Executive Attention Deficits In Persons With Aphasia: Conflict Resolution and Goal Maintenance

by

KyoungYuel Lim

Bachelor of Science, Daegu University, 1999

Master of Science, Daegu University, 2002

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This dissertation was presented

by

KyoungYuel Lim

It was defended on

October 19, 2011

and approved by

James T. Becker, Professor, Psychiatry

Michael Walsh Dickey, Assistant Professor, Communication Science and Disorders

Patrick J. Doyle, Associate Professor, Communication Science and Disorders

William D. Hula, Adjunct Assistant Professor, Communication Science and Disorders

Dissertation Advisor: Malcolm R. McNeil, Distinguished Service Professor and Chair, Communication Science and Disorders

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KyoungYuel Lim, Ph.D.

University of Pittsburgh, 2011

An understanding of the relationship between attentional deficits and language processing can provide insight into the language disorders in persons with aphasia (PWA) (McNeil, Odell & Tseng, 1991). Executive attention is a critical component of the attentional system (Cowan, 2005). Core features of executive attention are goal maintenance and conflict resolution (Engle, Kane & Tuholski, 1999). The relationships among executive attention, language processing and aphasia have not been studied extensively.

The purpose of this study was to investigate the role of goal maintenance and conflict resolution in word-level processing in PWA. Picture-Word Interference (PWI) tasks were used whereby written words were superimposed on pictures in congruent (word and picture match), neutral (word with polygon) or incongruent (word with non-matching picture) conditions. The incongruent condition was presented at 19% and 73% proportion. Ten PWA and 20 normal individuals (NI) categorized words into animal or non-animal. Button press response times (RT) and error were measured. Conflict resolution was measured by comparing RTs in the incongruent condition to those in both the neutral and congruent conditions. Goal maintenance was measured by comparing Errors on the incongruent condition between the two proportions.

A mixed model examined RTs among conditions for the 19% incongruent proportion between groups. PWA showed significantly ($p<.05$) longer RTs for the incongruent and neutral conditions, but no significant group difference for the congruent conditions. The NI showed significantly more errors on the lower proportion, however, the PWA showed no significant difference between two proportions.

Given that there was no significant group difference on the congruent condition, the significantly longer RTs for the PWA on the incongruent conditions is interpreted as evidence that PWA demonstrated impaired on conflict resolution.

The finding that NI showed a significant proportion effect and the PWA did not is interpreted as evidence that the PWA demonstrated impaired goal maintenance. RT and error data indicate deficits of these components of executive attention in the PWA. Moderately high correlation coefficients for the PWA between RTs from the incongruent condition and measures of working memory and aphasia severity suggest a meaningful relationship between these attentional impairments and language processing impairments.

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PREFACE

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1.0 INTRODUCTION

The relationship between language processing and attention has been a critical research topic in linguistics and psychology for a long time. Following the suggestion that the cognitive construct of attention (e.g., Kahneman, 1973) may be related to the impaired language performance in aphasia (McNeil, 1982), researchers have increasingly investigated the notion that linguistic deficits and communication disorders in aphasia go beyond simply an impaired language system. Indeed, these deficits may be tied to a complex mixture of cognitive deficits (Helm-Estabrooks, 2001, 2002; Murray, 2003). Many persons with aphasia (PWA) have shown a variety of impairments in cognitive functions, including those involving attention (McNeil, Odell, & Tseng, 1991; Murray, 1999; Robin & Rizzo, 1989; Tseng, McNeil, & Milenkovic, 1993), working memory (Caspari, Parkinson, LaPointe, & Katz, 1998; Gutbrod, Cohen, Mager, & Meier, 1989; Valler, Corno, & Basso, 1992; Van mourik et al., 1992), planning (Purdy, 2002), and problem solving (Vilkki, 1988).

Researchers have introduced and explained the notion of working memory to account for limitations in and disorders of language comprehension. This concept has gained increased interest in aphasia with respect to examining whether a reduced or limited verbal working memory capacity can explain impaired language comprehension and/or poor cognitive performances in PWA (Waters & Caplan, 1996). Understanding working memory (WM) has been considered vital to examining all functions of complex thinking such as reasoning, problem solving, and language comprehension. Its importance becomes evident especially in language processing which must deal with perceiving and producing a sequence of symbols over time (Just & Carpenter, 1992). That is, WM plays a critical role in storing the partial and final products of computations during the comprehension of a stream of words in a text that allows the mental pasting together of ideas that are mentioned separately or are only implied (Daneman & Carpenter, 1980; Carpenter & Just, 1989). Therefore, researchers have studied WM in detail by decomposing it into different components according to their functions. The three common components of storage, processing (computation) and executive attention are generally accepted in most models of WM (Baddeley & Hitch, 1974; Daneman & Carpenter, 1980; Carpenter & Just, 1989; Engle, Kane, & Tuholski, 1999), although there are still diverse views as to what additional components should be included. Despite gross agreements on the general structure of WM, it has been difficult to determine the critical sources of Working Memory Capacity (WMC) that contribute to cognitive and language processing.

Whereas most WM researchers have modeled the functions of computation and storage, Engle and colleagues have concentrated on the executive attentional component. In this conceptualization, the constructs of goal maintenance and conflict resolution, under interference conditions, were proposed as core factors underlying the construct of executive attention (e.g., Engle et al, 1999; Engle & Kane, 2004) as it functions with WM. Studying WM in young healthy college students, Kane and Engle (2003) found that executive attention, as measured by the Stroop interference task, accounted for the increase in processing times and error rates. That is, conflict resolution and goal maintenance as measured in low proportion of the incongruent color-word Stroop task accounted for the majority of the variance in performance. However, these effects have not been examined systematically in PWA as a critical component of their attentional resources, which could underlie their language performance and other cognitive processing impairments.

The primary objectives of the current study were twofold: 1) to investigate conflict resolution by examining significant group differences (i.e., PWA vs. normal Individuals (NI)) in response times and error rates among the incongruent, congruent and neutral conditions of the Picture-Word Interference (PWI) tasks and 2) to examine goal maintenance by assessing significant group differences in response times and error rates between the 19% and 73% incongruent proportions.

Specific Hypothesis A: Engle and his colleagues (1999; 2003; 2004) hypothesized that the executive attention is the primary component of WM. The role of the executive attention can be assessed in an interference (e.g., Picture-Word Interference) task, in which accuracy (i.e., error rate) and the response time (RT) represent the relative success of resolving conflict across relevant experimental conditions.

The current study assessed PWA and NI groups using the PWI task to investigate the differential condition and group effects within the executive attention system. It was predicted that there would be significant group differences between PWA and NI for response times (RTs) and error rates on the incongruent conditions of the PWI task. It was predicted that the PWA group would evidence significantly longer RTs and greater error rates than the age-matched NI group in the incongruent conditions of this task due to executive attention deficits. However, it was predicted that the PWA group would show no significant difference in the RTs and error rates compared to the NI group in the congruent and neutral (no interference) conditions.

