as was the case with the attention-shifting task used by Segalowitz and Frenkel-Fishman and other commonly used tasks, such as the Stroop task. The overlap demonstrates the need to test inhibition using a separate task when measuring shifting, and vice versa. The results of both sets of tasks would be the best way to gauge whether bilinguals truly show advantages (or disadvantages) in shifting, inhibition, or both.

Inhibition. Inhibition is the ability to suppress irrelevant information (Bialystok et al., 2004). Previous research conducted on bilinguals’ verbal inhibition ability has produced mixed results. While some have found bilingual advantages on interference suppression (Bialystok, Craik, & Luk, 2008; Hernandez et al., 2010; Zied et al., 2004) more recent research has not found differences between group performances (Kousaie & Phillips, 2012). Kousaie and Phillips (2012b) tested 25 monolinguals and 26 high proficiency bilinguals on three measures of inhibition (Stroop, Simon, and Erikson flanker tasks). Participants in the high proficiency bilingual group had learned French
before the age of 7, reported high usage of French in their everyday lives, and scored similarly on an animacy judgment task used to assess L2 proficiency. Results for all three tasks showed no significant group differences between groups. Bialystok, Craik, and Luk (2008) evaluated monolingual and heterogeneous bilingual, young and old adults and found that bilinguals respond more rapidly to the conflicting condition of the Stroop (verbal inhibition) task. While bilingual advantages are rarely seen on verbal tasks due to bilinguals’ delayed word retrieval (Ivanova & Costa, 2008), the studies above show advantages on nonverbal tasks have repeatedly been observed (Bialystok & Feng, n.d.; Costa et al., 2008; Prior & MacWhinney, 2010).

There are some factors that should be given consideration with respect to how bilingual performance on verbal cognitive tasks has been analyzed thus far. Most importantly, many of the executive functions have not been studied directly. For example, research on working memory subtly alludes to the usage of updating, but tasks believed to specifically target updating are not used. Similarly, while shifting and inhibition may go hand in hand, shifting is rarely measured directly. The second major point of concern is with the assessment of proficiency and the separation of groups by proficiency. While in some studies, the importance of proficiency for bilingual advantages is alluded to, it is not always measured, is sometimes measured by self-reports, and is at other times measured by a single vocabulary task. It is believed that using tasks to specifically examine working memory and each executive function in addition to separating groups using standardized methods to assess proficiency should provide an accurate assessment of whether bilingualism aides, hinders, or has null impact on verbal cognitive task performance.
Taken together, the review above shows a scarcity of research on young bilingual adults in the cognitive domains of interest. Many of the studies used limited tasks to assess one cognitive domain (working memory, updating, shifting, inhibition,) and there are conflicting experimental results within the published literature. Working memory and shifting have been shown to be impacted by language, updating has not been measured directly, and studies measuring inhibition have shown mixed results. Additionally, while some studies analyze proficiency in the bilingual participants, studies in which heterogeneous samples of bilinguals were used made it difficult to compare the results on cognitive tasks between language groups, limiting the generalization of the results.

In order to obtain a clear understanding of whether bilingual proficiency effects on cognition are seen based on the type of task presented to participants, the current study compared performance of low and high proficient Spanish-English bilinguals with monolinguals on multiple verbal and nonverbal working memory and executive function tasks. The following hypotheses were tested:

i. High language proficiency in two languages would impact nonverbal performance on working memory and executive function tasks. High proficiencies in Spanish and English were predicted to provide advantages in performance on nonverbal measures of working memory and executive functions. Highly proficient Spanish-English bilinguals were predicted to have greater recall on the nonverbal working memory and updating measures, experience a lower shift cost on nonverbal shifting tasks, and experience less inhibition on nonverbal inhibition tasks than the other two language groups. Low proficiency bilinguals were predicted to outperform monolingual participants in nonverbal tasks only.
ii. High language proficiency in two languages would impact verbal performance on working memory and executive function tasks. High Spanish and English proficiencies were predicted to have an inverse relationship with task performance on verbal working memory and executive function tasks (e.g., monolinguals were predicted to outperform both high and low proficiency bilinguals on verbal working memory and updating tasks). They were also expected to have the lowest shifting costs, and inhibition effects on verbal shifting and inhibition tasks.

iii. Language proficiency would not be related to domain performance. Language proficiency was not predicted to increase overall performance (on a combination of verbal and nonverbal tasks) on working memory or any specific executive function.

While countless factors could cause bilingual advantages on nonverbal tasks and disadvantages on verbal tasks, the level of bilingual proficiency in both languages was predicted to be the primary cause.
METHOD

Participants

One hundred twenty-five undergraduate students between 18 and 45 participated in the study. In order to control for decline in executive function due to aging, participants were excluded if they were above 45 years of age. Additionally, participants were excluded if they reported having a learning disability, reported fluency in languages other than Spanish or English, and if they did not come in to complete both verbal and nonverbal tasks. Using these exclusion criteria, 114 participants composed the final sample, of which 40 were English monolinguals (35 females), 37 were low proficiency Spanish-English bilinguals (33 females) and 37 were high proficiency Spanish-English bilinguals (29 females). A demographic and bilingual questionnaire was administered to gauge English and Spanish usage for each participant. Monolingual participants were all native English speakers who reported no or limited proficiency in a second language. Those with limited proficiency reported exposure to a second language in a classroom setting at older ages, and none reported attaining high proficiency. All the participants attended Florida Atlantic University at the time of participation.

