

ABSTRACT

Title of Thesis: EXECUTIVE FUNCTION IN APHASIA: IS THERE A
BILINGUAL ADVANTAGE?

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Previous studies have demonstrated that there is a bilingual advantage in neurotypical populations on tasks of executive functions, particularly inhibition. However, little research has been conducted on a population with aphasia. This study examined whether bilingual persons with aphasia (BPWA) and monolingual persons with aphasia (MPWA) displayed any differences on tasks of executive functions. Four BPWA and four MPWA matched for age and Western Aphasia Battery subtest scores were administered a linguistic Stroop task, a nonlinguistic Stroop task, a trail-making task, and a non-verbal memory task. Results demonstrated that the two groups did not have significantly different scores on any of the tasks. While both groups of PWA were slower than neurotypical adults on reaction time measures, accuracy on all four tasks was unimpaired and within the normal range. These results, although preliminary, given the small sample size and high performance accuracy, suggest that there may not be a clear “bilingual advantage” on tasks of executive function.

EXECUTIVE FUNCTION IN APHASIA: IS THERE A BILINGUAL ADVANTAGE?

By

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Introduction

Human speech, while apparently effortless in most situations, is a complex process which consists of selecting the appropriate word or words from the mental lexicon, retrieving the corresponding phonological representations (sounds), and articulating the sequence of sounds, all within a second (Indefrey & Levelt, 2004). For bilinguals, or people who speak two or more languages regularly, this process is complicated even further by the need to select the appropriate language for a given context and suppress the competing language. Exactly how bilinguals are able to accomplish this task so adeptly is not well known, but is becoming of increasing importance and relevance as there are an estimated 35 million people living in the United States who are proficient bilinguals (U.S. Census, 2011).

The question of how bilinguals manage two vocabularies and two sets of grammatical rules has become a more heavily researched topic in recent years, and the relationship between bilingualism and cognition especially has garnered a lot of attention. Some consequences of bilingualism may include a smaller vocabulary in each language than monolinguals have in one language, slower picture naming, reduced verbal fluency, more tip-of-the-tongue moments, and increased reaction times in lexical decision tasks due to interference (Bialystok, 2009). However, bilingualism could also lead to some cognitive benefits. Researchers hypothesized that a lifetime of suppressing the irrelevant language in a given context and attending to the target language could result in increased executive functioning (EF) skills, and more specifically, inhibitory skills (Bialystok, 2009; Bialystok, Craik, Klein & Viswanathan, 2004; also see Hilchey & Klein for a critical analysis of data). Green (1998) proposed a more efficient supervisory attentional system (SAS; Baddeley, 1986) for bilinguals compared to monolinguals. The SAS suppresses irrelevant information during various tasks, including non-linguistic tasks.

The nature and the extent of any bilingual advantage are not currently well understood, and even less is known about how a bilingual advantage may alter the effects of brain damage in bilingual individuals. It is reasonable to hypothesize, however, that enhanced EF skills as a result of bilingualism might result in more preserved EF after damage due to cognitive reserve. Indeed, a very preliminary report by Bialystok et al. (2007) suggests that bilingual individuals may experience later onsets of dementia compared to monolinguals by up to four years. Other studies by Purdy (2002) and Penn et al. (2010) examined performance of executive function in persons with aphasia (PWA), who are persons with language deficits due to stroke or brain damage. They found higher EF scores in small groups of bilinguals compared to monolingual persons with aphasia. Penn et al. (2010) suggested that enhanced EF skills in normal bilinguals may translate to preserved EF skills in bilingual PWA. Another line of thinking argues for a potential bilingual disadvantage: if bilinguals truly rely more on EFs to perform both linguistic and non-linguistic tasks, then EF deficits might contribute to the appearance of language deficits post-stroke. Both of these studies are preliminary due to the small sample size and design flaws. Therefore, further research is warranted to clarify whether BPWA score better than MPWA on measures of executive functions. A better elucidation of the EF abilities of PWA is important because it is known that EFs not only influence communicative success, but also other treatment outcomes (Fridriksson et al., 2006; McDonald & Pearce, 1998; Penn et al., 2010; Purdy, 2002).

This study aims to compare executive functioning skills between two groups, monolingual persons with aphasia (MPWA) and highly proficient bilingual persons with aphasia (BPWA) in order to examine the hypothesis that bilinguals will have more preserved EF skills when compared to MPWA matched for subtest scores of aphasia (e.g. the auditory comprehension subtest of the Western Aphasia Battery – Revised; Kertesz, 2007) and severity of

aphasia. The following section will provide a brief background on bilingual lexical processing and its implications on cognitive control. Studies have shown that bilinguals activate both languages when accessing a word in the mental lexicon (Colomé & Miozzo, 2010; Costa et al., 1999; Kroll & Stewart, 1994; van Hell & Tanner 2012;). Because we know that bilinguals are able to speak in a selected language with minimal interference from the non-target language, there must be a process by which bilinguals suppress the irrelevant language. Next, a brief overview of EF will be given, with particular focus on inhibition. Factors which affect testing EF will be addressed and a critical review of studies which explored EF skills in bilinguals will be given. In the following sections, aphasia and executive functions will be explored, highlighting literature from both monolingual and bilingual studies.

Lexical Access in bilingual speakers: implications for cognitive control

As described in many models of speech production (Caramazza, 1997; Kroll & Stewart, 1994; Levelt, Roelofs, & Meyer, 1999), activation of a concept influences selection of the corresponding lexical representation. For example, if an individual wants to select a word with the attributes “large + animal + trunk,” the word “elephant,” will probably be activated, but “whale” or “giraffe” might be activated, too, because they share two of the three attributes. Lexical representations that are semantically related to the target word may be simultaneously activated and may compete for selection (for example, the concept of horse may activate lexical representations of donkey and cow). The irrelevant word(s) are suppressed by inhibitory mechanisms and the target word proceeds to phonological encoding (Dell, Schwartz, Martin,

Saffron, & Gagnon, 1997; Levelt et al., 1999)¹. In bilinguals, the process of lexical selection may become more complicated due to the potential for activation of related lexical representations, not only within the same language, but also across the multiple languages of the speaker (Costa et al., 1999; Finkbeiner et al., 2006). The revised hierarchical model of bilingual memory (Kroll & Stewart, 1994) highlights the interconnectivity that exists between both lexicons in a bilingual individual and suggests that both lexicons may be activated during word retrieval. Numerous studies have examined whether the non-target language is activated during lexical selection in bilingual speakers and have found evidence of dual activation (Colomé & Miozzo, 2010; Costa et al., 2009; Hermans, Bongaerts, de Bot & Schreuder, 1998).

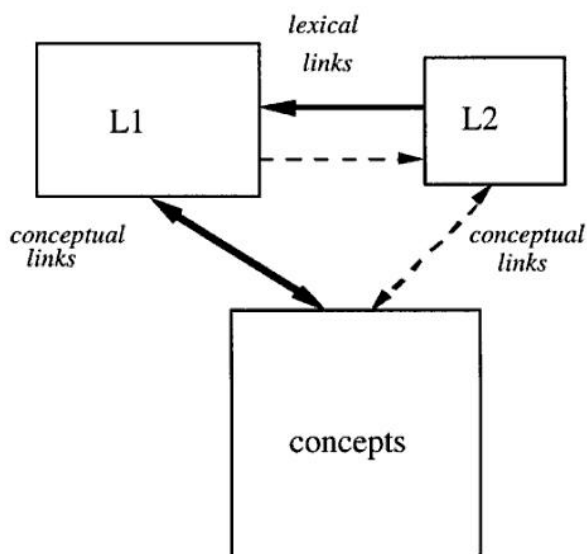


Figure 1. Taken from Kroll & Stewart’s (1994) revised hierarchical model of bilingual memory. The solid lines indicate a strong connection while the dotted lines indicate a weaker connection. In the model, Kroll and Stewart explain that the link between L2 and concepts strengthens as proficiency in L2 increases.

¹ This is a general overview of the lexical selection process. It must be pointed out that the exact mechanisms of lexical competition and ensuing inhibition are debated and unresolved. These are beyond the scope of this study.

Even though bilinguals have been shown to have slower reaction times in most lexical naming tasks, bilingual individuals converse in a monolingual context as effectively as monolinguals. A bilingual speaker, having chosen one language to use in a given context, will generally not experience “intrusions of the non-selected language, and misunderstandings arising from mistaking an input for a word in the other language are rare” (de Groot, 2011, p. 279). Given that the non-target language is rarely produced by normal bilingual speakers, the implication is that bilinguals must exert strong inhibitory processes to suppress the multiple irrelevant lexical representations. Researchers have proposed that this constant inhibition of the non-target language could lead to a generalized improvement of inhibitory mechanisms that extend beyond the linguistic domain (Colome & Miozzo, 2010; Costa et al., 1999; Green, 1998; Green & Abutalebi, 2008; Hermanns et al, 1998; Poulisse, 1999; van Hell & Tanner, 2012).

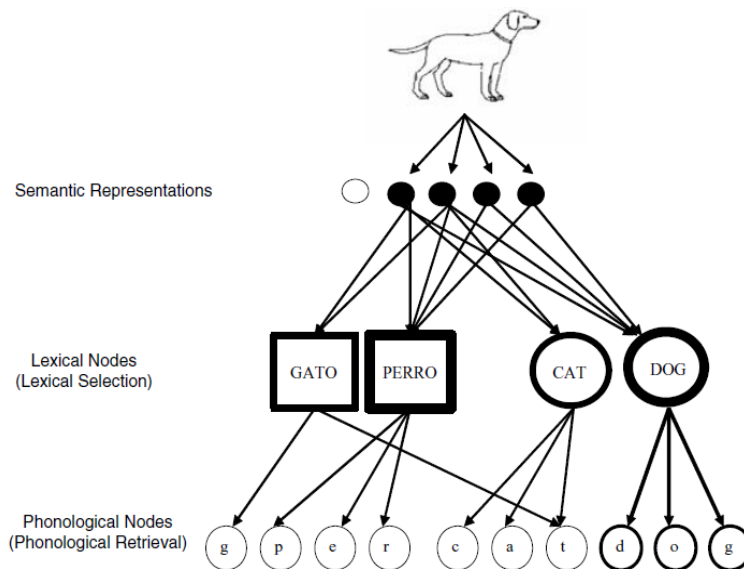


Figure 2. This figure from Costa, La Heij, & Nevarrette (2006) shows dual activation of L1 and L2 at various levels of language processing. At the level of semantic selection, the semantic concept *cat* may be selected due to its close semantic relationship to *dog*. At the level of lexical selection, both *cat* and *dog* and their Spanish correspondents *gato* and *perro* are activated. At the level of phonological retrieval, the bold lines indicate the correct selection of *d*, *o*, and *g*.

Some researchers have proposed that, if bilinguals are constantly inhibiting the competing non-target language, then they may have an overall enhanced ability to suppress competing cues even in non-verbal tasks (Bialystok, 1999; Bialystok, Craik, et al., 2004; Green, 1998;). Inhibitory mechanisms, which are subsumed under the broader area of executive functions, are discussed further in the next section. Neuroimaging findings have further supported the idea that compared to monolinguals, bilingual speakers may utilize additional brain circuitry related to cognitive control (Abutalebi, 2008; Crinion et al., 2006; Goral, Levy, Obler, & Cohen, 2006). In a review of neuroimaging studies of language processing of the second language in bilinguals, Abutalebi (2008) noted that most studies report activity in brain regions associated with cognitive control such as the prefrontal cortex, the anterior cingulate cortex and the caudate nucleus (located in the basal ganglia; see Figure 3 for a list of studies). Some researchers hypothesize that these additional neural resources used to switch and inhibit between L1 and L2 may give bilinguals an advantage in other inhibition tasks. In the next section, complex cognitive functions such as inhibition which have been implicated in language control will be explored.