Specific Hypothesis B: Kane and Engle (2003) hypothesized that the congruency proportion[1] on the interference task (e.g., color-word Stroop test) would heavily influence the goal maintenance components of executive attention. They claimed that the interference condition on the Stroop task that consisted of mostly/all incongruent stimuli (e.g., 100% incongruent condition) reminds participants of the task goal on each trial as the external cue, which can reduce the burden on executive attention compared to that on the infrequently occurring incongruent condition (e.g., 25% incongruent condition).

It was predicted that there would be no effect of the congruency proportion of the PWI task for the PWA group, but that there would be for the NI group. Specifically, it was predicted that the PWA group would show no significant difference in RTs and error rates in the incongruent conditions of the PWI task between two proportions (19% and 73% incongruent proportions) due to executive attention deficits. However, the NI group would produce longer RTs and higher error rates in the 19% incongruent proportion than in the 73% incongruent proportion. It was further hypothesized that the 19% incongruent proportion requires more goal maintenance capacity/resources than the 73% incongruent proportion. Unlike the NI group who was hypothesized to be sensitive to the proportion effect in the incongruent condition of the PWI tasks, the PWA group was predicted to show an impaired goal maintenance causing unchanged poor performance between the two proportions of the PWI task. Therefore, an interaction between group and congruency proportion of the PWI task was predicted.

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[1] The congruency proportion indicates the ratio of incongruent stimuli in an interference task. In the color-word Stroop task (Kane & Engle, 2003), the low congruency proportion condition consisted of 20/25% incongruent stimuli (the word red in the BLUE color) and 80/75 % congruent stimuli (the word red in the RED color).

2.0 BACKGROUND AND SIGNIFICANCE

2.1 BACKGROUND

2.1.1 Attention, Language, and Working Memory in Aphasia

2.1.1.1 Attention and Aphasia

For a better understanding of attentional deficits in PWA, they must be considered relative to definitions of attention and their proposed architectures. Kahneman (1973) depicted attention as a capacity-limited commodity in which the limited resources can be flexibly and simultaneously deployed and strategically allocated. Therefore, a failure to complete a given task or a set of tasks will occur if task demands exceed the available capacity (i.e., insufficient capacity), or if it is inappropriately (i.e., misdirected resources) or inefficiently (e.g., slow or partial mobilization of resources) allocated (McNeil, 1982; 1986). Kahneman's resource allocation model has been useful as a theoretical framework for studying attentional deficits in persons with brain damage in a variety of situations. Based on the limited attentional resource hypothesis, many experimental studies have been conducted in the PWA.

LaPointe and Erickson (1991) investigated an auditory vigilance task (monitoring a stream of words for one in particular) by using a dual-task paradigm to monitor the performance of six PWA and six gender-matched controls. Four hundred words were presented in isolation and in a dual-task condition in which the participants were asked to listen for and identify target words while simultaneously conducting a simple card-sorting task. The two participant groups showed nearly identical patterns of accuracy performance when the vigilance task was performed alone.

However, the performance of PWA significantly decreased under the dual-task condition (identifying target words with card sorting) compared to the control group who showed the same accuracy as in the isolation condition. These results were replicated and extended by Erickson, Goldfinger, and LaPointe (1996). They utilized a nonlinguistic auditory vigilance task (tone detection) and the Wisconsin Card Sorting Test. Their two participant groups were 10 PWA and 10 NI controls. As in the LaPointe and Erickson (1991) study, PWA performed significantly less accurately on this nonlinguistic auditory vigilance task in the divided attention condition than in the undivided attention condition; their performance was also significantly less accurate than the control group in the divided condition. The researchers interpreted the result as evidence of deficient cognitive processing in PWA, irrespective of types of the stimulus (linguistic or non-linguistic), especially in the presence of competing stimuli.

Tseng, McNeil, and Milenkovic (1993) studied the effect of priority manipulation based on the voluntary resource allocation method. The researchers required PWA and normal individuals to detect phonetic and semantic targets simultaneously while listening to word lists. Tseng and colleagues varied the target occurrence probability (e.g., phonetic-to-semantic target ratio of 80: 20, 50:50, or 20:80) under the premise that participants would allocate greater attentional resources to the more infrequently occurring targets in order to maximize the performance accuracy. The explicitness of instructions was also differentiated: (a) an explicit condition in which participants were told how frequently targets would occur, and (b) an implicit condition in which participants were not given such instructions. This experimental manipulation was designed to explore whether difficulties in allocating attentional resources could be controlled at a level that could be considered relatively conscious (explicit instructions), subconscious (no explicit instructions), or both. As the probability of target occurrence increased, the normal participants performed the detection tasks as predicted. In contrast, PWA failed to show this probability effect, regardless of instruction explicitness. They failed to utilize consciously or subconsciously the probability information. Tseng and colleagues claimed that the inefficiency in allocating attention was a reflection of either a poor determination of task demands or a slow mobilization and distribution of attentional resources.

A similar interpretation of dual task data was given by Murray and colleagues (Murray, Holland, & Beeson, 1997a, b) who investigated underlying sources of resource allocation deficits in PWA. They hypothesized that two factors – the failure to monitor the accuracy or the difficulty in evaluating task demands, or both - were related to the resource allocation deficit of PWA. Murray and colleagues examined the ability of monitoring subjects' accuracy and evaluating the task difficulty with the semantic judgment task and the lexical decision task under a variety of listening conditions (isolation, focused, and divided attention condition) and with distracters (nonverbal tone discrimination task vs. verbal semantic/lexical secondary, competing task). 16 PWA and 8 normal controls participated in the study. In the isolation condition, the participants completed each task (semantic judgment and lexical decision) without distraction. In the focused and divided condition, each task was completed in competition with the secondary, nonverbal task (i.e., tone discrimination task) or the other linguistic task (semantic/lexical). The researchers found that the accuracy of the PWA was not different from those of normal participants during the single lexical decision task. That is, two groups showed a similar positive relationship between the accuracy and the perceived accuracy rating. In contrast to monitoring the accuracy, PWA performed inconsistently in terms of perceived task difficulty, reaction time, and task complexity. That is, if the perception of the task difficulty reflects the amount of resources invested in completing given tasks (as claimed by Derrick, 1988; Yeh & Wickens, 1988), poor performances of PWA would be attributable to their failure to appreciate and satisfy task demands. Murray and her colleagues concluded that the resource allocation deficits of PWA may be indicative of an inadequate evaluation of task or resource demands rather than an inadequate monitoring of the accuracy. Like Tseng and colleagues, Murray and colleagues (1999a; 1999b) suggested that such difficulties in appropriately allocating cognitive resources might represent a failure of the individuals with aphasia to judge appropriately either task demands or performance capabilities, or both.