The background variables of all three groups (age, years of education, and block design) are shown in Table 1. Scaled block design scores were used as a measure of nonverbal intelligence. A one-way ANOVA showed that mean Block Design scores differed significantly between language groups, $F(2,113)= 11.35$, $p<.0001$. Post hoc
comparisons showed that low proficiency bilinguals had significantly lower scores than both high proficiency bilinguals and monolinguals (Bonferroni’s multiple comparisons, p<.05) (See Table 1). The bilingual participants in the current study had similar language experience; all reported exposure to Spanish in their home environments while growing up. Participants were categorized into either high or low Spanish-English proficiency levels using combined English and Spanish scores on the Bilingual Verbal Ability Test (Muños-Sandoval, Cummins, Alvarado & Ruef, 1998).

Of the 37 low proficiency bilinguals, 10 participants (27.0%), learned English first, 26 participants learned Spanish first (70.3%) and one participant (2.7%) learned both languages concurrently. In the low language proficiency group, 21 participants preferred using English (56.8%), 13 participants preferred using Spanish (35.1%) and three had no preference (8.1%).

Five of the 37, or 13.5% of the high proficiency bilinguals learned English first and 31 (83.8%) high proficiency bilinguals learned Spanish first. One (2.7%) member of this group learned both languages simultaneously. For the high proficiency bilinguals, 21 (56.8%) preferred using English, 9 (24.3%) preferred Spanish, and seven (18.9%) had no preference.

**Tasks and Participants**

Testing was conducted in two sessions. During the first session, participants were given the Block Design task from the Wechsler Adult Intelligence Scale to assess non-verbal intelligence, the Bilingual Verbal Ability Tests in English and Spanish (when applicable) and either a series of verbal or non-verbal computerized executive function and working memory tasks. The computerized tasks were used to assess working
memory, updating, shifting, and inhibition. The verbal tasks consisted of the Forward Digit Span subtest from the Wechsler Adult Intelligence Scale, the Letter Memory task, the PlusMinus task, and the Stroop task. The non-verbal tasks consisted of the forward Corsi block task, the Tone Monitoring task, the Local-global task, and the simple version of the Simon task. Administration of the verbal and non-verbal computer tasks occurred on two separate days, and the DirectRT (Version 2006.2.28; Empirisoft Corporation; New York, NY) software randomized task presentation for each section. Order effects were controlled by rotating the session in which participants were administered the BVAT and by rotating presentation of verbal and nonverbal batteries. Participants were given one series of tasks (either verbal or nonverbal) at the end of their first session and came back for another session to take the second set of computer tasks.

**Bilingual Verbal Ability Tests (BVAT).** The BVAT (Muños-Sandoval et al., 1998) were used to assess participants’ language comprehension and speaking abilities in both English and Spanish (when applicable) using picture vocabulary, oral vocabulary and verbal analogies subtests. Administration of the BVAT took approximately 30 minutes per language. Each subtest began with baseline questions at a designated starting point for college students. The scores for each subtest were calculated and standardized. For the picture vocabulary subtest, participants could earn a maximum of 599 points in English and 598 in Spanish (group norm = 526.9 points). For the oral vocabulary (synonyms and antonyms) section, participants could earn a maximum of 595 points in English and 610 points in Spanish (group norm = 533.8 points). For the verbal analogies subtest, participants could earn a maximum of 574 points in English and 565 points in Spanish (group norm = 522.4 points). For monolinguals, the points earned for each
subtest were simply totaled. For bilinguals, the total English BVAT score was combined with the total Spanish BVAT score. A median split of bilinguals combined scores was conducted to separate the group into high and low proficiency. Participants could earn a maximum of 1768 points on the English version of the BVAT and 1773 points on the Spanish version of the BVAT; therefore, participants who took the test in two languages could earn a maximum of 3541 points. The median score for the bilingual sample was 3114.5 points. Participants with a score of 3115 or above were classified as high proficiency Spanish-English bilinguals. Bilingual variables are shown by proficiency in Table 1.

**Block Design subtest (Wechsler, 1991).** The Block Design subtest of the Wechsler Adult Intelligence Scale-IV (WAIS) is a 14 item, non-verbal measure of reasoning. It has also been shown to be a reliable measure to test equivalence between groups for non-verbal intelligence (Mercy & Steelman, 1982; Salvatierra & Rosselli, 2010; Weschler, 1991). Participants were given practice trials to familiarize them with instructions and were then scored based on the amount of time used to construct the figures. Block Design scores were used as a covariate on all comparisons due to group differences in performance.

**Dependent measures**

Working memory and each executive function (updating, shifting, and inhibition) were assessed using non-verbal and verbal tasks. All computerized tasks were administered using DirectRT (Version 2006.2.28; Empirisoft Corporation; New York, NY).
Nonverbal tasks. Four tasks were administered in the nonverbal battery. Working memory was assessed using the forward Corsi block task. Updating was assessed using the tone monitoring task. Shifting was assessed using the local-global. Inhibition was assessed using the simple version of the Simon task.