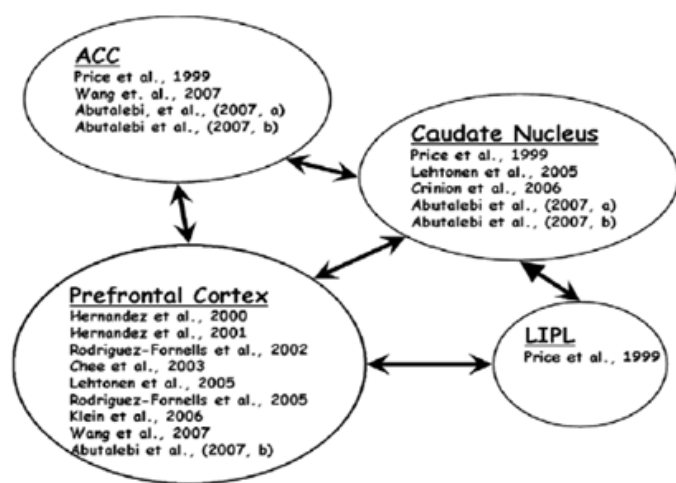


Figure 3. From Abutalebi & Green (2008). This figure shows neuroimaging studies that have found activation of the anterior cingulated cortex, the prefrontal cortex, and the caudate nucleus in tasks that required bilinguals to inhibit the irrelevant language.

Executive Functions

Miyake (2000) refers to executive functions as “general-purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition” (p.50). Executive functions allow individuals to plan, organize, and complete more basic activities (Alvarez & Emory, 2006). For example, walking down the street while conversing requires the individual pay attention to his surroundings, follow pedestrian signs, formulate language, and listen/process what the conversational partner says. Coordination of all of these various actions is accomplished through executive functions. A variety of processes may be considered to be part of executive functions, (including inhibition, shifting, initiation, working memory, attention, planning/organization, and self-monitoring). Executive functions are generally believed to be controlled by neural substrates in the frontal lobe (Keil & Kazniak, 2002), although there is some speculation that executive functions are more diffuse in the brain (Murray, 2012). The three processes which have been more closely examined in the literature include inhibition, working memory, and sustained and selective attention² (Alvarez & Emmorey, 2006; Miyake et al., 2000). Inhibition is required to suppress irrelevant information during conversation (such as extraneous auditory signals or a second language). Working memory allows a person to hold information for a short period of time in order for it to be manipulated and used. For example, if a person is read five words and asked to pick out the two words that go together, they would hold the five words in working memory to be able to select the correct answer. Attention plays a role in shifting tasks and could have implications for

² Researchers use different terms to refer to component processes of executive functions. For example, Miyake et al., 2000 uses “shifting” instead of sustained and selective attention and “updating” instead of working memory. For the purposes of this study, the term “working memory” will be used to refer to short-term memory and the term “attention” will refer to sustained and selective attention.

switching topics in conversation (Penn et al., 2010). Since executive functions are considered regulatory, this means that they only occur when higher-level coordination of a task is needed (Miyake & Friedman, 2012). This has implications for testing, as will be discussed in the following section.

Tests of Executive Function. Executive functions are considered regulatory processes; making them difficult to measure since they cannot be examined without also tapping into the processes they are regulating (Miyake & Friedman, 2012). For example, in order to investigate inhibition, an individual may be required to visually recognize objects and name them, which taps into vision and language processes not related to inhibition. While separate substrates of executive functioning have been postulated, the interactive nature of these components makes it difficult to define what substrate correlates with which tasks. The manifestation of executive functioning is dependent on the existence of other lower tasks, a problem known as the task impurity problem (Miyake et al., 2000; Miyake & Friedman, 2012). As a result, teasing apart executive functions during testing can be tricky because tasks may tap into irrelevant processes, as described above. Miyake and colleagues have suggested a latent-variable approach to measuring executive functioning skills, which uses multiple tasks that have the target skill in common. By doing so, it allows the researcher to extract the target skill using statistical analysis, resulting in a clearer measure of the skill. Table 1 highlights a variety of tasks used in both clinical and experimental settings to examine inhibition, shifting, and working memory. When more than one executive function is listed for a test, the first listed is the function considered most utilized during the task. Despite these difficulties in testing EF, tests such as those found in Table 1 can provide relatively reliable information about an individual's EF skills, as discussed in the following section.

| Test name | Executive Function | Description |
|---|------------------------------------|---|
| Tower of Hanoi | Working memory Shifting | Participant must move a set of disks from one set of pegs to another. Requires planning and goal-setting. Participant scored on speed of task completion. |
| Stroop Test | Inhibition Shifting (Attention) | Participant must suppress word name and say the color of the print when given a cue. Participant is scored on speed and correctness of answers. |
| Trail Making Tests A & B | Shifting (Attention) Inhibition | A – Participant draws lines to connect 25 numbers distributed on paper. B- Participant draws lines to connect alternating numbers and letters. Participants are scored on speed of response |
| De Renzi (1975) non-verbal short-term memory test | Working Memory | Consists of digit forward, digit pointing span, and picture pointing span tasks. Participant is required to repeat or point to numbers/pictures presented by the administrator. |
| Flanker task | Inhibition, Shifting (Attention) | Participant must push a button that corresponds to the direction a target arrow is pointing (right or left). The target arrow is flanked by two arrows on each side. When the target arrow is flanked by arrows pointing the same direction, the trial is congruent. When the flanking arrows point the opposite direction of the target arrow, the trial is incongruent. |
| Simon task | Inhibition | Participant must press a right or left key that is associated with a colored stimulus. |

Table 1.³ Selected Tests of Executive Functions

³ This table is not an exhaustive list of all EF tasks, but is intended to give the reader a general overview of the types of tasks typically employed to evaluate EFs. For a more thorough list, see Keil & Kasniak(2002) and de Groot(2011).

Executive Function: findings in healthy bilinguals. A considerable amount of research has examined whether bilinguals experience enhanced cognitive abilities as a result of a lifetime of maintaining two languages. Findings from developmental and healthy adult research support the “bilingual advantage” (Bialystok, 1999; Bialystok, Martin, & Viswanathan, 2005; Martin-Rhee & Bialystok, 2008; for a critical analysis, see Hilchey & Klein, 2011). In these studies, a standard Simon task was used to test bilingual and monolingual children’s ability to maintain attentional and inhibitory control, even on non-linguistic tasks (see Table 1 for a description of the Simon task). The Simon effect is the increased response time for incongruent trials⁴ in comparison to the response time for congruent trials (Martin-Rhee & Bialystok, 2008). Martin-Rhee & Bialystok (2008) found that, compared to monolingual children, bilingual children had faster reaction times on both congruent and incongruent trials during the Simon task and that this difference between groups was statistically significant. The researchers interpret this difference in reaction times to mean that bilingual individuals possess generally superior cognitive skills, specifically inhibition, which is not limited only to linguistic tasks, but extends to non-linguistic tasks as well.

In order to investigate if this increased inhibitory skill extended into adulthood, Bialystok and colleagues conducted similar studies with young, middle-aged, and older adults (Bialystok, et al., 2004; Bialystok, Craik, et al., 2005; Bialystok, 2006; Bialystok et al., 2008). These studies have been largely inconclusive (for a critical review, see Hilchey & Klein, 2011). Bialystok et al. (2008) used a spatial Stroop task (similar to the Simon task) to examine inhibitory control in

⁴ In the Simon task, participants are asked to press either a right or left button when a stimulus appears on the screen. When the stimulus appears on the opposite side of the screen from the button on the keyboard, this is an incongruent trial. When the stimulus appears on the same side of the screen as the button on the keyboard, this is a congruent trial.

young adults and elderly adults. The researchers found that bilinguals performed 10ms faster on incongruent trials compared to monolinguals, but that monolinguals performed 50ms faster on congruent trials compared to bilinguals, although these differences were not statistically significant. This study failed to support a global executive functioning advantage for bilinguals (Hilchey & Klein, 2011). Other studies investigating young adults found that bilinguals had faster global reaction times on the flanker task (Costa et al., 2009), the Simon task (Bialystok, Craik, et al., 2005); and the spatial Stroop task (Bialystok & DePape, 2009; see Hilchey & Klein, 2011).

These findings raise questions as to the nature of this “bilingual advantage.” First, the superior performance of bilinguals on these tasks has not been consistently replicated (as described above and critically reviewed in Hilchey & Klein, 2011). Second, in studies in which a bilingual advantage is demonstrated, bilinguals tend to outperform monolinguals on both congruent and incongruent trials (Hilchey & Klein, 2011; Martin-Rhee & Bialystok, 2008). This second finding seems to suggest that, if there is indeed an advantage, bilinguals may possess not just superior inhibitory processing skills, but rather superior general executive functioning skills compared to monolinguals (Hilchey & Klein, 2011). Third, any significant advantages found in these studies seem to occur in young children and older adults, whereas fewer differences between bilinguals and monolinguals are seen in young adults (Bialystok, 2009). This may indicate that a bilingual advantage may only be evident in individuals with a comparatively low baseline performance.

In addition to inhibitory control, several studies have examined attention and working memory skills in the bilingual population, generally in children. Typically, these studies include digit span or word span tasks, which focus largely on storage capacity of working memory.

Ardila and colleagues discovered that digit span varies across languages (Ardila, Rosselli, & Puente, 1994; Ardila et al, 2000) and that this may be based in the phonological length and composition of the number names themselves. As an example, average English digit span is 7, while average Spanish digit span is 5.8 (Ardila, 2003). Furthermore, an individual's language proficiency can also affect success on digit span tasks. As one might expect, as language proficiency increases, so does digit span (Ardila, 2003). In one study, researchers looked at both English and Spanish digit span scores in 69 Spanish-English bilinguals of low proficiency and high proficiency (Ardila et al., 2000). They found that low proficiency English learners had lower digit span scores in English compared to English monolinguals, but that Spanish digit span scores were higher than the norm for Spanish monolinguals. High proficiency English learners scored better in English than on the Spanish digit span task and had comparable Spanish digit span scores when measured against the norm. This seems to indicate that there is additional information being used by bilinguals to complete the digit span tasks such as previous experience with another language (Ardila et al., 2000). Other tasks used to examine working memory include an additional component which requires the participant to not only store information, but update this information as the task progresses, such as a n-back task⁵, which can be linguistic or nonlinguistic, or the Competing Language Processing Task. Gutierrez-Clellan, Calderon and Weismer (2004) found that there was no difference in verbal working memory between bilingual and monolingual children on the Competing Language Processing Task and the Dual Processing Comprehension Task. These tasks require the participant to listen to a sentence of 2-6 words, respond "true" or "false" to indicate comprehension, and recall the last word of every sentence.

⁵ In a n-back task, the participant is asked to respond nonverbally via a button press to stimuli which appears 1 or 2 items before to current item (referred to as 1-back and 2-back tasks, respectively).

In another study, bilinguals were found to recall fewer words in a recall task (Fernandes et al., 2007). It is important to note that these studies focused on verbal working memory versus non-verbal working memory.

To summarize, studies examining bilingualism and its effect on cognitive control have been inconclusive. Some studies suggest an enhanced inhibitory mechanism for bilinguals, while others maintain that any advantage is more global in nature. Others suggest that there are no significant advantages in inhibition, attention, or working memory at all or find bilinguals to be at a slight disadvantage. In studies that examined bilingualism and EF after brain damage, bilingual individuals were shown to have reduced or slowed damage due to dementia (Bialystok, Craik, & Freedman, 2007) and aphasia (Penn et al., 2010). These studies suggest that perhaps any bilingual advantage, even if not significantly detected in normal individuals, may influence communicative success after damage. A review of aphasia and EF follows in the next sections.