In order to establish a causal relationship between attentional deficit and language disorder in PWA, it is required to quantify the amount of individual's resource utilization and investigate the interaction between task demand and resource capacity. Therefore, the theoretical background of the relationship between cognitive attention and language abilities was borrowed from WM literature. WM was used as the framework for measuring attentional capacity with the assumption that the primary component of WM is executive attention (Engel et al, 1999; Kane & Engle, 2003; Engle & Kane, 2004). Many researchers have found a close link between individuals' WMC and their attentional abilities.

2.1.1.2 Working Memory and Language

Working memory was first linked to language computations by Baddeley and Hitch (1974). In their view, the working memory (WM) system consists of temporary memory stores with two associated mechanisms for rehearsing the stored information and a mechanism of the central or executive attention that regulates the contents of the active portion of memory. That is, WM consists of both language-based and visuospatial-based temporary storage systems and their associated rehearsal buffers, along with a central executive component analogous to Norman and Shallice's (1986) supervisory attention system that regulates the flow of thought and is responsible for implementing task goals (Engle & Kane, 2004). Its formal measurement was first proposed by Daneman and Carpenter (1980).

Daneman and Carpenter's (1980) WM measure was composed of reading span tasks that were proposed to draw on the processing and storage resources. Following the development of these WM tasks, studies of WM have steadily accumulated. Daneman and Carpenter (1980; 1983) demonstrated the importance of WM limitations in reading comprehension and stressed that reading span is dependent on the working memory capacity and that this capacity is a crucial factor for individual differences in language comprehension. They suggested two potential sources of individual differences: the processing of the written information and the storage of intermediate products that were thought to compete for the limited resources that draw on a common pool available to WM (Perfetti & Lesgold, 1977). They assumed that the two roles of the single WM system (processing and storage) were equally important.

Just and Carpenter (1992) presented a theoretical integration of the two functions of working memory in language comprehension. They proposed a computational theory in which both storage and processing are fueled by the same commodity: neural activation. In this framework, the WM capacity that is operationally defined as resources can be defined as the maximum amount of neural activation available in working memory to support either computation or storage. Just and Carpenter (1992) assumed that during language comprehension, information becomes activated by virtue of being encoded from spoken or written texts, generated by a computation, or retrieved from the long-term memory. As long as an element's activation level is above some minimum threshold value, that element is considered part of working memory, and consequently, it is available to be operated on by various processes. However, if the total amount of activation that is available to the system is less than the amount required to perform a particular task or complete the building of a particular representation, then some of the activation that is maintaining old elements will be deallocated, producing a forgetting by displacement (Just & Carpenter, 1992).

According to Just and Carpenter (1992), the trading relation between storage and processing occurs under an allocation scheme that takes effect when the activation maximum is about to be exceeded. The allocation scheme implies that when the task demand is high, the processing will slow down due to a distribution of resources to a related computation and immediate storage and consequently some partial results may be forgotten. The time course and content of the language processing within this system depend on the capacity for storage and computation. When the task demand exceeds the available resources, both the storage and the computational function are degraded. Just and Carpenter (1992) called this theory "Capacity Constrained Comprehension."

A central thesis of Just and Carpenter (1992) is that the nature of a person's language comprehension depends on his/her WMC. That is, the capacity theory notes that some of the performance differences among individuals within a task domain will be explained in terms of WMC. When the task demand is high enough to exceed the capacity, individuals with a smaller working memory capacity will more readily show decrements in the performance of computations and the quick storage of intermediate products. A related implication is that within any task domain large performance differences among individuals will emerge, primarily when the task demand consumes a sufficient degree of the total capacity to exhaust participants' resources. In the domain of language comprehension, capacity limitations are more evident when the linguistic construction is more complex or when there is an extrinsic load, as tasks exhaust one's capacity (Just & Carpenter, 1992).

2.1.1.3 Aphasia and Working Memory

There has emerged a general consensus that the WM system is important for the language processing (Aboitiz, Garcia, Bosman, & Brunetti, 2006; Caplan & Waters, 1999; Wright & Shisler, 2005). Therefore, the integrity of WM in PWA has received considerable attention in the literature in recent years. Although theories vary in details regarding the processing of linguistic information, there appears to be a broad agreement that PWA have limited resources or low efficiency of resource allocation (e.g., Caplan & Waters, 1995; LaPointe & Erickson, 1991; McNeil & Kimelman, 1986; McNeil, Odell, & Tseng, 1991; Murray, Holland, & Beeson, 1997a, 1997b; Slansky & McNeil, 1997; Tseng, McNeil, & Melankovic, 1993). Such findings have led to further questions regarding the role of working memory in language, specifically for PWA.

Caspari, Parkinson, LaPointe, and Katz (1998) explored the relationship between working memory and reading/listening comprehension abilities in 22 PWA. The participant group consisted of five severe, two moderately severe, three moderate, three mild-moderate, and nine mild PWA diagnosed by Western Aphasia Battery (WAB) (Kertesz, 1982). The researchers used a modified Daneman and Carpenter (1980) Reading Span Test to measure working memory. As the original Reading Span task was not appropriate for PWA, three modifications were made: (a) shortening the 13 to 16 word sentences to 5 to 6 words; (b) changing the recall task to a recognition task; and (c) changing the recognized word from the final word of the sentence to a separate word from the sentence, similarly to LaPointe and Erickson (1991). Two versions of the task were administered: reading and listening versions. PWA were tested with the Aphasia Quotient subtests of the WAB (Kertesz, 1982) for measuring language function and with the Reading Comprehension Battery for Aphasia (RCBA; LaPointe & Horner, 1979) for measuring reading comprehension. Fourteen participants' data (13 with fluent aphasia and 1 with non-fluent aphasia) were used to compute correlations between the reading span and RCBA scores because several PWA could not complete the reading span task. The researchers found significant and positive correlations between listening span and WAB Aphasia Quotient scores (p = .77, n=22) and between the reading span and RCBA scores (p = .61, n=14). Caspari and colleagues (1998) concluded that the working memory capacity is a useful predictor of the language comprehension performance and the preserved working memory system is important for successful comprehension.