1. Forward Corsi block task. This task was the computerized version of the task described by Baddeley (2003). This task was used to assess nonverbal working memory. Each trial began with a cross hatch in the center of the screen. Following the cross hatch, nine grey blocks were shown at their relative standard positions on a black background on the computer screen. After 1000 ms, blocks were highlighted in yellow at the rate of 1000 ms per block highlighted, after which participants were once again shown a cross hatch, followed by the screen with nine grey blocks. Participants were instructed to use a mouse to click on the blocks in the order in which they were highlighted. The blocks were not highlighted when the participants clicked on them. A 2000 ms gap was kept between each trial. Participants were given four practice trials: the first two examples showed one block was highlighted, and during the second two practice trials, two blocks were highlighted. Participants were given feedback for each of the practice trials. Following the four practice trials, participants were given 24 trials during which sequence lengths varied from 1 through 8 highlighted blocks. Three trials were presented for each sequence length. The dependent variable was measured as the point at which participants got all three trials of a single length incorrect.
2. **Tone Monitoring Task.** Participants were given four blocks of 25 tones (high, medium, and low) presented for 500 ms each and an interstimulus interval of 2500 ms. As in Miyake et al., (2000), each block consisted of 8 high-pitched tones, 8 medium-pitched tones, and 8 low-pitched tones and one tone randomly selected from either the high, low, or medium category. Participants were instructed to press a response key every time they heard the fourth tone of each pitch. Therefore, there were six correct responses in each set of tones. In the event that participants responded to an incorrect tone (e.g., responding to the third high-pitch tone as opposed to the fourth), the tone count was reset on the computer so future responses are not marked as incorrect. Participants began the task with two practice trials, one of which consisted of 14 tones, and the other consisted of 25 tones. Researchers instructed participants on the first practice session and computer feedback was given for responses on the second practice trial. The dependent measure was the amount of correct responses out of a possible 24 correct responses.

3. **Local-global task.** This task was originally used by Miyake et al. (2000) to measure shifting. Participants were presented with a geometric, global, figure composed of much smaller, local, figures (i.e., Navon figures) on a computer screen. Depending on the color in which the figure was presented (blue vs. black), the participants named the number of straight or diagonal lines composing the figure (e.g., 0 for circle, 2 for X, 3 for triangle). An incongruent trial was one in which the smaller figure and the
larger figure had a different number of lines, e.g. a square (4 lines) composed of circles (0 lines). A congruent trial was one in which the larger and smaller figures were composed of the same number of lines (e.g. a triangle composed of Hs both had 3 lines). Stimuli were presented for 300 ms, followed by 500 ms response-to-trial intervals. When a figure was presented in blue ink, participants were instructed to count lines for the global (larger) figure, whereas a figure presented in black (smaller) ink meant that participants had to count the lines composing the local figure. Sixteen practice trials (on which participants were given the correct answer and reminded of the rules of the task) were followed by 96 target trials. The order of the stimulus presentation was pre-randomized so that half of the trials required shifting between naming the number of lines in global then local figures (or vice versa), and half of the trails did not require such shifting. The dependent variable was the shifting effect, calculated by subtracting the average processing speed for responding when both shapes in the Navon figure had the same number of lines from the processing speed for naming lines when the two figures had an incongruent number of lines.

4. **Simon task.** The simple version of Simon task (Simon & Rudell, 1967) was used to measure inhibition in bilinguals. Participants were shown either red or green colored squares on either the right or left side of the computer screen and were asked to press either the right shift key for red squares or the left shift key for green squares, regardless of the side of the
screen on which the stimulus was presented. Each stimulus was presented for 250 ms, after which a crosshatch was shown, and participants were asked to respond as quickly as possible. Congruent stimuli were stimuli presented on the same side as the response key, and incongruent stimuli were stimuli presented on the opposite side of the response key. The order of presentation will be randomized for all participants by the DirectRT software. The dependent variable was the Simon effect, calculated by subtracting the processing speeds of response when stimuli were presented on congruent sides as the response key from the processing speeds for pressing a response button when stimuli were presented on incongruent sides. This task consisted of 16 practice trials for which the participants received feedback, and 48 target trials.

**Verbal tasks.** Four tasks were administered in the verbal battery. Working memory was assessed using the forward digit span. Updating was assessed using the letter-memory task. Shifting was assessed using the plus-minus task. Inhibition was assessed using the Stroop task.

1. **Forward Digit Span tasks.** The forward span task from the WAIS- IV (Wechsler, 2008) was transcribed into a computerized version and administered using the same numbers and in the same order as the paper version. Numbers were presented at the rate of 2000 ms per number. Participants were presented number lists containing between 2 to 9 numbers. There were two trials for each digit length before the trial length was increased by one digit. Once all of the numbers of a set were
presented, participants were cued to recite numbers into a headset microphone in the order in which they were presented. Participants began with a 2 number practice trial, followed by sixteen scored trials. Participants’ digit spans (the dependent variable) were categorized as the point at which participants incorrectly repeated two lists of the same length (i.e., incorrectly repeating two consecutive series of the same length). The maximum span was nine numbers.