Aphasia

As previously mentioned, aphasia is an impairment of language due to a stroke or brain injury, which can result in a variety of comprehension and/or production symptoms. Aphasia is often caused by damage due to a left middle cerebral artery (MCA) stroke which tends to affect the frontal regions of the brain (Keil & Kasniak, 2002). Given that executive functioning is typically associated with frontal areas bilaterally and other diffusely distributed regions, including subcortical areas such as the anterior cingulate cortex (ACC) and parts of the basal ganglia (see Figure 3; Abutalebi & Green, 2007; Crinion et al; 2006; Keil & Kasniak, 2002), an

MCA stroke may also cause damage to these processes as well as language.⁶ Individuals with aphasia may also exhibit executive function deficits (Fridriksson et al., 2006; Murray, 2012; Purdy 2002; Wiener et al., 2004) and it can be important to distinguish between these deficits in order to assess and treat patients. In the following sections, a review of literature regarding aphasia and executive function deficits will be given, with an emphasis on testing and the issues that may arise when testing multiple impairments. Next, studies which have examined the effects of executive dysfunction on aphasia and vice versa will be critically reviewed.

Executive Functions in Aphasia. The relationship between language and executive functioning is a complex one. As such, executive functioning deficits may exacerbate the linguistic deficit, but the reverse may also be true: a person's ability to use language inwardly may affect their ability to plan and execute a variety of tasks (Keil & Kasniak, 2002). The contributions of a deficit in language to executive functioning abilities and vice versa are an issue when testing executive functions in persons with aphasia. Several studies seem to indicate that participants with aphasia may have co-occurring executive functioning deficits, but testing those deficits is confounded by the language difficulties. For example, most tests rely heavily on language abilities for task instruction and response mode (Beeson, Bayles, Rubens, & Kasniak, 1993; Glosser & Goodglass, 1990; Purdy 1992). One technique that has been used to overcome the linguistic confound while testing executive functions in an aphasic person has been to use nonverbal tasks, thus hypothetically bypassing the language system and accessing directly those aspects of executive functions one wishes to examine (Glosser & Goodglass, 1990; Keil & Kasniak, 2002; Purdy, 1992; Wiener, Conner & Obler, 1994). For example, de Renzi and

⁶ It should be noted that the ACC and basal ganglia are also supplied by the anterior cerebral and anterior choroidal arteries and that damage to those arteries tends to lead to EF deficits.

Nichelli (1975) developed a nonverbal working memory test which uses linguistic stimuli, similar to a digit span task, but allows the participant to respond to a sequence by pointing to blocks or pictures. However, nonverbal tests may access different processes such as nonexecutive motor and visuospatial processes (Keil & Kasniak, 2002). Furthermore, even if the tests themselves were perfectly designed to access the desired processes of the brain without interaction from language, the participant would still need to use language skills to understand the instructions for the task and task demands. This can present a problem for individuals with aphasia, as has been documented in several studies (see Keil & Kasniak, 2002 for a review).

Relatively few studies have directly examined EFs in persons with aphasia. The existing studies suggest that deficits in executive functions may co-occur with aphasia and that these deficits are highly variable depending on site of lesion and severity of the aphasia. (Beeson, Bayles, Rubens, & Kaszniak, 1993; Fridriksson et al., 2006; Glosser & Goodglass, 1990; Purdy, 2002; Wiener, Conner & Obler, 2004). Glosser & Goodglass (1990) tested left-hemisphere-damaged, right-hemisphere-damaged, and healthy participants on tests related to planning, sequencing, and monitoring goals. These tests included the nonverbal continuous performance test, graphic pattern generation, sequence generation task, and the Tower of Hanoi. The researchers modified the tasks (minimizing verbal instruction, requiring nonverbal responses, and eliminating time constraints) in order to reflect linguistic and efficiency deficits in aphasic participants. The researchers found that left frontal lesions resulted in worse scores on the tests, indicating that EF impairments may occur separately from linguistic deficits in that population, and that EF impairments are less likely to occur with nonfrontal lesions.

Another study examined the effects of co-occurring EF and linguistic deficits on functional communication⁷ (Fridriksson et al., 2006). The researchers examined the relationships between performance on tests of aphasia, EF, and functional communication and found a statistically significant correlation between the number of errors on the Color Trails Test (CTT) and the Functional Assessment of Communication Skills for Adults (ASHA FACS) test in 25 participants with aphasia resulting from a single stroke. This suggests that skills needed to complete the CTT successfully, such as sequencing, inhibition, planning, working memory, and sustained and divided attention, may be associated with functional communication tasks. There were some design flaws in this study, as there was no control group of brain-damaged non-aphasic participants and the participants themselves were highly variable in terms of age (range: 33 to 84 years) and aphasia symptoms.

Beeson, Bayles, Rubens, & Kaszniak (1993) found that working memory and long-term memory may be more impaired for individuals with aphasia arising from frontal lesions compared to individuals with posterior lesions. By comparing nonverbal responses of free recall of semantic information versus cued recall, the researchers found that participants with anterior lesions were shown to have more difficulty with working memory than their posteriorly-lesioned peers and that this deficit extended into long-term memory as well. Even with repeated recall trials, the anterior lesion group was still not as successful with memory tasks, suggesting that items were not encoded into long-term memory and that deficits in working memory may contribute to a lack of encoding. Studies of various types of attention have also shown that individuals with aphasia tend to display deficits in some capacity, although the breadth of this

⁷ An operative definition of functional communication comes from Frattali, Thompson, Holland, Wohl, & Ferketic (1995): “The ability to receive or to convey a message, regardless of the mode, to communicate effectively and independently in a given [natural] environment.”

research has not been comprehensive, especially given the myriad types of processes included under the umbrella of attention (e.g., selective attention, divided attention, attention switching) (Murray, 2012; Sturm, Willmes, Orgass, & Hartje, 1997).

One study of inhibition in Wernicke's aphasia used the Stroop task to compare the Stroop interference to measures of auditory comprehension (Token Test and the Complex Ideational Material subtest of the BDAE) (Wiener, Conner & Obler, 2004). The researchers found that individuals with Wernicke's aphasia took more time to complete the Stroop task and made more errors than normal, matched peers. The correlation of poor performance on the Stroop task was found to correlate positively with auditory comprehension deficits, a common symptom of Wernicke's patients. Purdy (2002) also found that PWA experienced impairments in accuracy, efficiency, and speed with regards to tests of executive function. Purdy (2002) examined executive function ability in monolingual individuals with aphasia compared to a normal control group and found that the aphasic group experienced slower and less efficient success on half of the tests administered (Porteus Maze Test, Wisconsin Card Sorting Test, Tower of London, Tower of Hanoi). Specifically, the PWA group had difficulty with the Wisconsin Card Sorting Test, which tests shifting attention and working memory, and the Tower of Hanoi, which tests planning and requires attending to specific rules. Together, these studies suggest that aphasia and executive dysfunction are frequently concomitant conditions.

To summarize, studies to date have shown that individuals with aphasia demonstrate a wide spectrum of executive functioning abilities and that individuals with more frontal lesions tend to exhibit more severe EF deficits than those with posterior lesions (Glosser & Goodglass, 1990; Keil & Kasniak, 2002). Some individuals may score within the normal range (Keil & Kasniak, 2002; Murray, 2012) and some perform very poorly (Fridriksson et al., 2006; Purdy,

2002; Wiener, Conner & Obler, 1994). As mentioned before, the confounding factors in this line of research are the effects of executive dysfunction on the appearance of language deficits and the effects of language deficits on the testing of executive function.

Aphasia in bilingual speakers. Compared to persons who are monolingual, there are fewer studies which have examined patterns of language difficulty in bilinguals. Or rather, it is likely that many studies report language difficulties in the primary language of the speaker (e.g. Chinese or Dutch), without much reference to patterns of language difficulty in the non-native languages. Studies that have examined aphasia in bilingual speakers have reported a variety of patterns of breakdown across languages. Reviews by Paradis (2001) and Fabbro (1999) found that parallel recovery seems to be the most typical pattern of recovery, meaning that both languages recover at the same rate. In other cases, the two languages are impaired to different extent, as in selective recovery (recovery of only one language) and successive recovery (recovery of one language first, then the other language). There have been a few reports of spontaneous translation between one language and another, or intrusions from the non-target language, called code mixing (Fabbro, 1999). Code mixing and selective recovery or selective use of one language, could be interpreted as an impairment of the language control mechanism (Abutalebi et al., 2008). However, recovery patterns may differ from individual to individual depending on other additional factors such as location of lesion, age of L2 acquisition, language dominance, and L2 proficiency (Green, in Kroll & deGroot, 2005). Hence it is unclear if, and to what extent, inhibitory control plays a role in cross-language impairments in bilingual persons with aphasia (BPWA).

A review of literature revealed only one investigation of bilingual aphasia and executive functions (Penn et al., 2010). Penn et al. (2010) examined executive functions in two BPWA and eight MPWA. All the MPWA were native speakers of English, while the BPWA were nonnative speakers. PWA with severe impairments were not included in the study, and there was no statistically significant difference found in severity ratings on the WAB aphasia quotient between the monolingual and bilingual participants. However, the range of type of aphasia was quite varied and it is not clear that statistical analysis of WAB subtest scores was completed. Of the two bilingual participants, one had conduction aphasia and the other anomia. The monolingual group included participants with anomia, Broca's, and conduction aphasia, as well as one participant with right hemisphere damage. The tests were all administered in English and involved verbal instruction. The tests that were administered and the findings are given in Table 2. It is evident from the table that the bilingual participants scored within the normal range on most tests (except Raven's Progressive Matrices) while the monolingual participants displayed highly variable scores. On most of the tests, the difference between groups was significant, although the authors incorrectly attributed significance to score differences on the Stroop task and the Complex figures test ($p < .10$).

Some elements in the construct of this study may affect the results. For example, one of the bilingual participants had suffered from a posterior lesion while the monolingual participants had varying lesion locations, including frontal and right-hemisphere lesions. In addition, no clear statistical analysis was performed to account for the heterogeneity of the aphasia symptoms between groups, as the authors only report comparison of WAB aphasia quotient scores and not individual subtest scores. Although results from this study are preliminary, the findings suggest

that there may be a bilingual advantage for executive functions. Due to the small bilingual sample size (n=2) and due to methodological flaws, these results cannot be generalized to all BPWA and further research is warranted.

The Current Study

The review of literature outlines some key points related to bilingualism. Bilinguals experience dual activation of both the target word (L1) and non-target word (L2) during lexical selection (de Groot, 2011; Green, 1998; Kroll & Stewart, 1994), which has led some researchers to hypothesize that bilinguals possess enhanced linguistic and non-linguistic inhibition skills (Bialystok 2006; Bialystok, Craik, et. al., 2005; Bialystok, Martin, et al., 2005). However, these studies have yielded highly variable results. Some studies show a bilingual advantage for children and older adults (Bialystok et al., 2004), while others show no bilingual advantage (Bialystok 2006; Bialystok, Craik, et. al., 2005; Bialystok, Martin, et al., 2005). On studies that have shown a bilingual advantage (Bialystok et al., 2004), participants displayed advantages on both incongruent trials such as the Simon or Stroop tasks as well as congruent trials. This has led researchers to propose that bilingualism may have consequences on EF skills in general rather than on inhibition only (Hilchey & Klein, 2011; Prior & MacWhinney, 2010).

Studies that have investigated the effects of brain damage and executive functions on monolingual individuals show that many individuals suffer executive functioning deficits in addition to expected linguistic deficits (Fridriksson et al., 2006, Keil & Kasniak, 2002; Murray, 2012; Penn, et al., 2010; Purdy, 2002; Wiener et al., 2004). Other studies have shown that executive functions can truly impact an individual's functional communication skills (Fridriksson et al., 2006; Penn et al., 2010; Purdy 2002). Very few studies have examined the

consequence of bilingualism on effects of brain damage and findings are preliminary. One study reported a later onset of dementia in bilinguals (Bialystok & dePape, 2009) and another study has shown that BPWA may have preserved executive functioning skills where compared to MPWA (Penn et al., 2010). The differences that have been found between BPWA and MPWA can have implications for communicative success or failure in daily interactions and may impact potential clinical assessment and therapy.

| Construct | Test | Difference between MPWA & BPWA groups | Significance (p < .05) |
|--------------------------|--|--|----------------------------------|
| Interference Control | Stroop Color Word Test (Golden, 1978) | p < .10 | no |
| Inhibition | Trail Making Test (Lezak, Howieson & Loring, 2004) | p < .05 | yes |
| Working Memory | 1. Self Ordered Pointing Test (Spreen & Strauss, 1998) | p < .05 | yes |
| | 2. Complex Figures (Spreen & Strauss, 1998) | p < .10 | no |
| | 3. Wisconsin Card Sorting Test (Ormond Software Enterprises, 1999) | p < .05 | yes |
| Planning/Problem Solving | 1. Tower of London (Shallice, 1982) | p < .05 | yes |
| | 2. Raven's Progressive Matrices (Raven, Raven, & Court, 1998) | p < .05 | yes |
| Reconstitution | 1. Five Point Test (Spreen & Strauss, 1998) | p < .05 | yes |
| | 2. Design Fluency (Spreen & Strauss, 1998) | p < .05 | yes |

Table 2. Summary of Penn, Frankel, Watermeyer & Russell (2010) showing which tests resulted in a significant difference between bilingual and monolingual PWA using the Mann-Whitney U test.