Tompkins, Bloise, Timko, and Baumgaertner (1994) investigated the working memory ability in adults with right and left hemisphere brain damage as one part of their study. They included 25 adults with right hemisphere brain damage (RHD), 25 with left hemisphere brain damage (LHD), and 25 NI individuals. Sixteen of the LHD participants had been previously diagnosed with aphasia. The LHD group showed a significantly poorer performance on the auditory comprehension measure than the RHD and NI groups. Tompkins and colleagues developed a listening span task similar to Daneman and Carpenter's (1980) Reading Span Test that was simpler and shorter, to measure the working memory span of their participants. Participants were instructed to judge the truthfulness of each sentence, and then remember the final word of each sentence for later recall. They found that both brain-damaged groups made more errors on the task than the control group. From the total 42 opportunities to recall final words, mean errors were 12.4 for the RHD, 16.8 for the LHD, and 6.4 for the NI. They divided the LHD group into high and low auditory comprehension, and additional analyses were performed. Tompkins et al. found that the low comprehension group made significantly more word errors on the working memory measure compared with the high comprehension group. They suggested that the working memory measure might be a useful predictor of performance of individuals with brain damage on high information-processing load tasks. That is, if a task does not exceed the individual's working memory capacity limits, then no relationship between performance on the task and working memory capacity should occur. Conversely, if the task does exceed one's capacity limits, then a significant relationship is expected. The findings were interpreted to indicate that individuals with brain damage had reduced working memory capacities.

Friedmann and Gvion (2003) also investigated the relationship between verbal working memory and sentence comprehension in PWA. The three participant groups consisted of three persons with conduction aphasia, three persons with agrammatic aphasia, and six normal controls. All participants performed working memory tasks including several span measures: digit, word, and non-word, a listening span task similar to Tompkins and colleagues' (1994), and a 2-back task[2]. The researchers found that both groups with aphasia had limited working memory abilities but performed differently on the sentence comprehension task. The group with agrammatic aphasia performed poorly in comprehending object-relative sentences, whereas the group with conduction aphasia was significantly above the chance level on all sentence types but failed to understand the sentences that required phonological reactivation when the phonological distance was long. Therefore, Friedmann and Gvion concluded that the required processing types (i.e., semantic, syntactic, or phonologic) in sentences are affected by the verbal working memory deficit in sentence comprehension.

The results of most WM studies in PWA have suggested that the impairment of WM may contribute to the language processing difficulties of PWA. To investigate which components of WM system contribute specifically language disorders of PWA, two components (STM and computation) of WM have been manipulated in various studies. Many of these studies have utilized linguistic complexity to load the computational component of tasks and/or the number of stimuli used to load the STM component of the tasks to assess the critical role of WM in language processing.

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[2] The 2-back task is one type of the n-back task. The n-back task has been used to assess WM ability in neurologically intact individuals as well as numerous clinical populations (Jonides, Lauber, Ahw, Satoshi, & Koeppe, 1997). The n-back requires participants to process a stream of incoming information and respond when the current stimulus is the same as the stimulus “n items ago”. The n-back has several strengths. First, modality of presentation can be customized to the population of interest (i.e., auditory or visual). Second, response modality is via button press, making it manageable for PWA. Third, task difficulty can be parametrically increased by using a higher number of items “back”. Finally, at the “easiest” levels (i.e., 1-back), the task is manageable for many clinical populations.

2.1.1.4 The Effects of STM and Computation of WM in PWA

Caplan, Waters, and colleagues (Caplan & Waters, 1996, 1999; Rochon, Waters, & Caplan, 2000) have perhaps studied the WM capacity in people with aphasia more intensively than any other group. They hypothesized that two types of processing in WM control entirely different cognitive systems that underlie language processing. The first, "interpretive processing" is used for syntactic comprehension and the extraction of semantic and syntactic information from linguistic signals. The second, "post-interpretive processing" is used for other verbally mediated tasks, such as reasoning, planning, or storing semantic information (Caplan & Waters, 1999).

Caplan and Waters have compared the effects of the syntactic complexity and those of the concurrent memory load across clinical groups to demonstrate the separate verbal WM components between these two types of processing. Caplan and Waters (1996) investigated whether the performance of PWA on a sentence-picture matching task is affected by the concurrent digit load. They predicted that performance on the sentence comprehension task would not be affected by concurrent digit load in PWA as a function of the syntactic complexity, however, the number of propositions in sentence comprehension would be affected by the concurrent digit load; the type of task that taps into post-interpretive processing. Under the dual-task condition with digit recall and sentence-picture matching tasks, PWA first listened to series of digits whose number was equivalent to their digit span (span condition) and one less than their span (span-1 condition). Participants maintained the series of digits while they listened to a sentence. Immediately after the sentence was given, they were required to point to a picture from two choices based on the sentence stimuli, and then recall the digits. They found that the performance on both the sentence-picture matching task and digit recall measures were unaffected by the concurrent memory load as a function of the syntactic complexity. However, the effect of the number of propositions was significantly larger in the span condition than the span-1 condition on the digit recall accuracy measure. Based on these findings, they concluded that “the processing resource system that underlies syntactic processing is substantially separate from the one that is used for some other verbally mediated functions” (Caplan & Waters, 1996, p. 525). The results of this study were also consistent with the previous findings in people with dementia of the Alzheimer Type (DAT) (Waters, Caplan, & Rochon, 1995). In that study, Waters and colleagues found that persons with DAT had a significantly lower digit span than the control group, but there were no significant effects caused by the concurrent digit load on the accuracy either in the sentence-picture matching task or in the digit-recall task as a function of syntactic complexity. However, comprehension of sentences with more propositions was significantly affected by the larger digit loads. Waters and colleagues (1995) argued that “this finding strongly supports the view that there can be a reduction in processing resource pools associated with verbally mediated tasks that does not affect the availability of resources in a pool utilized by the on-line psycholinguistic processes involved sentence comprehension” (p. 27).

From all of their studies, Waters and colleagues argued that PWA failed to show an exacerbation of the syntactic processing deficit under the concurrent memory load (Caplan & Waters, 1996), whereas patients with dementia of the Alzheimer’s type (DAT) and Parkinson’s disease (PD) showed intact syntactic processing and severely impaired memory span (Caplan & Waters, 1995; Rochon, Waters, & Caplan, 1994). These effects support Caplan and Waters’ (1999) contention that the “working memory capacity, as measured on a task that emphasizes controlled, conscious manipulation of verbal information, will not correlate with processing efficiency for any components of the interpretation process" (p. 93).

Other researchers have investigated language-related WM impairments in aphasia (e.g., Miyake, Just, & Carpenter, 1994; 1995; Caspari, Parkinson, LaPointe, & Katz, 1998; Wright, Newhoff, Downey, & Austermann, 2003). However, they have hypothesized a single, low-capacity linguistic resource pool, rather than the interpretive and/or the post-interpretive aspects of language as the source of the impairment in aphasia.

Miyake, Just, and Carpenter (1994; 1995) proposed the conception of the reduced WM capacity for the language comprehension deficit in aphasia. Specifically, they hypothesized a reduction in the activational resources needed to process incoming language and retain intermediate products of this processing. They conducted a series of experiments with non-brain-damaged normal individuals, divided into two groups of low- and high-span according to Daneman and Carpenter's (1980) reading span task. Miyake et al. (1994) investigated the comprehension patterns of young normal individuals by using temporal constraints that was designed to make them perform aphasic-like during a reading task (i.e., rapid serial visual presentation, RSVP). They assumed that when the WM demands manipulated by accelerating the visual presentation rate increased, individuals with the low WM capacity would show a degraded performance on sentence comprehension especially under a complex sentence condition if the combination of the two factors of the fast presentation rate and syntactic complexity exceeds their capacity. Results revealed that participants with low WM spans performed more poorly on complex sentence types than participants with higher WM spans, and the low-WM participants also performed more poorly at faster RSVP rates. Based on the results that normal adults showed similar patterns to PWA under RSVP and complex sentence conditions, they endorsed a normal-to-aphasia continuum of WM resources for language comprehension based on resource constraints and resource allocation strategies.