2. **Letter Memory.** The letter memory task served as a measure of updating. For this task, participants were presented serially with lists of letters of various lengths and were asked to recall the last four letters they were shown. Letters were presented one by one on the computer for 2000 ms per letter. As in Miyake et al. (2000) article, participants were asked to vocalize the last four letters presented out loud by mentally adding and subtracting letters from the list. For example, on the first example problem, participants should have said, “C…CB…CBE…CBED…” BEDA” and then recalled “BEDA” at the end of the trial. Letter lists were randomized in length between lists of 5, 7, 9, or 11 letters. Participants were given three practice trials of 5, 7, and 9 letters, respectively. Following the practice session, participants were given 12 trials (four trials for each length presented in random order) for a total of 48 letters recalled. The dependent variable was the number of letters recalled correctly out of 48.
3. **Plus-minus task.** The plus-minus task was also adapted from Miyake et al. (2000) in order to measure shifting. Participants were given three lists of simple arithmetic problems; the numbers for each list were presented one by one on a computer screen for 1000 ms at a time. Each list consisted of 30 two-digit numbers. All of the numbers from 10-99 were pre-randomized, with no repeated stimuli. For the first list, participants were told to mentally add 3 to the number presented and give an answer as quickly as possible into a microphone attached to a headset. For the second list, participants were instructed to subtract 3 from the numbers presented. For the third list, participants were to rotate adding 3 to the first number presented followed by subtracting 3 from the second number presented, and to continue rotating adding and subtracting 3 to the numbers presented on the computer screen. If a participant reversed the order of operation on the third list, the initial mistake was marked as incorrect, and the following responses were adjusted so the participant was not continually penalized. Each stimulus was presented for 1000 ms.

Reaction times were measured using DirectRT v2006. The numbers of correct responses for each of the three lists were calculated. Additionally, the processing speeds for each of the three lists were calculated. The shift cost was used as the dependent variable. It was calculated by subtracting the average time used to solve the addition and subtraction lists from the time taken for the rotation list.
4. **Stroop task.** In this inhibition task, participants were shown a series of asterisks in color ink and color words (e.g. blue) in either congruent or incongruent ink. Participants were asked to name the color ink in which either the asterisk or color word was presented while ignoring the color word (in the case of incongruent stimuli). Participants were shown each stimulus and were instructed to give a response as quickly and accurately as possible. Six color inks were used for the task: orange, green, purple, yellow, red and blue. Fourteen practice trials were randomized and administered. Of them were four trials with asterisks, two trials in which color words were shown in congruent ink, and eight trials with color words shown in incongruent ink. Practice trials were proceeded by test trials. Participants were given feedback for each of these trials. The scored portion of the task consisted of the same stimuli as in Miyake et al. (2000). The DirectRT program randomized presentation of the 72 asterisks, 60 color words shown in different color ink, and 12 color words shown in congruent ink. Stimuli were presented for 2000 ms and participants had 3000 ms to respond. The dependent measure was the Stroop effect, calculated by subtracting the average processing speed for responding to all asterisk stimuli from the average processing speed for naming all incongruent stimuli.

**Statistical Analyses**

A mixed Multivariate Analysis of Variance (MANOVA) with one between subjects factor and two within subjects factors was performed to test the impact of language
groups (monolingual, low proficiency bilingual, and high proficiency bilingual) on task type (verbal and nonverbal) and domain (working memory, updating, shifting, and inhibition tasks). Z-scores were calculated to standardize each of the dependent variables. Individuals’ working memory and updating scores and shifting and inhibition costs were subtracted from the mean for each task and that value was divided by the sample’s standard deviation for each task. This was done so participants overall performance for each task could be compared regardless of the different scales used to assess each task. A MANOVA was deemed appropriate for data analysis as it determines whether there are statistically significant mean differences between groups in situations with multiple dependent variables (Aron & Aron, 2003). The between-subjects comparison compared each language group’s z-scores on the dependent variables of each of the tasks. Means and standard deviations of z-scores used for analyses are shown on Table 3.

The unexpected significant differences of the nonverbal measure of intelligence prompted running a Multivariate Analysis of Covariance (MANCOVA) in order to test whether results found for the MANOVA changed after controlling for nonverbal intelligence scores. Pairwise comparisons using the Bonferroni adjustment for multiple comparisons were conducted (on the between and/or the within subject factors) to discriminate between means when the MANOVA and MANCOVA yielded significant results. The role of nonverbal intelligence was tested using regression analyses for each task. In total, one MANOVA, five MANCOVAs and eight regression analyses were used to analyze the data.
RESULTS

The present study was designed to assess the role of proficiency and task type on working memory and executive function tasks performance. Specifically, highly proficient bilinguals were predicted to perform significantly better on nonverbal tasks than the other two language groups, and monolingual participants were predicted to outperform both bilingual groups on all verbal tasks. Participants’ performances on verbal and nonverbal tasks are presented on Table 2. Scores for working memory and updating tasks and processing speeds for shifting and inhibition tasks were standardized for comparisons. Standardized values used for comparisons are shown on Table 3. Standard scores that exceeded three standard deviations above or below the mean were changed to a standard score of +/- 3. This was done because theoretically, standard scores should not exceed approximately three standard deviations above or below the mean (Aron & Aron, 2003). Reported effects were significant at an alpha level of .025 (unless otherwise specified) and any significant interactions were decomposed with Bonferroni post-hoc analyses (alpha level of .05). Results without a covariate will be reported first followed by results using a covariate.