Given the unresolved question of bilingual advantage on inhibitory control and general EFs, the current study proposes to examine executive functions in bilingual persons with aphasia. In order to address whether bilingualism may confer linguistic inhibitory advantages or more general cognitive advantages or both, the study will compare three of the several components of EF: inhibition (linguistic and nonlinguistic), working memory, and attention. Although there are several components of executive functions, including working memory, self monitoring, self-regulating, inhibiting irrelevant stimuli, shifting between concepts or actions, the focus of this study will be inhibition, attention, and working memory because, as Miyake (2000) pointed out, these functions are united, but also more easily distinguishable via tests (Keil & Kazniak, 2002; Miyake, 2000). Functionally, deficits in these areas can also impact communication for PWA in terms of holding a conversation (Fridriksson et al., 2006; Penn et al., 2010).

The present study seeks to examine the following measures of executive functions between monolingual and high-proficiency bilingual persons with aphasia (PWA) and proposes the following questions and hypotheses: 1) Do BPWA and MPWA differ in linguistic inhibition, as measured by the linguistic Stroop task (Golden, 1978)? If bilingualism has a specific influence on linguistic inhibition, then it is hypothesized that BPWA will be superior to MPWA on tests of linguistic inhibition (Stroop task; Golden, 1978). If there is no significant difference between groups, then there is no bilingual inhibitory advantage in PWA. 2) Do BPWA and MPWA differ in non-linguistic inhibition, as measured by a spatial Stroop task? If bilingualism has a specific influence on non-linguistic inhibition, then it is hypothesized that BPWA will be superior to MPWA on tests of non-linguistic inhibition (Spatial Stroop task; Golden, 1978). If there is no significant difference between groups, then there is no bilingual inhibitory advantage in PWA. 3) Do BPWA and MPWA differ in attention, as measured by the Symbol Trails subtest of the

Cognitive-Linguistic Quick Test (Helm-Estabrooks, 2001)? If bilingualism engenders general cognitive advantages, then it is hypothesized that BPWA will be superior to MPWA on tests of inhibition, as well as a test of attention (Symbol Trails subtest of Cognitive-Linguistic Quick Test; Helm-Estabrooks, 2001). If there is no significant difference between groups, then there is no general bilingual advantage in PWA for executive functions. 4) Do BPWA and MPWA differ on working memory, as measured by de Renzi and Nichelli's (1975) test of working memory? If bilingualism engenders general cognitive advantages, then it is hypothesized that BPWA will be superior to MPWA on tests of inhibition, as well as a test of working memory (de Renzi & Nichelli, 1975). If there is no significant difference between groups, then there is no general bilingual advantage in PWA for executive functions.

Methods

Experimental Design

The study used a between group experimental design in which the performance of age and severity-matched monolingual and premorbidly high-proficiency bilingual PWA on executive functions was compared. High-proficiency bilinguals were used because low-proficiency L2 bilinguals demonstrate some processing differences in terms of dual lexical activation (Kroll & Stewart, 1994), as well as differences in neural architecture (Abutalebi & Green, 2008). The independent variable is the language status of the groups (high-proficiency bilingual vs. monolingual). The dependent variables are reaction times on linguistic and non-linguistic versions of the Stroop task (Golden, 1978), and accuracy scores on de Renzi &

Nichelli's (1975) short-term memory test and the Symbol Trails task of the CLQT (Helm-Estabrooks, 2001). Other matched group variables included severity of the aphasia and participant age.

Participants

Participants were recruited from the Aphasia Research Center at the University of Maryland as well as neighboring communities. The monolingual and bilingual groups each consisted of four persons who had experienced one or more left CVA strokes (from medical and radiology report) and who were six months or more post-onset. Both groups had a diagnosis of aphasia with no co-morbid conditions such as significant apraxia or neglect. Both groups used English as a primary language and bilingual participants were proficient in at least one other language. Exclusionary criteria for all participants were as follows: history of neurological or psychiatric conditions, prior substance abuse, and cognitive decline. Although lesions occurring in the anterior cingulate cortex (ACC), the caudate nucleus, and prefrontal cortex are not typically found in aphasia, participants noted to have a lesion occurring in these areas were excluded from the study due to those areas' involvement in inhibition and executive functions (Abutalebi, 2008). Additionally, 21 young, neurotypical (YN) participants were recruited to obtain normative data for the computerized Stroop tasks. All participants were right-handed monolinguals. The average age of the young normal group was 19.78 years (range 18-21) and consisted of 10 males and 11 females.

Consent and Background Testing

Participants were given a consent form which explained the aim of the study, the requirements of participants (described below), and storage of personal information. Participants were given the opportunity to read the document and ask questions. They were asked to sign the consent form and given a copy for their personal records. All individuals received remuneration for their participation. Aphasia type and severity were established using the Western Aphasia Battery (WAB-R; Kertesz, 2007). The WAB-R consists of spontaneous speech, comprehension, repetition, and naming subtests, which can be used to compute an overall severity measure called the Aphasia Quotient (AQ; maximum score = 100). For the purposes of this study, inclusionary criteria were a score above 50 on the AQ portion of the WAB-R and a score of 4 or above on the auditory comprehension subtest of the WAB-R. This was to ensure that the participant had a linguistic impairment, but was still able to understand the directions for experimental tasks. Bilingual participants were given the Bilingual Language Profile questionnaire (BLP; Gertken, Amengual, & Birdsong, 2011) and individuals included in the study received a language dominance score between -100 to 100 (total range: -210 to 210 with a score of 0 indicating balanced bilingualism) based on a self-report of language history and use. All participants were screened for apraxia using the verbal apraxia subtest from the Boston Diagnostic Aphasia Examination (BDAE-3, Goodglass, Kaplan & Barresi, 2000). Screening for limb and oral apraxia was done using the limb and oral apraxia subtests from the WAB-R. Corrected vision and hearing of all participants was within normal limits and was screened before testing.

| Participant # | Age | Gender | Bilingual Language Profile Score | # of strokes | Months post onset | Years of education | Language status | Languages spoken | Occupation |
|----------------------|------------|---------------|---|---------------------|--------------------------|---------------------------|------------------------|-------------------------|-----------------------|
| AP25 | 52 | M | 45.3 | 1 | 59 | 12 | Bilingual | Korean, English | retired |
| AP11 | 57 | M | 25.16 | 1 | 146 | 18 | Bilingual | Spanish, English | president, IT company |
| AP45 | 55 | F | 84.37 | 3 | 8 | 19 | Bilingual | Hungarian, English | unemployed |
| AP46 | 65 | M | -7.9 | 1 | 34 | 20 | Bilingual | French, English | on disability leave |
| APM10 | 69 | M | n/a | 1 | 41 | 16 | Monolingual | English | retired |
| APM8 | 41 | M | n/a | 1 | 36 | 17 | Monolingual | English | unemployed |
| APM7 | 55 | F | n/a | 1 | 96 | 18 | Monolingual | English | retired |
| APM14 | 58 | F | n/a | 1 | 103 | 18 | Monolingual | English | retired |

Table 3: Participant Demographic Information

Participants were also screened for color blindness since the experimental tasks require discrimination of color. Participants were asked to match colored cards (red, yellow, and green). A Mann-Whitney U-test ($p < .05$) revealed no significant differences between the subject groups in terms of age and WAB aphasia quotient scores.

| Participant # | Language Status | AQ | Spontaneous Speech score | Auditory Comprehension Score | Repetition Score | Naming and Word Finding Score |
|---------------|-----------------|------|--------------------------|------------------------------|------------------|-------------------------------|
| AP25 | Bilingual | 78.7 | 13 | 9.35 | 8 | 9 |
| AP11 | Bilingual | 96.4 | 19 | 10 | 9.6 | 9.6 |
| AP45 | Bilingual | 90.8 | 19 | 9.6 | 8.2 | 8.6 |
| AP46 | Bilingual | 89.3 | 18 | 9.85 | 8.4 | 8.4 |
| APM10 | Monolingual | 77.7 | 18 | 7.75 | 5.8 | 7.3 |
| APM8 | Monolingual | 93.8 | 18 | 10 | 9.4 | 9.5 |
| APM7 | Monolingual | 97 | 20 | 9.9 | 8.8 | 9.8 |
| APM14 | Monolingual | 75.3 | 15 | 8.45 | 6 | 8.2 |

Table 4: Participant WAB aphasia quotient and subtest scores

Experimental tasks

Stimuli

There were four experimental tasks, each pertaining to one research question. Linguistic inhibition was measured using a computerized version of the Stroop Color Word Test (Golden, 1978), nonlinguistic inhibition was measured using a computerized version of the spatial Stroop task (developed from the Stroop Color Word Test; Golden, 1978). Short term memory was measured using a non-verbal memory test (de Renzi & Nichelli, 1975), and attention was measured using the Symbol Trails subtest of the Cognitive Linguistic Quick Test (CLQT; Helms, Estabrook, 2001).

Linguistic Stroop task. The Stroop tasks were developed using DMDX software (Forster, 2008). For the linguistic Stroop task, the words *red*, *green*, and *yellow* were used as test stimuli and the word *plan* was used as a neutral stimuli. A linguistic neutral stimulus with no color association is preferred over a symbolic one (e.g. %%%%), since the latter does not engage reading while naming the color. The words were typed using the “Times New Roman” font (size 76) in lower case and presented on a white background. For every color word there was one congruent condition (for example, naming *red* when the word is written in red ink), one incongruent condition (for example, naming *red* when the word is written in green ink) and one neutral condition (naming the ink color of the word *plan*). A total of nine conditions (three colors x three conditions) were present in the task. There were 20 trials in each condition for each color (congruent, incongruent and neutral; total n = 180). The order of these trials was pseudo-randomized for presentation, ensuring that each color and its three conditions occurred equal number of times with no repetition of the target word and condition on adjacent trials (i.e., the design avoided negative priming from a previous trial).

Non-linguistic Stroop task (developed from the Stroop Color Word Test, Golden, 1978). This task consisted of a square color block stimulus (red, yellow, or green) which appeared on the right, left, or bottom of the screen. The color blocks were 30mm in length and height and presented on a white background. For every color block, there was a congruent trial (for example, pressing the red button on the right side of keyboard when a red block appears on the right side of the screen) and two incongruent trials (for example, pressing the red button on right side of keyboard when a red block appears on the bottom of the screen). A total of six conditions were present in this task. There were 20 trials in each condition for each color (total: n = 180).

De Renzi & Nichelli's non-verbal working memory test (1975). This test was designed to assess memory in the aphasic population and to reduce the interference of language deficit on the task by using a nonverbal response mode from the participant (while most other tests of memory span require spoken output). The test consisted of three tasks: digit pointing span, picture pointing span, and spatial pointing span. Nine wooden blocks with digits were used to test digit pointing and spatial pointing span (See Appendix A). The picture pointing span consisted of nine colored pictures in a 3x3 array (pipe, ladder, shoe, apple, bed, cup, key, bread, cat).