Although there has been a general agreement on the notion that WM consists of three components (STM, Computation (or alternatively, interference), and Executive Attention), most WM studies in PWA have investigated the effects of STM and computation by manipulating the number or/and complexity of stimuli. Executive attention, considered a component of WM, has been a minimally explored black box due to the absence of a theoretical framework before 1999.

In 1999, Engle and Colleagues began an extensive examination of the contributions of executive attention to WM. They hypothesized that executive attention was a substantial component (source) of WMC. The following section will review the role of executive attention in WM as discussed by Engle, Kane, and their colleagues.

2.1.2 Executive Attention in Working Memory Models

Many researchers (e.g., Baddeley, 1986; Engle, 2002) suggest that WM involves a critical executive attention component that is necessary to coordinate and integrate the storage and processing aspects of a given task. This enables more than processing efficiency (Daneman & Carpenter, 1980; 1983) and storage capacity (Bayliss, Jarrold, Gunn, & Baddeley, 2003). In contrast to the view of WM being composed of STM and computation, the general capacity approach (Engle et al., 1999) is less concerned with the structure of individual WM components (e.g., Repovs & Baddeley, 2006) or a trade-off between storage and processing (e.g., Daneman & Carpenter, 1980, Daneman & Carpenter, 1983; Just & Carpenter, 1992). Instead it focuses on the role of the central executive attention system, which is related to a number of domains (Engle, Kane, & Tuholski, 1999).

2.1.2.1 The Executive Attention of Working Memory

Engle and his colleagues have studied the nature of the relationship between span measures of WM and complex cognition. One of the most important findings is that "WM span measures predict strongly a very broad range of higher-order cognitive capabilities, including language comprehension, reasoning, and even general intelligence" (Engle & Kane, 2004, p. 145). Engle and his colleagues emphasized the interaction of attentional and memorial processes in the working memory system, and they assumed that this interaction is an elementary determinant of broad cognitive ability. Moreover, they endorsed Cowan's (1995; 1999) proposal that the coding, rehearsal, and maintenance processes of immediate memory work upon activated long-term memory (LTM) traces rather than on separate representations in domain-specific storage structures as buffers. As illustrated in Engle and Kane's (2004) WM model depicted in Figure 1, STM is represented as activated LTM, and this activation may be maintained or made accessible via a number of strategies or skills (e.g., chunking, phonological rehearsal) that may differ across various stimulus and/or response domains. Attentional or "executive" processes may also contribute to maintaining access to memory traces if routine rehearsal strategies, such as inner speech, are unavailable, unpracticed, or otherwise unhelpful for the task at hand, or if potent distracters are present in the environment. Engle and coworkers supposed that immediate memory and executive attention in particular, are especially important for maintaining access to stimulus, context, and goal information in the face of interference or other sources of conflict (Engle & Kane, 2004).

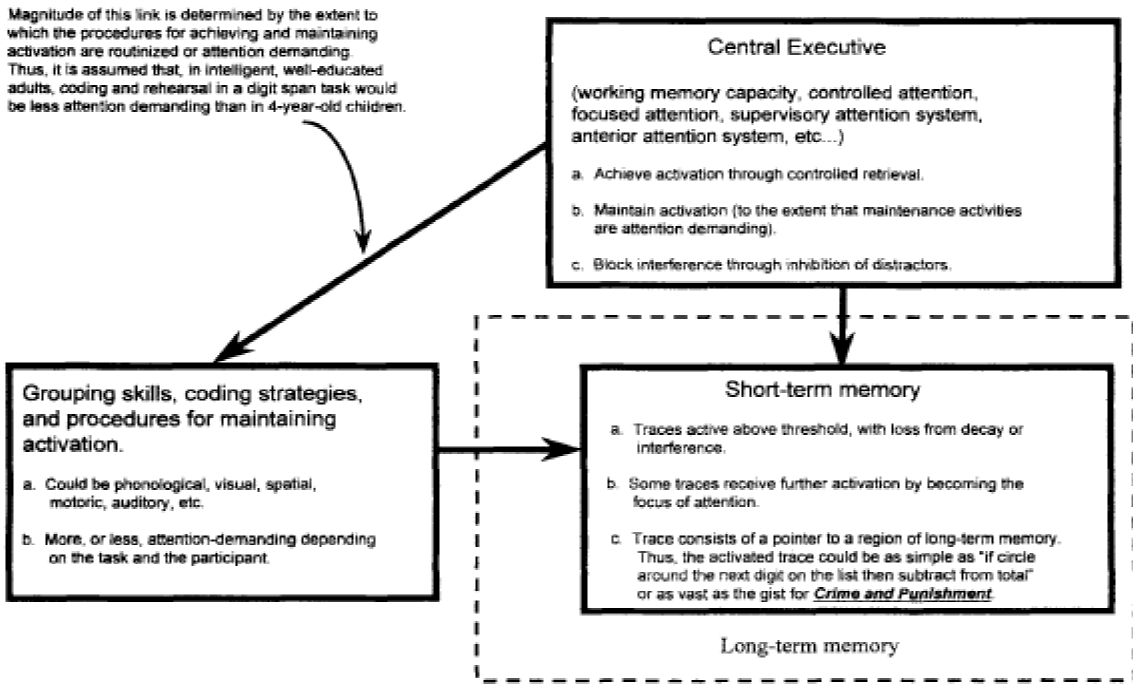

Figure 1. Relationship of components of the working memory system (from Engle et al., 1999, p. 311)

In this deconstruction of WM, Engle et al. (1998) conceptualized the first component as the short-term “store,” consisting of LTM traces in a variety of representational formats active above a threshold. The second is the rehearsal processes and strategies for achieving and maintaining the activation and the third is executive attention (Engle & Kane, 2004, p. 149). Engle and colleagues (1999) and Engle and Kane (2004) assumed that the executive control of attention is responsible for individual differences in WM and maintains goal-relevant information in a highly active, accessible state under conditions of interference or competition. In other words, Engle et al. believed that the central executive is responsible for dealing with the effects of interference and avoiding the effects of distraction that would capture attention away from maintenance of stimulus representations, novel productions, or less habitual response tendencies. Engle and colleagues also believed that WM is a domain general construct, important to complex cognitive function across all stimulus and processing domains.