Proficiency’s Impact on Task Performance

A Language Group (monolingual, low proficiency bilingual and high proficiency bilingual) and Task Type (nonverbal and verbal) and Domain (working memory, updating, shifting, inhibition) mixed MANOVA was conducted for the dependent
variables standardized scores for each of the four domains. The results of the MANOVA showed a significant interaction between language group and task performance, $F$ (12, 214) = 2.35, $p=.01$, partial $\eta^2 = .12$. As expected, the main effect of language groups was not significant (Pillai’s Trace), $F$ (4,222)= .86, $p=.50$, partial $\eta^2 = .02$. The results of univariate analyses of performance showed a significant impact of proficiency on nonverbal task performance, $F$ (6,333) = 3.10, $p=.01$, partial $\eta^2 = .05$, but not on verbal task performance, $F$ (6,333)= 2.23, $p=.04$, partial $\eta^2 = .04$. However, performance on non-verbal tasks did not significantly differ between language groups in post-hoc comparisons. It was assumed that the significant interaction of language group on nonverbal task performance was a Type I error based on the small effect sizes and lack of significant differences on pairwise comparisons. The significant interaction between language groups on nonverbal task performance may have also been the result of earlier differences found on Scaled Block performance. In order to examine this possibility, a MANCOVA was used, with Scaled Block design scores used as a covariate.

**Task Performance with Nonverbal Intelligence**

A mixed MANCOVA was undertaken to test whether accounting for controlling for nonverbal intelligence would impact results. Scores on the Block Design were used as a covariate. As expected, nonverbal intelligence scores had a significant impact on dependent variables, (Pillai’s Trace), $F$ (2,109) = 3.36, $p=.04$, partial $\eta^2 = .06$. Using scaled Block Design scores as a covariate impacted interaction effects. There was no longer a significant interaction between language groups and task performance on nonverbal and verbal working memory, updating, shifting, or inhibition tasks, (Pillai’s Trace), $F$ (12,212) = 1.53, $p=.12$, partial $\eta^2 = .08$. The results once again indicated no
significant main effect for language group, (Pillai’s Trace), $F(4,220)= .77$, $p=.55$, partial $\eta^2 = .01$. As result, language group differences on verbal and nonverbal tasks could not be analyzed further. However, MANCOVAs for language groups on each domain were performed as a precautionary measure.

**Individual Domain Comparisons**

There were no significant differences between language groups on nonverbal working memory performance, $F(2,110) = 2.51$, $p=.25$, partial $\eta^2 = .03$, or verbal working memory performance, $F(2,110) = 1.39$, $p=.09$, partial $\eta^2 = .04$. Additionally, there were no significant differences for performances on updating tasks. The tone monitoring (nonverbal) task showed no significant group differences, $F(2,110) = 1.76$, $p=.18$, partial $\eta^2 = .03$, as did the test of between subject effects for the letter memory task (verbal), $F(2,110) = 1.19$, $p=.31$, partial $\eta^2 = .02$. The shifting tasks also showed no significant differences on nonverbal, $F(2,110) = .14$, $p=.87$, partial $\eta^2 = .00$ and verbal tasks, $F(2,110) = .42$, $p=.66$, partial $\eta^2 = .01$. Results for inhibition task performance resembled those of the other domains, with both nonverbal, $F(2,110) = 1.73$, $p=.17$, partial $\eta^2 = .03$, and verbal task performance, $F(2,110) = .25$, $p=.77$, partial $\eta^2 = .01$ not showing any significant differences between groups.

**Nonverbal Intelligence and Task Performance**

Although the premise of this study was to test whether language proficiency could explain task performance, a confound may have impacted the outcome. Linear regression analyses were used to test if nonverbal intelligence scores significantly predicted participants’ performances on working memory and each of the executive function tasks. Regression results for the nonverbal working task indicated that the nonverbal
intelligence explained 10.7% of the variance ($R^2 = .107, F(1,113) = 13.43, p < .001$). It was found that nonverbal intelligence significantly predicted forward Corsi block performance ($\beta = .33, p < .001$). The results of the regression for performance on the verbal working memory task indicated that nonverbal intelligence explained 6.9% of the variance ($R^2 = .069, F(1,113) = 8.27, p = .01$). It was found that nonverbal intelligence significantly predicted forward digit span performance ($\beta = .26, p = .01$).

The results of the regression analyses for performances on verbal updating ($R^2 = .016, F(1,113) = 1.88, p = .17$), nonverbal shifting ($R^2 = .002, F(1,113) = .23, p = .63$) and verbal shifting ($R^2 = .015, F(1,113) = 1.65, p = .20$) tasks showed that nonverbal intelligence did not significantly impact performance on any of these tasks, However, nonverbal intelligence significantly predicted tone monitoring (nonverbal updating) performance ($R^2 = .092, F(1,113) = 11.37, p = .001$) ($\beta = .30, p = .001$) and performance on both inhibition tasks. It was found that nonverbal intelligence significantly predicted Stroop effects ($\beta = -.28, p = .004$). Regression results for the nonverbal inhibition task indicated that the nonverbal intelligence explained 4.0% of the variance ($R^2 = .04, F(1,113) = 4.65, p = .03$). It was found that nonverbal intelligence significantly predicted Simon effects on the simple condition ($\beta = -.20, p = .03$). The results of the regression for performance on the verbal inhibition task indicated that nonverbal intelligence explained 7.8% of the variance ($R^2 = .078, F(1,113) = 9.49, p = .003$).
DISCUSSION

On the basis of previous results (Bialystok, Craik, & Luk, 2008; Colzato et al., 2008; Costa, Hernandez, and Sebastian-Galles, 2008) this study expected to find young adult bilingual advantages on nonverbal working memory and executive function tasks and monolingual advantages on verbal working memory and executive function tasks when participants were tested for proficiency. Proficiency was objectively analyzed using the Bilingual Verbal Ability Tests on both monolinguals and Spanish-English bilinguals. Language groups were compared on verbal and nonverbal working memory, updating, shifting, and inhibition tasks. The data did not support the predictions: Bilingual proficiency did not impact task performance on any task type or any cognitive function domain.