Symbol Trails test (CLQT). This task was designed to test attention, along with planning and mental flexibility. It is intended to reduce linguistic demands upon the participant by presenting nonlinguistic stimuli (Helm-Estabrooks, 2001). The stimuli consisted of 11 nonlinguistic symbols (six circles and five triangles) of varying shape and size presented in black font on a white 8.5 x 11 inch piece of paper (see Appendix B).

Stroop Task Young Normal Group. Twenty-one young normal (YN) participants were administered both Stroop tasks as a control group in order to determine the robustness of the tasks. It was particularly important to determine if these tasks showed a slowing for incongruent trials relative to congruent trials. The stimuli for the task were the same as described above. Administration procedure and data analysis for both the linguistic and non-linguistic Stroop tasks are described in later sections. Reaction times were recorded during the task via DMDX software (Forster, 2008). A failure to press the key during the 3000ms window was considered an error, as was pressing the wrong key. For each participant, incorrect responses were removed, as were all RTs that were 2.5 standard deviations above or below the mean. Additionally, all RTs shorter than 300ms or longer than 2000ms were excluded. After data cleaning for incorrect

responses and outliers, the mean Stroop effect was calculated for congruent and incongruent conditions for each participant. This was achieved by subtracting the mean RT of all neutral trials from each congruent and incongruent RT. Mixed effects analysis of variance ($p < .05$) was used to compare mean Stroop effect between congruent and incongruent trials (Baayen, Davidson, and Bates, 2008). On the linguistic Stroop task, mixed model analysis of variance revealed a significant effect of condition (congruent vs. incongruent), $F(1, 123.5)=44, p<.001$. The mean Stroop effect for incongruent trials was 34.2 ms (SE =5.9) and for congruent trials was -11.1 (SE=5.9), which means that Stroop effect for incongruent trials was significantly larger than that for congruent trials. Moreover, the positive Stroop effect value indicates that incongruent trial RTs were generally slower than neutral RTs. The negative Stroop effect value for congruent condition indicates that congruent trials were slightly faster than neutral trials. Similar results occurred on the nonlinguistic Stroop task. Mixed model analysis of variance revealed a significant effect of condition (congruent vs. incongruent), $F(1, 119.2)= 96.28, p<.001$. The mean Stroop effect for incongruent trials was 56.0 ms (SE = 6.6) and for congruent trials was -13.1 ms (SE = 6.6), which again means that the Stroop effect was significantly larger for incongruent trials versus congruent trials.

Procedure

Testing occurred at the Aphasia Research Center or the participants' homes, depending on availability of the experimenter and participants. All screening and experimental procedures were administered in one two-hour session, with breaks allowed whenever requested.

Background testing was completed prior to the experimental tasks and experimental tasks were presented in a counter-balanced sequence across participants in order to minimize order effects.

Linguistic Stroop task. Participants were presented with stimuli on a computer and were seated approximately 24 inches from the screen. Each trial began with the fixation “+” symbol in the center of the screen. The fixation symbol remained visible for 800 ms, followed by 250 ms of a blank interval. A stimulus (e.g. *red, yellow, green* or *plan*) then appeared in the center of the screen and remained on the screen for 3000 ms. After 3000 ms the screen became blank if there was no response. The participant was instructed to press a button on the keyboard that corresponded with the color of the ink using his or her non-dominant hand (see Appendix C). After a 500 ms blank interval, the next trial began. Nine practice trials were administered to the participant in order to familiarize them with the instructions before the task began.

Non-linguistic Stroop task. Participants were presented with stimuli on a computer, as described above. Stimuli were presented on the screen as described for the linguistic Stroop task. However, the stimuli for the non-linguistic task were colored blocks. As with the linguistic Stroop task, nine practice trials were administered to the participant in order to familiarize him or her with the instructions.

Working memory (de Renzi & Nichelli, 1975). The instructions for this task were the same as those described by the authors. The participant was required to complete three tasks: digit pointing span, picture pointing span, and spatial pointing span. For the digit point span task, the participant was read a series of digits ranging in length from 2 to 8 at a rate of one per second. After the digits were read, a board with blocks of numbers was placed in front of the participant and he or she pointed to the corresponding blocks matching the verbally presented digits. The picture pointing span task was similar to digit span, except that participants were required to point to names of pictures that were presented by the experimenter and the number of pictures presented increased sequentially from one to two, then three, and so on. For the spatial

pointing span, the participant was presented with blocks arranged in the same display as for the digit point span task, but without the numbers hidden from the participant's view. The researcher tapped a series of blocks ranging from two to eight at a rate of one item per second and the participant was asked to tap the same sequence immediately afterwards. In all three subtests, testing was discontinued after the participant failed to point to all pictures in the correct order or when the participant completed a series of eight. All sequences within these tasks were administered twice until the participant failed on both trials at a given length.

Symbol Trails subtest of the CLQT (Helm-Estabrooks, 2001). The participant was given a pencil and a stimulus sheet. In the scored task, the individual was asked to manipulate two concepts (increasing size and alternating shapes) in order to make a trail that began from the smallest circle and goes to the smallest triangle to the next biggest circle, and so on. Two practice trials were completed before moving on to the task. In the first practice trial, the participant was asked to connect the circles from smallest to largest. In the second practice trial, the participant was asked to connect circles and triangles of the same size. Participants were asked to complete the task as quickly as possible.

Scoring and Data Analysis

Linguistic and non-linguistic Stroop task. The data were cleaned up as described earlier for the YN group. The number of items removed (outliers) was noted and accuracy was also recorded to ensure that participants were not guessing on trials. Mixed effects analysis of variance ($p < .05$) was used to compare mean Stroop effect for reaction time between monolingual and bilingual groups (Baayen et al., 2008).

De Renzi & Nichelli’s (1975) working memory task. The participant received 1 point for each correct series during the first trial and received 0.5 points if he or she repeated the same series correctly on the second trial as well (total possible score on each sub-task: 10.5). The total score for each subtask was noted and compared between groups using the Mann-Whitney U test ($p < .05$). Scores were also compared with norms provided by authors to identify impairment.

Symbol Trails subtest of CLQT (Helm-Estabrooks, 2001). Participants earned points for how well they followed the rules and connected the shapes correctly, with a maximum score of 10. The total score for each subtest was noted and compared between groups using the Mann-Whitney U test ($p < .05$). Helm-Estabrooks (2001) tested normal participants and established criterion scores of 9 for ages 18-69 and 6 for ages 70-89. For the purposes of this study, a score lower than these criterion scores indicated impairment on this task.

Results

Four BPWA and four MPWA were given tasks to measure linguistic and nonlinguistic inhibition, working memory, and attention. In the following sections, the findings of each of the four experimental tasks will be presented, first with group data followed by additional individual participant data. Table 5 displays group mean and variability for all four tasks.

| | | YN Mean (Standard Error) | MPWA Mean (Standard Error/Deviation) | BPWA Mean (Standard Error/Deviation) |
|---|-------------|--------------------------------|---|---|
| Linguistic Stroop | Congruent | -11.572(5.9) | 9.3 (SE = 21.6) | -8.332 (SE = 21.7) |
| Effect (milliseconds) | Incongruent | 34.285(5.9) | 108.086 (SE = 21.9) | 47.858 (SE = 21.0) |
| Nonlinguistic Stroop | Congruent | -13.134 (6.6) | -34.359 (SE = 19.2) | -53.454 (19.3) |
| Effect (milliseconds) | Incongruent | 56.01(6.6) | 91.835 (SE = 19.3) | 67.239 (SE = 19.3) |
| Symbol Trails (max=10)** | | -- | 8.5 | 10 |
| Non-verbal Memory (mean normal=5.54) | | -- | 5.375 (SD = 1.9) | 4.83 (SD = 2.1) |

Table 5: Group mean and variability for bilingual and monolingual persons with aphasia (BPWA, MPWA) on the four experimental tasks. Stroop effects of young normal group (YN) are also included.

**Note that only one participant, APM14, scored below the maximum possible score

Linguistic and Nonlinguistic Stroop

Information regarding accuracy and number of trials removed during the data cleanup process was collected. Overall, BPWA had 98.5% accuracy while the MPWA group had 99.4% accuracy combined across both linguistic and nonlinguistic Stroop tasks. These results indicate that both groups were correctly and consistently responding to stimuli and not randomly guessing during the tasks. Percentage of RT outliers was 2.2% for BPWA and 1.8% for MPWA.

Mean RTs for each participant were also reviewed in order to identify any differences in speed of response between the YN and PWA groups, although they were not statistically compared. These reaction times can be found in Table 6. One monolingual participant, APM8, was found to have much faster RTs across all tasks and conditions compared to the other participants in both groups and more closely resembled RTs of the YN group. However, all PWA participants displayed slower RTs across all tasks compared to the YN group, a result which is consistent with previous studies of aphasia and response time on tasks of executive function (Purdy, 2002; Wiener et al., 2004). Mean RTs for each group were also compared (Table 6). BPWA were found to be slightly slower (<90ms) on the linguistic Stroop task compared to MPWA, although these results may be affected by APM8's RTs. When APM8's RTs were removed, the MPWA group was found to be slightly slower (<100ms). On the other hand, MPWA were found to be slightly slower on the nonlinguistic Stroop task (<50ms) compared to BPWA and despite APM8's faster RTs. These results are consistent with previous studies that have noted faster RTs on similar tasks for unimpaired bilingual participants compared with monolingual participants and suggests that bilinguals continue to have faster processing times after stroke (Bialystok, Craik, et al., 2005; Bialystok et al., 2008; Bialystok & dePape, 2009; Costa et al., 2009; Martin-Rhee & Bialystok, 2008).

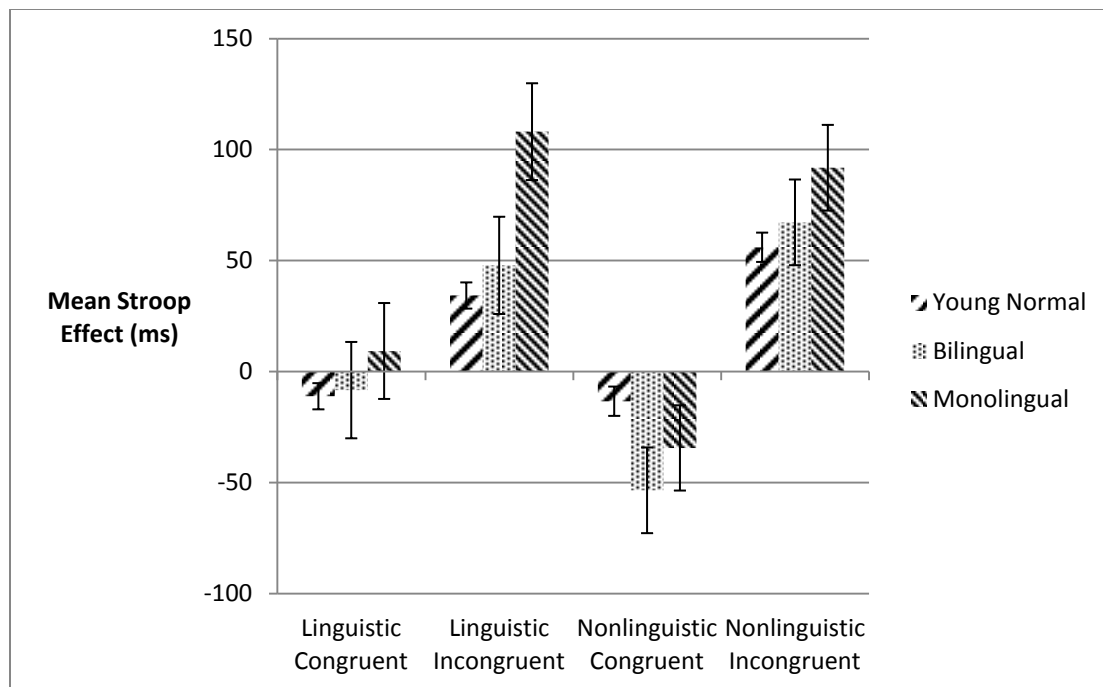


Figure 4: Mean Stroop effect for young normal, BPWA, and MPWA groups across task (linguistic and nonlinguistic) and condition (congruent and incongruent). Error bars are standard error.