To support this view, Engle, Tuholski, Laughlin, and Conway (1999) employed a latent-variable approach and demonstrated that the critical aspect of WM tasks is the ability to control attention. They assumed that working memory consists of: 1) domain-specific memory stores; 2) associated rehearsal procedures; and 3) domain-general executive attention. They used a hypothetical construct measured by operation span, reading span, and counting span and then removed the task-specific error variance measured by these three traditional STM span tasks. What remained was the variance that putatively represented the latent construct of interest, free of those variables that represented STM. The researchers also extracted the common latent variance from two tests of general fluid intelligence[3] (G*f*); the Ravens Progressive Matrices (Raven, Court, & Raven, 1977) and the Cattell Culture Fair Test[4] (Cattell, 1973). Exploratory factor analysis and structural equation modeling were performed on the data. Engle and

[3] Fluid and crystallized intelligence (abbreviated G*f* and G*c*, respectively) are factors of general intelligence originally identified by Raymond Cattell (1971). Fluid intelligence is the ability to find meaning in confusion and solve new problems. It is the ability to draw inferences and understand the relationships of various concepts, independent of acquired knowledge. Crystallized intelligence is the ability to use learned skills, knowledge, and experience. It is not memory or knowledge, although it relies on information from long-term memory.

[4] Raymond B. Cattell created the Culture Fair Intelligence Test and argued that general intelligence (g) exists and that it consists of fluid intelligence and crystallized intelligence. Culture-fair tests, also called culture-free tests, are designed to assess intelligence (or other attributes) without relying on knowledge specific to any individual cultural group. The first culture-fair test, called Army Examination Beta, was developed by the United States military during World War II to screen soldiers of average intelligence who were illiterate or for whom English was a second language.

colleagues found that the reading, operation, and counting span tasks reflected a common factor that was separate from, but strongly related to the factor for the STM tasks (see Figure 2).

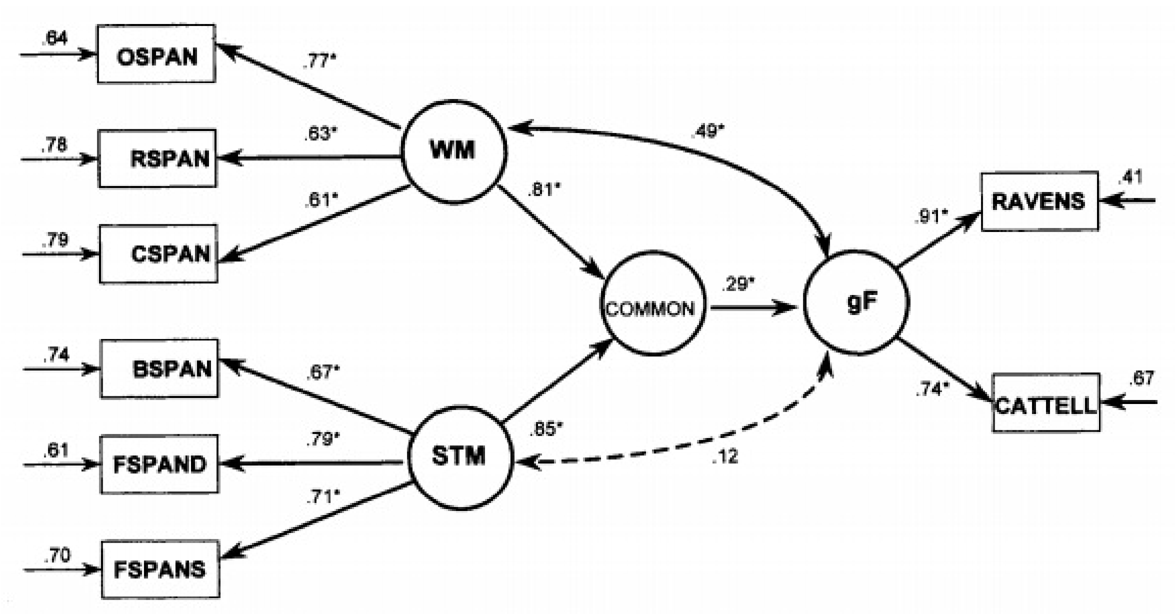

Figure 2. Path model of Confirmatory Factor analysis (from Engle et al., 1999, p. 324). OSPAN = operation span, RSPAN = reading span; CSPAN = counting span; BSPAN = backward word span; FSPAND = forward word span with dissimilar sounding words; FSPANS = forward word span with similar sounding words, gF = general fluid intelligence.

This finding is consistent with the notion that traditional STM tasks tap only the storage component of the WM system, whereas WM span tasks tap both storage and executive attention. In the subsequent structural equation model with both storage and executive attention represented by separate latent variables, the variance common to both was removed and the correlation between the residual of WM and the G*f* latent variable remained in the .50 range. The STM residual showed no relation to intelligence as measured by G*f* (Engle et al, 1999). Engle and colleague (1999) argued that if the shared variance between WM and STM reflects storage, then the residual of WM should reflect executive attention. Importantly, the executive-attention component of WM was most strongly correlated with the G*f* latent variable (Kane, Bleckley, Conway, & Engle, 2001).

Based on the WM hypothesis outlined above, Engle and colleagues hypothesized that the core source of WM affecting individual differences may be executive attention, not the storage or processing components of WM. To address the function of the executive attention in WM, Engle and colleagues proposed a two-factor theory of executive control (Engle & Kane, 2004). The first control factor is the *goal maintenance* of the task in active memory. Engle and Kane viewed the maintenance as a resource-demanding endeavor and argued that individuals with high WMC are better able to expend that resource on a continuing basis. The second factor in the executive control of behavior is *the resolution of response competition or conflict*, particularly when pre-potent or habitual behaviors conflict with behaviors appropriate to the current task goal (Engle & Kane, 2004). This perspective is consistent with the Cohen model in which competition resolution depends on activated goal representations (Cohen et al, 1990; Cohen & Servan-Schreiber, 1992).

The conclusion derived from the executive attention hypothesis was that WM is related to an executive attention ability that supports the active maintenance of goal-relevant information and competition resolution in the face of interference. This attention ability is most critical in interference-rich conditions because correct responding cannot be achieved via automatic spreading activation among memory representations or habitual responding (Conway, Kane, & Engle, 2003).

A central thesis of Engle, Kane, and Tuholski (1999) is that the nature of individual differences in the face of interference depends on the subject's executive attention. That is, the executive attention hypothesis suggests that some of the performance differences among individuals within a task domain will be explained in terms of executive attention (goal maintenance and conflict resolution). For instance, when a participant is required to say a color instead of a word in a Stroop test, individuals with a smaller WM span should be less able to perform the task quickly or they will make more errors. One important implication of this view is that the processing time slows down and the accuracy of response decreases under conditions of interference or distracters.