The initial MANOVA, used to test whether language groups would perform differently based on task type (nonverbal and verbal) and domain (working memory, updating, shifting, and inhibition) found a significant overall interaction between language group and nonverbal task performance; however, post-hoc analyses revealed no significant group differences. The disappearance of the significant interaction between language groups and nonverbal task performance once block design scores were held constant indicated that the initial significant interaction may have been the result of either a Type I error or a confounding variable, nonverbal intelligence, or both. Both the lack of significance for post-hoc analyses and small effect sizes indicate that the groups
performed similarly on tasks, and that the significant interaction between language group and nonverbal task performance may have been the result of a Type I error. Additionally, the significantly lower Block Design (nonverbal intelligence) scores of the low proficiency group in the analysis of variance for background variables may have resulted in an interaction caused by low nonverbal performance of the low proficiency group. Once nonverbal intelligence was accounted for, this interaction disappeared. In either case, because the differences between group performance on verbal and nonverbal tasks were null once nonverbal intelligence was held constant, our first and second hypotheses could not be explored. As predicted for the third hypothesis, language groups did not differ on their performance for any particular cognitive domain when task type was not accounted for.

Moreover, regressions were conducted to examine the role of nonverbal intelligence on task performance, and it was found that nonverbal intelligence significantly predicted performances on nonverbal updating tasks, and both nonverbal and verbal working memory and inhibition tasks. The data show that nonverbal intelligence is a better indicator of cognitive task performance than language proficiency in young adults.

Although this study attempted used the American Council of Teaching Foreign Language’s guidelines to define proficiency and selected a proficiency measure that was believed to assess bilingualism in a way that fit the ACTFL’s definition, its results cannot be compared to the only previous study that thoroughly analyzed proficiency (Costa et al., 2008), as they did not test for differences in intelligence between groups. In a study by Costa et al. (2008), high proficiency, young adult bilinguals were shown to perform
significantly better on a nonverbal inhibition task than monolinguals. However, the group did not give participants an intelligence measure because they believed that using a large sample (n= 200) should eliminate group differences in intelligence. Costa et al. also did not use a low proficiency group while testing for cognitive advantages of bilingualism. The current study tested a relatively large sample and found that nonverbal intelligence was the factor that played a considerable role in the outcome. The low proficiency group was found to have significantly poorer nonverbal intelligence scores in our analyses. It is important to assess and separate low proficiency groups in order obtain the most generalizable results for bilinguals’ performance on cognitive function tasks.

Other studies comparing young adult bilinguals and monolinguals that have tested for differences in nonverbal intelligence have either not objectively tested for language proficiency, and/or have not divided the bilingual group based on proficiency (Bialystok et al., 2004; Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009; Salvatierra & Rosselli, 2010; Wodniecka, Craik, Luo, & Bialystok, 2010) making it difficult to compare previous results with the results of the current study or with other previous studies.

Our results are contrary to those observed by Prior and MacWhinney (2010) who found bilinguals demonstrate advantages in shifting as young adults. However, Prior and MacWhinney’s bilingual participants self-reported proficiency and spoke a heterogeneous languages (making objective testing of bilingualism a difficult feat). Participants were also only tested on a nonverbal shifting measure, which may have advantaged bilingual participants (Bialystok, 2009). Our study tested a group of homogenous (Spanish-English) bilinguals and objectively measured proficiency to divide
bilinguals into high and low proficiency groups. Participants were tested on both verbal and nonverbal methods of shifting and it was found that participants did not differ in shifting performance on either type of task. A possible explanation for differences observed between studies may be due to the method in which participants responded during shifting tasks. Prior and MacWhinney’s shifting paradigm asked participants to use the keyboard to enter responses, while both shifting measures in the current study asked participants to voice responses into a microphone.

Soveri, Rodriguez-Fornells and Laine. (2011) also reported nonverbal shifting advantages in bilinguals when participants gave button press responses to stimuli presented. Our shifting, verbal updating, and verbal inhibition measures required bilinguals to respond verbally into a microphone. Word retrieval has been shown to be slower in bilinguals than in monolinguals (Gollan et al., 2005; Ivanova & Costa, 2008). The button press format may allow bilinguals to respond more rapidly, lowering shift costs, as observed by Soveri et al. This emphasizes the importance of consistent assessment methods across multiple tasks.

Kousaie and Phillips (2012b) tested bilinguals on multiple inhibition tasks and found non-significant differences between monolinguals and bilinguals. The current study tested for and separated the bilingual group by proficiency and separated analyses by task type. These separations of groups and analyses were predicted to show group differences that were not observed by Kousaie and Phillips on task type (nonverbal and verbal) and cognitive domains tested. However, neither group of young adult bilinguals in the current study demonstrated any advantages in working memory or executive function tasks over monolinguals.
Our results also align with reports that executive advantages on inhibition tasks are not observed in young adults (Bialystok et al., 2004, Salvatierra and Rosselli, 2010, and Bialystok, 2006). However, these results conflict with those of previous studies which measured shifting and inhibition in bilinguals (Bialystok et al., 2006; Costa et al., 2008; Hernandez et al., 2010). The overall unidirectional lack of advantages on both shifting and inhibition was not surprising considering Meuter and Allport’s (1999) findings that shifting requires inhibition and that advantages tend to go hand-in-hand.