The mean linguistic Stroop effects are presented in Table 5 and group and individual data are plotted in Figures 4 and 5, respectively. Figure 4 shows that all three participant groups had an interference for incongruent conditions (positive values of Stroop effect). The BPWA group's Stroop effect for the incongruent condition on the linguistic Stroop task was closer in magnitude to unimpaired participants and was smaller than the MPWA group. This trend is in the predicted direction showing that the bilingual group was less affected by incongruent information than the monolingual group, although these results are not significant. Furthermore, there was a larger difference between congruent and incongruent Stroop effects for the MPWA group than for the BPWA group. Individual participant data was also analyzed to determine if participant patterns were similar to group results and this analysis revealed that bilingual participant AP25 had a larger Stroop effect compared to the other bilingual participants (see Figure 5), indicating that he

experienced more interference of irrelevant information. In addition, AP11 and AP46 had smaller Stroop effects (8.71 ms and 1.3 ms, respectively) on the incongruent condition than even the YN mean (34.552 ms), while all MPWA participants displayed a larger Stroop effect than the YN mean. Mixed model analysis of variance revealed a main effect of condition $F(1, 118.72)=15.27, p<.001$, but no main effect of group $F(1, 5.84)=2.72, p = .151$ or group by condition interaction $F(1, 796.82)=1.66, p =.199$. This indicates that both groups experienced a significantly larger Stroop effect on the incongruent condition versus the congruent condition, consistent with expected trends. However, the magnitude of the Stroop effect did not differ between groups. The negative Stroop effect seen in BPWA group indicates that BPWA performed faster on the congruent condition compared to the neutral condition and follows the same pattern seen in the YN control group.

The mean nonlinguistic Stroop effects are presented in Table 5, while group and individual data are plotted in Figures 4 and 6, respectively. As with the linguistic Stroop, all three participant groups experienced interference for incongruent conditions. The BPWA group had a smaller Stroop effect for incongruent and congruent conditions on the nonlinguistic Stroop task when compared to MPWA (Figure 4). This trend is in the expected direction and shows that the bilingual group is less affected by incongruent information compared to the monolingual group. Furthermore, mixed model analysis of variance revealed a main effect of condition $F(1, 118.62)=71.22, p <.001$ but no main effect of group or group by condition interaction $F(1, 817.66)=71.23, p=.806$. As with the linguistic Stroop task, this indicates a significant difference between incongruent and congruent conditions, but no difference of Stroop effect between groups. Additionally, both the BPWA and MPWA groups displayed a negative Stroop effect in the congruent condition, meaning that both groups experienced less interference on the

congruent condition compared to the neutral condition. Furthermore, both PWA groups had smaller Stroop effects compared to the YN group. Review of individual data revealed that all BPWA participants followed the same trend of a negative Stroop effect value for the congruent condition and a positive Stroop effect value for the incongruent condition, indicating that all participants were faster on the congruent than the neutral condition and experienced interference on the incongruent condition. Individual review of the MPWA participants revealed more varied results. Participant APM10 displayed a positive Stroop value on the congruent condition, indicating that he had slower RTs compared to the neutral condition, while the other MPWA participants followed the BPWA and YN trend of negative Stroop values on the congruent condition.

| | Linguistic Congruent | Linguistic Incongruent | Nonlinguistic Congruent | Nonlinguistic Incongruent |
|------------------|---------------------------------|-----------------------------------|------------------------------------|--------------------------------------|
| AP11 | 1311(15.3) | 1325(15.44) | 1163(19.67) | 1238(21.1) |
| AP25 | 1254(61.3) | 1362(65.24) | 920(19.97) | 1041(19.61) |
| AP45 | 1181(39.04) | 1305(48.78) | 1167(27.81) | 1382(28.01) |
| AP46 | 1013(14.14) | 1006(15.3) | 1028(13.96) | 1100(14.7) |
| APM7 | 1165(28.51) | 1316(39.24) | 1114(25.74) | 1320(25.29) |
| APM8 | 732(25.16) | 783(25.75) | 753(25.2) | 842(29.91) |
| APM10 | 1300(24.79) | 1401(26.9) | 1445(23.77) | 1450(18.13) |
| APM14 | 1229(23.76) | 1321(32.45) | 1146(19.51) | 1352(26.54) |
| BPWA Mean | 1190(32.44) | 1249(36.19) | 1070(20.34) | 1190(20.85) |
| MPWA Mean | 1107(25.56) | 1206(31.08) | 1115(23.55) | 1241(26.97) |
| YN Mean | 699(7.82) | 744(8.47) | 696(7.56) | 771(7.84) |

Table 6: Mean Stroop reaction times by participant in milliseconds and young normal (YN) mean reaction time. Shaded rows represent bilingual individuals with aphasia (BPWA). Standard error is represented in parentheses.

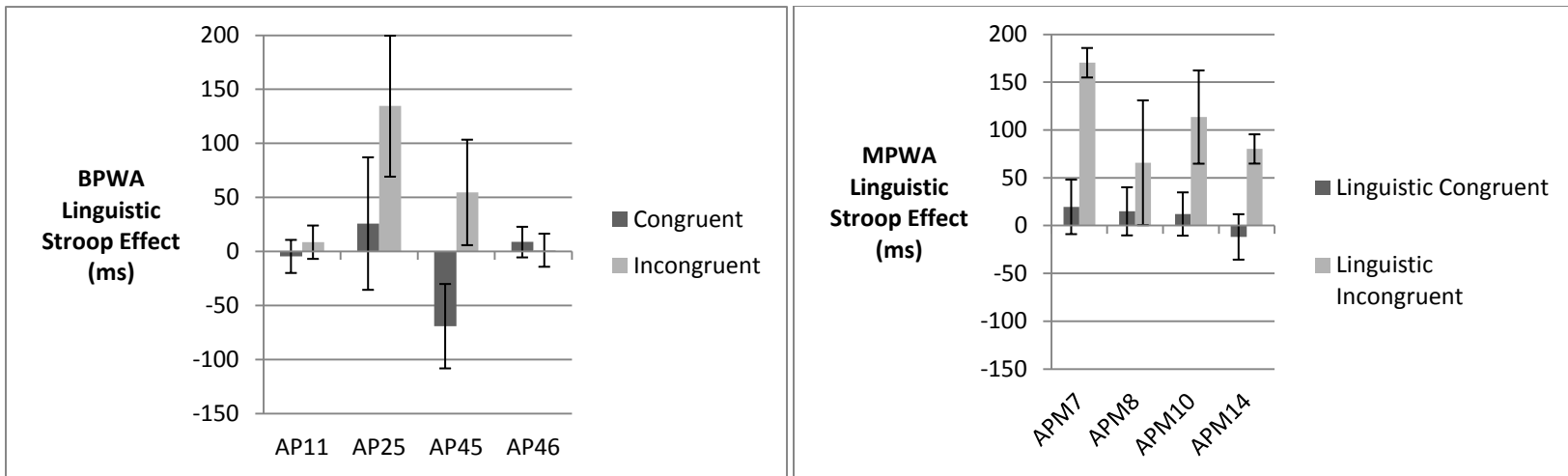


Figure 5: Mean linguistic Stroop effect and standard error by participant

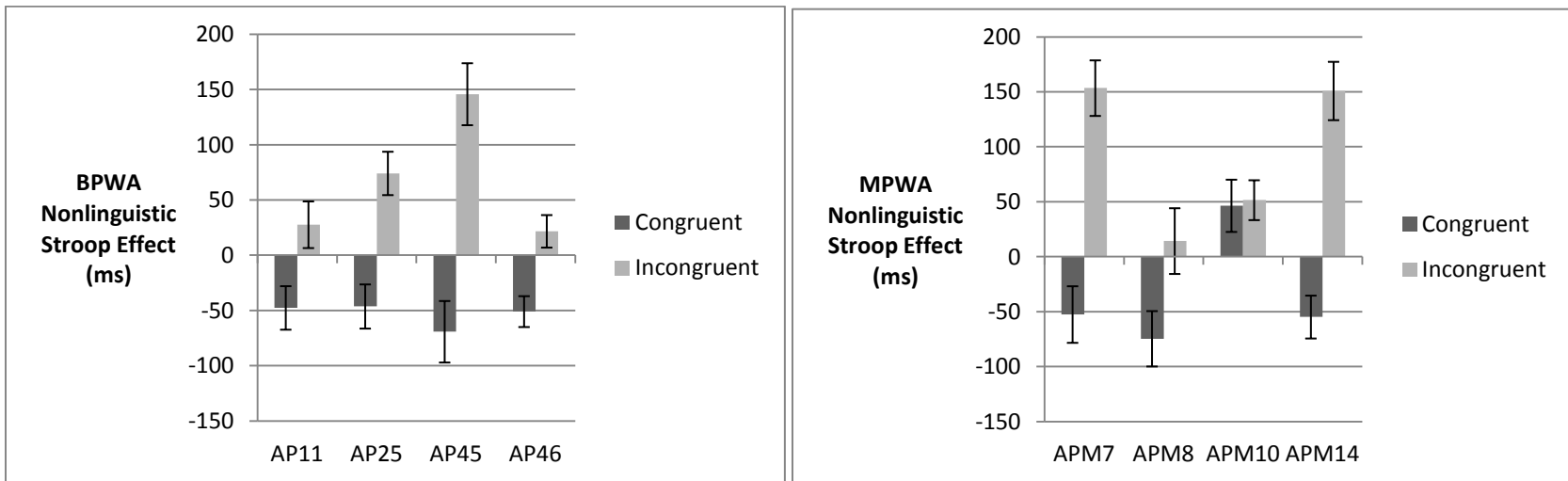


Figure 6: Mean nonlinguistic Stroop effect and standard error by participant

Symbol Trails Subtest

On the Symbol Trails subtest of the CLQT (Helm-Estabrooks, 2001), all of the participants with the exception of APM14 scored a 10 out of a maximum 10 points on the subtest, showing unimpaired performance (Table 4). Also, statistical comparison was not made since both groups scored at ceiling with one exception. The average mean for non-impaired individuals ages 18-69 is 9.63 (2.5 Standard Deviation below this mean= 3.36)

Non-verbal Working Memory Test

Table 4 provides the mean score and standard deviation for the bilingual and monolingual groups on de Renzi and Nichelli's (1975) non-verbal working memory test. The three subtest results were combined and analyzed to only compare bilingual versus monolingual performance. Each subtest had a possible maximum score of 10.5. The Mann-Whitney U-test was used to analyze performance between the two groups and no significant difference was found (Mann-Whitney $U=82$, $z = -0.55$, $p = .582$). Although no significant group difference was found, MPWA showed a trend of better performance than BPWA, scoring a mean of 5.375 (SD = 1.9) compared to the mean BPWA score of 4.83 (SD = 2.1). Review of individual data (Table 7) revealed that monolinguals were more widely varied in their scores for each subtest. For example, on the digit pointing task, bilinguals scored within a range of 4 to 5.5 points while the monolinguals ranged from 3 to 7.5. On the picture pointing subtest, bilinguals ranged from 3 to 5.5 and monolinguals ranged from 1.5 to 6. The developers of this test and the authors of the accompanying article normed this test on a variety of individuals, including a neurologically unimpaired group, a group with left hemisphere damage, a group with right hemisphere damage, and an additional two groups with brain damage in the left or right hemisphere as well as visual field deficits. For the purpose of this study, PWA scores were compared against the

neurologically unimpaired (n = 30) and left hemisphere damage with no visuospatial deficits (LH; n = 39) groups. These normed scores can also be seen in Table 7. In general, both PWA groups performed better than the LH norms provided by the authors, with the exception of AP45 and APM10. Additionally, all participants except for AP45 and APM 10 scored above the unimpaired norms for the spatial pointing task. Unfortunately, de Renzi and Nichelli (1975) did not describe the language abilities of the LH damaged individuals they tested, so it is difficult to make a clear comparison between the test groups in this study and the LH group in the authors' study. However, this does seem to indicate that, as a group, the PWA participants in this study do not have severe working memory deficits. A discussion of why working memory deficits were not seen will be addressed in a later section.

| Participant | Normed Score ¹ | | BPWA | | | | MPWA | | | |
|------------------|---------------------------|------------------|------|------|------|------|------|------|-------|-------|
| | Normal ² | LH- ³ | AP11 | AP25 | AP45 | AP46 | APM7 | APM8 | APM10 | APM14 |
| Digit Pointing | 5.9 | 3.07 | 5.5 | 4 | 5.5 | 5.5 | 3 | 7.5 | 2.5 | 4 |
| Picture Pointing | 4.81 | 2.62 | 4 | 4 | 3 | 5.5 | 4 | 6 | 1.5 | 3 |
| Spatial Pointing | 5.92 | 5.28 | 8.5 | 8 | 3 | 8 | 7 | 8 | 5.5 | 6 |

Table 7: Working memory test scores by subtest and participant (de Renzi & Nichelli, 1975)

¹ Based on results from de Renzi & Nichelli (1975)

² Normal = unimpaired group

³ LH = Left hemisphere damaged group (without visual deficits)

Discussion

The aim of this study was to identify any bilingual advantage on tasks of EF for individuals with aphasia, by investigating whether BPWA and MPWA displayed any differences on four tasks of executive functions. The primary finding of this study is that the two groups displayed no statistically significant differences across all EF tasks. In general, there was no

significant deficit in executive function evident for any task in this group of eight PWA. In the following paragraphs, the results of each experimental task will be discussed individually, with the caveat that these findings are preliminary given the extremely small group size. This will be followed by a more general discussion as to the implications of the results on individuals with aphasia and for theories of bilingualism. Finally, limitations of the current study which may have affected results will be presented, along with suggestions for future directions in this area of research.