2.1.2.2 The Effects of Executive Attention of WM

Microanalytic studies have tested a more focused approach to analyze span-ability relations. Quasi-experimental designs have examined WM span-related differences by comparing individuals with high WM span scores (from the upper quartile of subject distribution) to those with low WM span scores (from the lower quartile of subject distribution) in the performance of cognitive tasks (Engle & Kane, 2004).

Engle and his colleagues believed that these quasi-experimental designs could provide evidence for the association between WMC and executive attention capabilities. They hypothesized that individual differences in WMC were caused by the attentional demands of the interfering stimuli during retrieval from memory. A variety of experimental studies have demonstrated a strong connection between WMC and interference vulnerability. In these studies, extreme quartile groups of high- and low-WM span subjects differed in terms of recall accuracy or latency under high-interference, but not in low-interference conditions (Kane, Conway, Hambrick, & Engle, 2007).

Engle and colleagues hypothesized that goal maintenance and competition resolution are critical aspects of preventing inappropriate response tendencies from controlling behavior. That is, to block successfully a pre-potentiated response such as tendency to say a word instead of the target color in which it is printed or imbedded (blue in red ink) in a Stroop task, one must keep this goal especially accessible and resolve the conflict between the lexical item and the generation of the word for the color of the ink. Although it may be trivial to recall the rules of a task from LTM, it is often more challenging to behave, in the moment, according to these rules. Therefore, Engle and colleagues viewed that active goal maintenance and the resolution of competition were interdependent processes of executive control (Engle & Kane, 2004).

In an attempt to measure the relationship between WM capacity and executive attention, Kane, Bleckley, Conway, & Engle (2001) tested normal functioning individuals with high and low WMC on an antisaccade task. In this task, subjects were required to fixate in the middle of a visual display, and respond to the target information presented briefly and randomly to one side or the other of the display. Just before the target was presented, an attention-attracting cue occurred on the opposite side of where the target would appear. The cue always predicted that the target would occur on the opposite side of the display. Participants needed to resist the strong tendency to shift their attention to the attention-capturing cue to achieve the optimal performance in the antisaccade task. The experiments also included a prosaccade task as a control condition in which the attention-capturing cue occurred on the same side as the cue. Thus, the natural tendency to look at the cue expected the facilitation of performance in the prosaccade condition and the interference of performance in the antisaccade condition.

Kane and colleagues (2001) predicted that the performance of individuals with high and low WM spans should not differ in the prosaccade condition. However, if individual differences in the WM capacity correspond to differences in the executive attention, individuals with low WM spans should show more impaired performance than individuals with high spans in the antisaccade task in which the resource demands for the goal maintenance and the conflict resolution are increased.

As expected, the results showed that the two groups of subjects did not differ in time to identify target letters in the prosaccade condition. However, although both groups were slow in the antisaccade condition, the individuals with low spans were significantly slower and made more errors than the individuals with high spans. Participants also performed an extended set of antisaccade trials, and again Kane et al. found that individuals with low spans were substantially slower to identify the letters than individuals with high-spans. The findings indicated that people with low WMC were more vulnerable to the antisaccade condition requiring abilities of conflict resolution and goal maintenance as a function of executive attention. Moreover, Experiment 2 measured eye movements across hundreds of antisaccade trials, and the individual with high span showed fewer saccades toward the cue, faster recovery from these saccade errors, and faster correctly guided saccades than the individuals with low span.

Kane and colleagues claimed that their findings were consistent with a view that the underlying factor responsible for the WMC is the executive attention system. They insisted that differences of individuals with different WM capacities in memory tasks is a result of their different abilities to maintain information and resolve conflicts in the face of interfering conditions.

To gain additional evidence that WMC is tied to the executive attention represented by the goal maintenance and competition resolution, Kane and Engle (2003) tested individuals with high and low spans in several versions of the Stroop color-word task. They considered that the Stroop task was an example of an executive attention task in which a habitual, over-learned reading response should be repressed to control behavior with the novel color-naming goal. In order to control the requirements for actively maintaining access to task goals, the researchers manipulated the proportion of congruent trials. In the high-congruency condition, most trials presented words that matched their colors, so the goal of ignoring the word was not reinforced to participants in the task environment. Because the automatically elicited response to most stimuli was correct, it was assumed to have been easy to maintain a word reading rather than color naming goal. To respond accurately to stimuli on the rare incongruent trials that presented conflicting color words (BLUE in red ink), participants had to maintain the appropriate task goal. The performance accuracy therefore was expected to represent the integrity or facility of executive attention.

In contrast, the Stroop condition that presented few congruent trials and mostly incongruent trials reinforced the task goal for subjects. If every trial demands the task goal that the word should be ignored, it may be unnecessary to do the mental work that requires participants to actively maintain goal access. A predominance of incongruent Stroop trials was expected to enhance participants' performance in color naming rather than in word naming. Under these circumstances, Stroop interference is likely to reflect the effectiveness of the competition resolution carried out by the external cue, and should be evident in response latencies, that is, in slow but correct responses (Kane & Engle, 2003).

When 20% or 25% of the trials were incongruent, Kane and Engle (2003) found that individuals with low spans had substantially larger error-interference effects than individuals with high spans. These effects, across four samples in the three experiments, indicated that individuals with low span had a deficit in goal maintenance. Although low-span subjects understood the goal of the task, and in some experiments, even received accuracy feedback after every trial, they often made word-reading errors on incongruent trials. In contrast, when 100% of the trials were incongruent, modest span effects in RT interference were found. WMC-related differences were not found in errors indicative of goal neglect, but rather in latencies, suggesting a slowed resolution of the conflict between elicited and desired response.

Another attentional interference task in which the executive attention has been shown to be important is the dichotic-listening task (Cherry, 1953). In some dichotic paradigms, words presented to one ear for oral repetition, while information presented to the other ear is ignored. Conway, Cowan, and Bunting (2001) investigated a dichotic-listening task to assess the role of executive attention in WM. They had participants shadow words in one ear while ignoring words presented in the other ear. At some point across trials, each subject's first name was presented as a word in the ignored message. At the end of the study, the participants were asked whether they had heard their name during the trial. The researchers predicted that individuals with high span should be better than low span subjects at ignoring distracting information, and individuals with low span should be more likely to report hearing their name under these conditions.

The results showed that while only 20% of individuals with high-span reported hearing their name, 65% of individuals with low span reported hearing their name. Conway et al.

concluded that individuals with low WM spans are less capable than individuals with high WM spans of performing the mental work necessary to block distracting information.