The current study measured proficiency, assessed performance on a large battery of cognitive function tasks, and tested a large sample of bilinguals in each proficiency group. However, it is possible that there is no link between high proficiency in two languages and advantages working memory and executive functioning during young adulthood. De Groot (1965) reported that higher proficiency in a skill (his study focused on chess) would translate into better focus and attention to meaningful patterns in the exercise of that specific skill but benefits would not necessarily be seen in meaningless (irrelevant) tasks. It may be that highly proficient Spanish-English bilinguals do not outperform other groups on verbal or nonverbal tasks because the tasks tested have no relevance to effective communication in Spanish.

This research sought to determine whether bilingualism, specifically language proficiency, provides advantages in the performance of working memory and executive functions. Differences in language proficiency did not influence participants’ performance on nonverbal working memory or executive functions tasks. However, high proficiency bilinguals and monolinguals outperformed bilinguals with low Spanish-English proficiency on the task assessing nonverbal intelligence (Block Design). This
study shows that other cognitive differences may underlie task performance between monolinguals and bilinguals.

The major methodological differences between this work and previous studies are in the size of the sample, and the comprehensiveness with which language proficiency was evaluated. Most previous studies have used smaller samples and have not objectively examined proficiency. Also, most of the published literature has looked at advantages and disadvantages of bilingualism on a single, specific, cognitive task. As far as we know, the current study is the first to examine monolingual and bilingual differences on a battery of cognitive function tasks. In conclusion, this study shows young adults’ nonverbal intelligence scores are better predictors of cognitive task performance than language proficiency. While the advantages of bilingualism have been seen in children and in the elderly, (Biaystok, 1999, Bialystok et al., 2004; Bialystok, 2007; Salvatierra and Rosselli, 2010) our finding that no statistically significant advantages were demonstrated on any task tested by either bilingual group or monolinguals suggests a lull in the cognitive impacts of bilingualism during young adulthood (Bialystok, 2007).

Limitations

One possible limitation of the current study was fatigue resulting from the long duration of testing. Although presentation of materials was rotated in an attempt to prevent the effects of fatigue, a bilingual’s initial testing session ranged from one to two hours and a monolingual’s initial session ranged from fifty minutes to an hour and a half (at maximum). These differences may have impacted task performance, especially for the bilingual group. Additionally, bilinguals were not classified as balanced or nonbalanced. Previous research with bilingual adults has shown the effects of bilingualism were more
prominent when testing balanced bilinguals (Kroll & Stewart, 1994). Future research should classify participants objectively by proficiency and whether they are balanced or nonbalanced. A combination of balance and proficiency level may explain group differences in nonverbal intelligence and bilingual advantages and disadvantages on cognitive function tasks. Furthermore, the heterogeneous population of South Florida may not be representative of bilingual populations worldwide and so our results may not necessarily be generalizable to other bilingual populations. The unique nature of South Florida may allow Spanish-English bilinguals to practice their language both at home and in their school and work environments due to the large population of Hispanics in Dade and Broward counties. Bilinguals in other regions may not have as many opportunities to keep both languages active as frequently as the population tested in the present study and may not be exposed to as wide a variety of dialects as can be found spoken in South Florida.

**Future Research**

This study aimed to contribute to the larger body of research revolving around whether bilingual effects extend beyond language and whether bilingual young adults obtain the level of proficiency needed to see robust advantages on verbal and nonverbal tasks. With the number of bilinguals in the United States growing, there is a greater need for new understanding of the cognitive impacts of bilingualism. Future research should test participants on multiple executive functions and working memory with assessments that are not so long as to result in fatigue. Further research should also address differences between groups using behavioral and electrophysiological measures to identify additional group differences. Although Kousaie and Phillips (2012b) found no
significant group differences on behavioral measures between monolinguals and highly proficient bilinguals, differences were visible between groups’ event-related potentials. Objective separation of bilingual groups by proficiency in conjunction with electrophysiological measures may better help understand the impacts of bilingualism in young adulthood. We would also like to suggest that results be analyzed using Structural Equation Variance to reduce the occurrence of false positives. In addition, to provide a true composite view of the impacts of bilingualism on working memory and executive functions, it would be valuable to repeat testing in a group of bilingual children as young adults, and then again after 60 for proficiency and executive function measures. This would allow determination of whether the lull in the impacts of bilingualism in young adulthood that has been hypothesized to occur is in fact observable.
# TABLES

Table 1.

*Demographic and Bilingual Variables by Overall Proficiency Scores*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Monolingual (n=40)</th>
<th>Low proficiency (n=37)</th>
<th>High proficiency (n=37)</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>25.83 (6.43)</td>
<td>26.03 (6.09)</td>
<td>26.86 (7.18)</td>
<td>.266</td>
<td>.767</td>
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<tr>
<td>Years of Education</td>
<td>15.43 (1.15)</td>
<td>14.88 (1.15)</td>
<td>14.89 (1.24)</td>
<td>2.72</td>
<td>.070</td>
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<tr>
<td>Age of L2 Acquisition</td>
<td>--</td>
<td>9.71 (7.21)</td>
<td>7.95 (6.94)</td>
<td>1.13</td>
<td>.293</td>
</tr>
<tr>
<td>Block Design Score (scaled)</td>
<td>11.83 (2.99)</td>
<td>8.95 (2.55)</td>
<td>11.16 (2.69)</td>
<td>11.35</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>1590.38 (42.50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>English BVAT</td>
<td>1531.30 (39.98)</td>
<td>1589.46 (29.60)</td>
<td>29.90</td>
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<td></td>
</tr>
<tr>
<td>Spanish BVAT</td>
<td>--</td>
<td>1522.49 (49.48)</td>
<td>1545.89 (47.64)</td>
<td>23.33</td>
<td>.000</td>
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</table>
Table 2.