Inhibition as measured by Stroop Tasks

Linguistic and nonlinguistic Stroop tasks are classic experimental paradigms used to measure inhibitory control, the premise being that trials in which the target response is incongruent to the dominant or automatic response require greater inhibitory control than congruent or neutral trials. There are three findings in the current study. First, all PWA in this study performed with high accuracy in the Stroop tasks, which makes the RT analysis and its interpretation quite reliable. Second, all PWA showed a disadvantage for incongruent trials across linguistic and nonlinguistic Stroop, as shown by a main effect of congruent versus incongruent trials.

The crucial test for the first two hypotheses was the magnitude of Stroop effect between groups: BPWA showed a trend for reduced Stroop effect across both linguistic and nonlinguistic tasks compared to MPWA, although these results were not significant. While this trend is in the hypothesized direction, the lack of group difference suggests that there is no clear bilingual advantage on linguistic or nonlinguistic Stroop tasks. However, it should also be noted that, due to the small sample size, individual data may be skewing the results. Individual participant data show that two BPWA, AP11 and AP45 show almost no disadvantage for incongruent trials in the

linguistic Stroop task (Figure 5), suggesting a superior inhibitory ability for incongruent trials. The third key finding of this study is that reaction times across tasks and conditions (Table 6) were very similar among BPWA and MPWA, showing no clear evidence of significantly faster processing in BPWA. The result of slightly smaller Stroop effect for BPWA compared to MPWA and lack of significant difference on Stroop RTs supports recent studies and reviews on unimpaired individuals of various ages on linguistic measures of inhibition (Kousaie & Phillips, 2012) and on nonlinguistic measures of inhibition (Bialystok et al., 2008; Hilchey & Klein, 2011; Paap & Greenberg, 2013). In general, these recent studies have failed to find a consistent inhibitory advantage for bilinguals. Kousaie & Phillips (2012) examined monolingual and bilingual young and older adults on blocked trials of word naming, color naming, and incongruent color naming and found that inhibitory advantage was found only for young bilinguals and not the older group. Bialystok and colleagues (2008) failed to find an inhibitory advantage in both young and old unimpaired bilinguals. Paap and Greenberg (2013) examined a variety of nonlinguistic tasks thought to tap into inhibition (Simon, antisaccade, flanker, color-shape switching) and compared performance of monolingual and bilingual adults. They found that not only was bilingual and monolingual performance on these tasks similar, but also that the individual tasks themselves do not test the same aspects of cognitive function. For example, the flanker effects and Simon effects, frequently seen as equal representations of inhibitory control, were not found to have a strong correlation ($r = -0.01$). The authors caution that differences between tasks may affect interpretation of results and that it is not necessarily valid to assume that any bilingual advantages that have been shown are the result of a general EF advantage.

Kousaie & Phillips (2012) also point out that because results from a variety of studies are so contradictory and that results in favor of a bilingual advantage seem to rely on very specific tasks and conditions, this does not support a robust advantage for bilinguals.

To summarize, the first two hypotheses regarding a bilingual advantage for linguistic and nolingistic inhibition are rejected. The lack of a bilingual inhibitory advantage is not entirely surprising given 1) the inconsistent findings in neurotypical literature, 2) the small sample size of the present study which limits its statistical power, and 3) the overall high accuracy in PWA. To elaborate on the last point, the inhibitory control network may not have been sufficiently compromised in this sample of PWA, hence failing to show between-group inhibitory differences that could have emerged in more severely impaired monolingual and bilingual PWA. Unfortunately, given the experimental task demands, only mildly impaired PWA could be recruited.

Attention as measured by Symbol Trails test of CLQT

The Symbol Trails subtest of the CLQT assesses how well the participants were able to attend to changing instructions for drawing lines to connect nonlinguistic stimuli. The main finding from this test was that all participants except for APM14 received the highest possible score and performed the task within the three-minute time limit set forth by the author, indicating no clear difference between groups. This task was originally selected due to its nonlinguistic stimuli consisting of circles and triangles since the goal of the study was to examine attention separately from linguistic impairments. However, since the participants were generally high-functioning individuals with mild linguistic impairments and no prefrontal damage, the Symbol Trails subtest may not have been sensitive enough to reliably identify even minor differences in attention and task-switching between the two groups. Another option for examining attention in

this study was the Trail Making Test-B (TMT-B; Army Individual Test Battery, 1994), which uses alternating letters and numbers instead of alternating circles and triangles (Tombaugh, 2004). Scores are determined by the amount of time needed by the individual to complete the task, rather than accuracy, as measured in the Symbol Trails subtest of the CLQT. Furthermore, the TMT-B has been normed on a larger group of individuals and a large-scale study by Tombaugh (2004) also examined the effects of age and years of education on the 911 neurotypical participants. A task that measured RT and which had more robust norms compared to the Symbol Trails subtest of the CLQT could possibly have resulted in a more comprehensive evaluation of the EF processes involved in a trails task. A more thorough test of attention such as the Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) may also be warranted to examine different types of attention, including more difficult levels than that seen in the Symbol Trails subtest of the CLQT. The TEA also examines both auditory and visual modalities, which could give a more robust analysis of an individual's attention skills. Alternatively, different types of planning tasks could also be utilized. For example, the Tower of Hanoi is a task which requires the individual to move rings of different sizes from one post to another. Scoring is based on time and amount of moves, which again, provides more information than the CLQT in regards to accuracy. Although the CLQT has the examiner make a record of how many self-corrections the individual makes, these do not contribute to the overall score. The Tower of Hanoi was used as a measure of shifting attention and working memory in Purdy's (2002) study of EF and aphasia. In that study, the monolingual PWA group was found to be slower and less efficient on the Tower of Hanoi and the Wisconsin Card Sorting Test,

although it is important to note that the participants in the study were more severely impaired (ranging from 25-63 on the Porch Index of Communicative Abilities overall percentile; PICA) than those in the present study (Porch, 1981).

Working Memory

Digit span and word span tasks are generally utilized to measure working memory. Nonverbal versions of these tasks were employed to reduce linguistic involvement for the participants with aphasia. Two findings emerged from the data. First, no statistically significant difference was found between groups on the combined subtest scores of the nonverbal working memory task, suggesting that there is no advantage for BPWA on attention. In addition, there was no clear deficit in either group when compared against 30 neurologically unimpaired individuals (de Renzi & Nichelli, 1975). As previously noted, digit span ability can vary based on the language being used as well as previous language exposure (Ardila, 2003). While it is not obvious in this study that any particular individual benefited or suffered due to experience with a second language or lack thereof, future studies might take into account digit span norms for languages utilized by participants.

Individuals with aphasia are frequently noted to experience deficits in working memory (Caspari, Parkinson, LaPointe, & Katz, 1998; Christensen & Wright, 2010, de Renzi & Nichelli; Martin & Ayala, 2004; Wright, Downey, Gravier, Love, & Shapiro, 2007), although studies tend to use linguistic tasks such as digit span or word span tasks. A study by Martin and Ayala (2004) examined a variety of digit and word span tasks in an aphasic population, finding that performance tasks requiring a nonverbal response correlated with phonological and semantic

deficits. Thus, despite reducing linguistic processing factors in the paradigm, PWA may still experience difficulty with working memory tasks. The authors suggest that this correlation may be due to an overall deficit in working memory. These varying deficits were also found in a study by Wright and colleagues (Wright, Downey, Gravier, Love, & Shapiro, 2007). In the study, the researchers created 3 n-back tasks which were associated with very specific linguistic levels: phonology, semantics, and syntax. Individual analysis of the nine monolingual participants revealed that one participant performed worse on the semantic task compared to the phonological task and that two participants scored better on the depth version of the phonological task compared to the identity version of the same task. The authors suggested that individual variation of accuracy on the tasks may indicate that PWA experience varying degrees and types of linguistic deficits in working memory. However, this study did not compare the PWA with an unaffected control group, so it is difficult to know if the group trend is atypical.

As previously stated, linguistic tasks are typically used in studies of working memory and in order to obtain a broader view of working memory in the aphasic population, nonlinguistic tasks should also be utilized. Christensen and Wright (2010) recognized this need for nonlinguistic tasks and compared a PWA group and an unaffected control group on three n-back tasks with 1-back and 2-back conditions. Each type of task contained varying levels of linguistic information. In the linguistic task, individuals were asked to recall fruit items; in the semilinguistic task, novel shapes; and in the nonlinguistic task, blocks. An ANOVA analysis revealed that PWA performed significantly worse on all tasks. Interestingly, the PWA performed equally as bad on the semilinguistic and nonlinguistic tasks and performed best on the linguistic task. Previous studies of working memory had shown that normal individuals

deteriorate on working memory tasks when the stimuli are not easily encoded with linguistic information (Baddeley et al, 1984). Christensen and Wright interpreted the results of their study to mean that the PWA group had more difficulty in encoding linguistic information on the semilinguistic task. It has been suggested that individuals with aphasia may use a verbal strategy to perform even nonverbal tasks, such as saying the numbers aloud while pointing (Christensen & Wright, 2010; Martin & Ayala, 2004, Wright, Downey, Gravier, Love, & Shapiro, 2007). The use of compensatory strategies was not explicitly examined in the present study, but it was informally noted during testing that some participants said the number sequence aloud, even though a verbal response was not required. One participant, AP25, even repeated the number sequence in Korean although it was verbally presented in English. Although the precise nature of working memory and its relationship to lexical knowledge and bilingualism is not completely known, many studies across a variety of populations have shown that working memory and word-learning are associated (Baddeley, Papagno, & Vallar, 1988; Cheung, 1996; Gupta, 2003; Thorn & Gathercole, 1999). Cheung (1996) noted that when L2 proficiency was low, working memory was a better predictor of vocabulary learning and that, as language proficiency increased, phonological knowledge became more reliable predictor. Another study found that bilingual children were able to perform nonword repetition tasks based on English or French phonotactics while monolingual children displayed poorer performance on tasks based on the phonotactics of an unfamiliar language (Thorn & Gathercole, 2000). Thus, it is possible that PWA who experience phonological deficits may be at more of a disadvantage, regardless of bilingual status.