*Nonverbal and Verbal Task Performance Results by Language Groups*

<table>
<thead>
<tr>
<th>Task</th>
<th>Monolingual</th>
<th>Low Proficiency Bilingual</th>
<th>High Proficiency Bilingual</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
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<tr>
<td>Corsi block span (8)</td>
<td>5.68</td>
<td>0.97</td>
<td>5.54</td>
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<tr>
<td>Tone Monitoring (24)</td>
<td>12.51</td>
<td>5.19</td>
<td>9.73</td>
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<tr>
<td>Global Local Score (96)</td>
<td>91.48</td>
<td>6.85</td>
<td>91.95</td>
</tr>
<tr>
<td>GL Response Speed for Trials with Shifting (ms)</td>
<td>861.82</td>
<td>518.40</td>
<td>1214.90</td>
</tr>
<tr>
<td>GL Response Speed for Trials with No Shifting (ms)</td>
<td>860.82</td>
<td>533.83</td>
<td>1204.94</td>
</tr>
<tr>
<td>GL Shift Cost</td>
<td>1.00</td>
<td>111.86</td>
<td>9.96</td>
</tr>
<tr>
<td>Simon Simple Correct (48)</td>
<td>47.18</td>
<td>1.32</td>
<td>46.05</td>
</tr>
<tr>
<td>Simon Simple average time with Incongruent response (ms)</td>
<td>471.72</td>
<td>85.85</td>
<td>533.83</td>
</tr>
<tr>
<td>Simon Simple average time with Congruent response (ms)</td>
<td>449.64</td>
<td>84.66</td>
<td>490.52</td>
</tr>
<tr>
<td>Simon Simple Cost (ms)</td>
<td>22.08</td>
<td>32.53</td>
<td>43.31</td>
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<tr>
<td>Forward Digit Span</td>
<td>6.83</td>
<td>1.28</td>
<td>6.05</td>
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<td>Letter Memory (48)</td>
<td>35.65</td>
<td>9.02</td>
<td>36.89</td>
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<tr>
<td>Plus Minus Addition (30)</td>
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<td>.94</td>
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<td>Plus Minus Subtraction (30)</td>
<td>28.80</td>
<td>1.73</td>
<td>27.11</td>
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<td>Plus Minus Rotation (30)</td>
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<td>1.62</td>
<td>26.84</td>
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<tr>
<td>Plus Minus Addition Speed (s)</td>
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<td>11.39</td>
<td>29.90</td>
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<tr>
<td>Plus Minus Subtraction Speed (s)</td>
<td>23.79</td>
<td>11.25</td>
<td>30.00</td>
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<tr>
<td>Plus Minus Rotation Speed (s)</td>
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<td>13.44</td>
<td>31.07</td>
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<td>Plus Minus Shift Cost (s)</td>
<td>2.89</td>
<td>6.28</td>
<td>1.12</td>
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<td>Stroop Score (132)</td>
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<td>1.22</td>
<td>130.92</td>
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<tr>
<td>Stroop Incongruent Speed (ms)</td>
<td>676.97</td>
<td>266.12</td>
<td>812.58</td>
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<tr>
<td>Stroop Neutral Speed (ms)</td>
<td>591.21</td>
<td>232.23</td>
<td>691.47</td>
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<tr>
<td>Stroop Inhibition Cost (ms)</td>
<td>85.77</td>
<td>71.59</td>
<td>121.11</td>
</tr>
</tbody>
</table>

s = seconds                      ms = milliseconds
Table 3.

*Nonverbal and Verbal Task Z-Scores by Language Groups*

<table>
<thead>
<tr>
<th></th>
<th>Monolingual (n=40)</th>
<th>Low Proficiency Bilingual (n=37)</th>
<th>High Proficiency Bilingual (n=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Corsi block span</td>
<td>.08</td>
<td>1.10</td>
<td>-.23</td>
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<tr>
<td>Forward Digit Span</td>
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<td>-.28</td>
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<tr>
<td>Tone Monitoring</td>
<td>.17</td>
<td>1.05</td>
<td>-.39</td>
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<tr>
<td>Letter Memory</td>
<td>-.13</td>
<td>1.21</td>
<td>.03</td>
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<tr>
<td>GL Shift Cost</td>
<td>.03</td>
<td>.84</td>
<td>-.03</td>
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<tr>
<td>Plus Minus Shift Cost</td>
<td>-.08</td>
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<td>.16</td>
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<td>Simon Simple Cost</td>
<td>.25</td>
<td>.88</td>
<td>-.32</td>
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<tr>
<td>Stroop Inhibition Cost</td>
<td>.19</td>
<td>.85</td>
<td>-.23</td>
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REFERENCES


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Garbin, G., Sanjuan, A., Forn, C., Bustamante, J.C., Rodriguez-Pujadas, A., Belloch, V.,


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