Implications for Theories of Bilingualism

Although preliminary, the results of the current study have implications for current theories of EFs and, more specifically, inhibitory control with regards to bilingualism. Green's (1998) theory of inhibitory control and bilingualism proposed a supervisory attentional system (SAS) for bilinguals which responds and inhibits information based on the level of activation elicited by a particular stimulus. For example, if a bilingual individual has a strong level of activation for the word "horse" in both L1 and L2, the SAS would activate to a proportionally higher degree than it would for a word that does not have a strong representation in both languages because it is less commonly used in the L2. As discussed, this theory has been supported by studies that show bilinguals to have slower reaction times on naming and lexical decision tasks (for a review, see Hilchey & Klein, 2011). In the current study, BPWA were neither shown to be significantly faster or slower on the linguistic Stroop task, nor did they experience significantly smaller interference effects. In terms of Green's theory, these results suggest that the bilingual participants did not experience much dual lexical activation or that this dual activation was quickly resolved given the small number of varied lexical stimuli (e.g., the words *red*, *green*, *yellow*, and *plan*). Furthermore, BPWA were not shown to have a statistically significant advantage on the nonlinguistic Stroop, which does not support Green's theory that the SAS may extend beyond the linguistic domain.

Extending from Green's SAS theory, studies of inhibitory control developed largely by Bialystok and colleagues have led to conclusions that bilinguals enjoy an inhibitory advantage that is greater during childhood, diminishes into young adulthood, and then becomes more pronounced once again as a result of aging (see Bialystok, 2009 for a review). Because the majority of participants in the current study were under 50 years of age, it is possible that no

significant disparity was seen between the BPWA and MPWA groups because a bilingual advantage would not robustly manifest until a more advanced age. Previous studies have also suggested that faster RTs and less interference effect for bilinguals are also variable depending on the number of trials and amount of practice (Bialystok et al., 2008; Emmorey et al., 2009). When there are a large number of trials and/or increased practice, any bilingual advantage seems to decrease. As such, the large number of trials and practice given during this study may have diminished any potential bilingual inhibitory advantage. In addition, the results of previous studies suggest that maybe a bilingual advantage truly manifests itself as an ability to adapt more quickly to changing stimuli rather than as an advantage that lasts during longer stretches of inhibitory processing. However, further research is needed to investigate that theory as it is not currently well-examined in the literature.

Conclusions and Future Directions

Two main conclusions can be drawn from this study. First, based on the results of this small sample study, as well as evidence from previous studies, it would appear that there is no clear “bilingual advantage” on linguistic inhibition, nonlinguistic inhibition, attention, or working memory in this sample of persons with aphasia. Second, this sample of PWA displayed no clear impairment in any EF, showing that EF and linguistic impairment are not always concomitant conditions. This supports a poor association between EF and language deficits in persons whose damage is restricted to the left hemisphere language regions and sparing of prefrontal and subcortical regions.

There were several limitations to the present study. Given the time constraints of data collection, the sample size for this study was relatively small and it is possible that larger groups would have revealed more significant findings. In an effort to address this issue, data collection

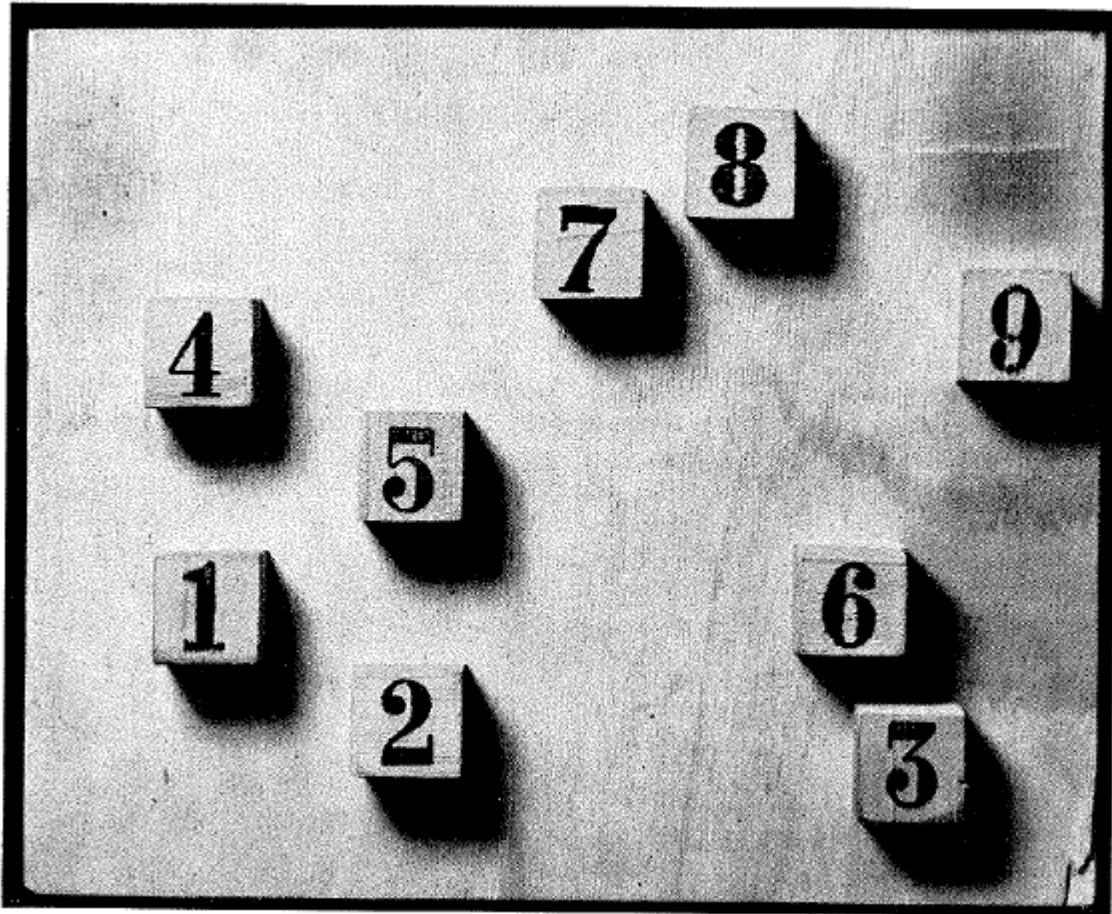
on additional persons with aphasia will continue, to make this study suitable for future publication. The limited number of experimental tasks and the quality of these tasks may have also limited the robustness of the findings. Paap & Greenberg (2013) suggest a number of ideas for improving studies of bilingualism and inhibition. Among these suggestions, the authors recommend further identification of “the specific component(s) of executive processing that should be enhanced by managing two languages” (p. 255). This includes continued examination of both unimpaired and impaired populations and further studies should continue to use both linguistic and nonlinguistic versions of EF tasks to further elucidate any similarities or differences between linguistic EF and general EF skills. As stated earlier, Miyake & Friedman (2012) advocated using several tasks that tapped into overlapping functions to assess EF; however, it was beyond the scope of this particular study to include additional experimental tasks. In terms of quality of tasks, as discussed previously, the CLQT was not sensitive enough to any deficits within the test groups. It is recommended that any future studies use a different measure of attention to further ascertain any differences between monolinguals and bilinguals. While the working memory task attempted to limit the linguistic load on the PWA, a task with nonlinguistic stimuli may have made an interesting comparison point that would have fit in well with the goals of this study. Additionally, some deficits were not examined thoroughly or at all. Although the participants in the current study were mildly impaired, further testing on a wider variety of PWA may need to include a screening of reading deficits, especially if future research includes more varied linguistic tasks.

Future research in this area should address limitations and concerns as discussed above. Investigation into subsets of inhibition, attention, and working memory, as well as refinement of tasks should be among the main goals for future research. There is no current consensus on the

nature of bilingualism and any advantages it might bring in terms of EF. Further examination of different tasks that tap into EFs may elucidate the circumstances under which bilinguals consistently outperform monolinguals. Although this study revealed no significant advantage for BPWA, it is important and warranted to further examine the differences between BPWA and MPWA on tasks of executive functions, as current research in this area is still quite limited and any bilingual advantage might be more visible in an impaired population compared to an unimpaired population.

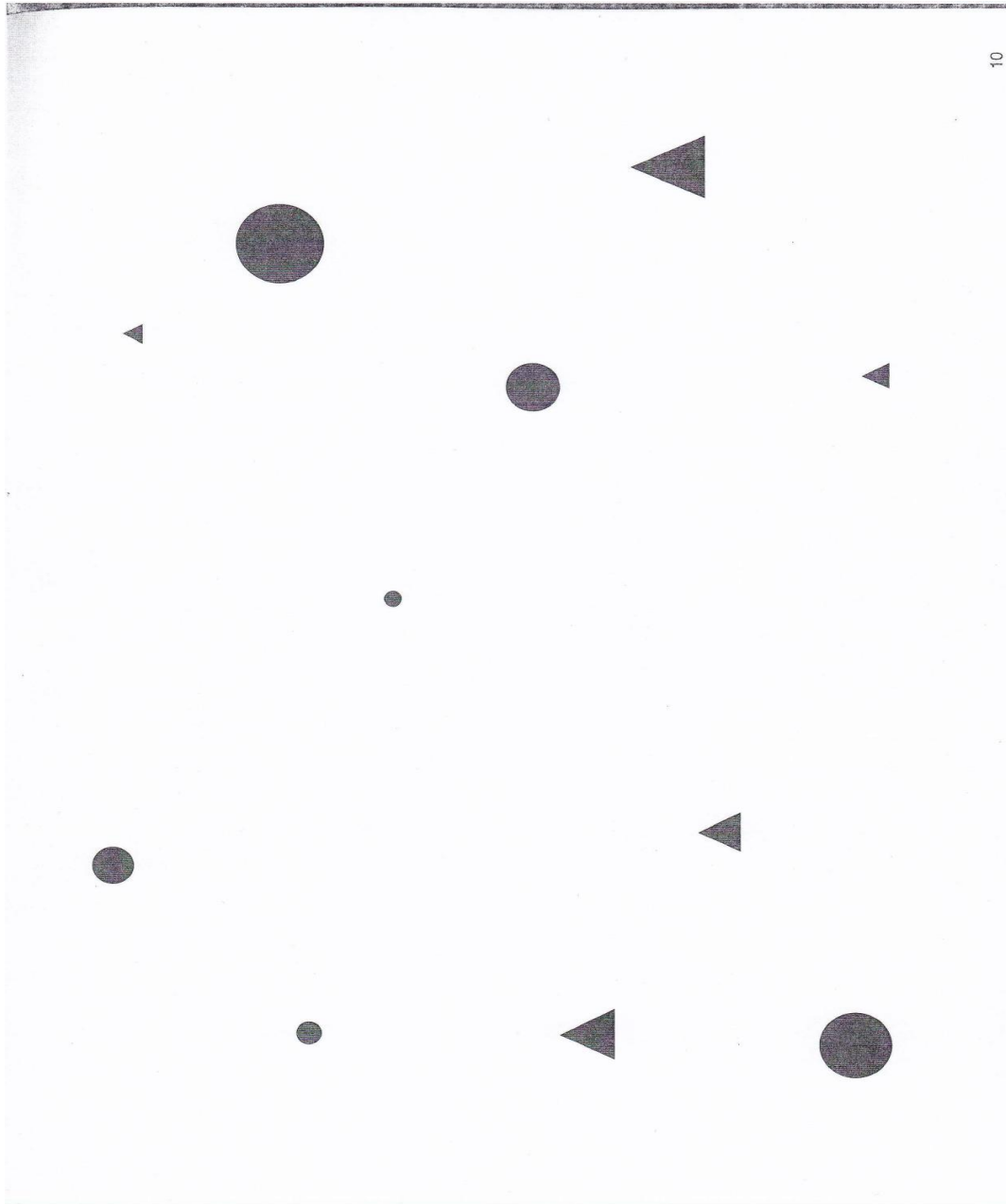
Appendix A

Image from de Renzi & Nichelli (1975) digit pointing scan task.



Appendix B

Image from Symbol Trails subtest of CLQT (Helm-Estabrooks, 2001).



Appendix C

Image of key press for non-verbal Stroop task



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