Wiener, Connor, and Obler (2004) investigated the cognitive process of inhibition and its relation to auditory comprehension in Wernicke's aphasia by using a Stroop-like task. They hypothesized that persons with Wernicke's aphasia would demonstrate impaired inhibition on such a task. The study adapted the computerized manual-response, numerical version of the Stroop test (Salthouse & Meinz, 1995) for 5 PWA and for 12 non-brain-injured controls. The researchers predicted that PWA would have greater difficulty than the non-brain damaged adults in this Arabic numeral Stroop test. The study included compatible, neutral, and incompatible conditions to measure the effects of facilitation (compatible vs. neutral) and interference (incompatible vs. neutral). The compatible condition represented the Arabic numbers 1 to 4 in congruent quantities (e.g., 333 or 4444). The neutral condition represented an "X" in its four possible quantities. The incompatible condition represented the Arabic numbers 1 to 4 in incongruent quantities (e.g., 1111 or 44).

The reaction time and error percentage were measured. Reaction times were not different between PWA and NI in the compatible condition. However, the interference effect (the incompatible condition minus the neutral condition) was significantly larger for PWA than the normal subjects. Consistent with Engle and colleagues' model, these results reflected an impairment of executive attention in PWA in the incompatible condition. In addition, the Stroop interference effect was significantly positively correlated with the clinical-behavioral symptom of the severity of auditory comprehension deficits as measured by a version of the Token Test. In contrast, the error percentage data showed that both groups made almost no errors in the compatible and neutral conditions; however, both groups made errors in the incompatible condition and the mean percentage of errors was significantly greater than zero. There was no difference between the groups in the facilitation effect for errors, whereas there were significantly more errors for the aphasic group than for control group in the incompatible condition.

The findings were consistent with the hypothesis that impaired goal maintenance and conflict resolution are core sources of language comprehension/higher-order cognitive capabilities (Engle & Kane, 2004) and that both were impaired in PWA. The correlation between the Stroop effect and the auditory comprehension deficits suggested that the impaired executive attention in PWA may be at least partially responsible for their auditory comprehension deficits. In other words, PWA didn’t suppress/inhibit the automatically evoked, distracting stimulus as effectively as normal controls.

2.1.3 Executive Attention and Interference Effect on the Picture-Word Interference Task

Although most researchers that have used Stroop interference tasks have been concerned with the color naming aspect of the task, modifications have been adapted to a variety of domains and various Strop-like tasks have been developed since the original Stroop study (Stroop, 1935). The following sections will review the Picture-Word Interference (PWI) task that has been used to examine the role of executive attention as a linguistic-domain attentional interference task. In the PWI task, participants see a word superimposed on a picture. The word either matches with the picture, or differs from the picture. Participants are required to judge whether each superimposed word is within a semantic category (e.g., animal or non-animal) while consistently ignoring the picture on every trial. For example, the word “sheep” may be printed within a picture of a sheep, or it may be printed in a picture of an apple. When a word and a picture do not match, an interference effect will be observed. When a word and a picture match, a facilitation effect will ensue. Although arguments continue over whether the PWI task is an example of a “Stroop” task (Dell'Acqua, Peressotti, & Pascali, 2007), it is often the case that the PWI effect is considered a Stroop effect (Maanen, Rijn, & Borst, 2009).

2.1.3.1 Semantic processing on The Picture-Word Interference task

Glaser and Glaser (1989) proposed a model mainly based on findings with picture-word stimuli. Within their model, a distinction was made between a semantic system that contains all semantic knowledge, and a lexicon that contains only linguistic word knowledge. The two systems are assumed to have different input and output functions. The semantic system controls, via an executive system, the perception of pictures and the action of physical objects. In contrast, the lexicon is thought to be responsible for the comprehension and production of spoken and written language. As a consequence of this architecture, when words have to be used, they will differentially and directly activate their word nodes within the lexicon. A picture, however, will first have to activate its concept nodes within the semantic system. After this, the corresponding word nodes are activated. When semantic information is required (e.g., identification of the category to which a word belongs), the pathway followed by a word will start at its word node, after which the corresponding concept node in the semantic system is activated. A picture will not have to make the detour. When stimuli are presented within the PWI paradigm, two pathways will be activated concurrently. If the dimensions of the PWI Stimuli differ (a word “dog” and a picture of sofa), interference will be observed when the irrelevant dimension (picture of a sofa) has privileged access to the system that is critical for the selection of the response (For example, the word “dog” on a picture of a sofa).

When the category to which a picture belongs has to be named, Glaser and Glaser assumed that the semantic system is relevant for the selection of the response. There will be a conflict between those category nodes activated by the word and those activated by the picture. Because the word does not have privileged access to the semantic system, the categorization of a picture will not be delayed. However, the picture will interfere with the categorization of the word because it has privileged access to the semantic system. Results consistent with this interpretation have been obtained in several studies (e.g., Glaser & Dungelhoff, 1984; Smith & Magee, 1980).

Smith and Magee (1980) sought to clarify the time course in which the information about pictures and words becomes available by considering the pattern of interference generated when incongruent pictures and words are presented simultaneously in a PWI situation. They assumed that incompatible information from a distracter would interfere with the response to a target only if this information is available prior to the generation of the target response. They predicted that an incongruent picture would interfere with word categorization, whereas picture categorization should be relatively unaffected by the presence of an incongruent word since previous research evidenced that categorization occurs more rapidly for pictures than for words. In their first experiment, 16 young normal participants were asked to verify the semantic category of the target stimulus. In accordance with the hypothesis that pictures access the semantic code more rapidly than words, there was a reversal in the interference pattern: word categorization suffered considerable disruption with an incongruent picture, whereas picture categorization was minimally affected by the presence of an incongruent word. Their finding supported a model of PWI whereby pictures access semantic information more readily than lexical information.

Houwer, Fias, and d'Ydewalle (1994) examined picture-word Interference effects by having participants name the season corresponding to the picture or to the word of a picture-word stimulus (e.g., flower for spring). They found that the privileged semantic processing of pictures was evidenced by a larger interference on words with picture distracters than on pictures with word distracters. They concluded that the interfering power of pictures on word processing was considerably larger than the effect of words on picture processing. This finding was interpreted as verification that pictures are assumed to have more privileged access than words to semantic information (Biggs & Markmurek, 1990; Glaser, 1992; Warren & Morton, 1982). The model, therefore, suggested that when semantic information is required, a color must go through the color system before it can enter the semantic system. A word has to make a detour via the lexicon. Because pictures have direct access to the semantic system, when semantic information is required, the pathway followed by the picture will be one step shorter than that followed by the word.

The PWI paradigm has been demonstrated to be an appropriate experimental task with which to investigate the relationship between language and attention; especially at the single word-level. This paradigm can accommodate the more essential language processing (semantic and lexical processing of various words) and diverse selections of target stimuli than other interference tasks (e.g., the color-word Stroop). In particular, the PWI task utilizes a simplified response method (manual response for categorization), which has important methodological advantages for PWA over vocal responses (e.g., color naming).

2.1.4 Probability effect in Aphasia

In young normal individuals, Kane and Engle (2003) utilized the congruency proportion of color-word Stroop tasks to increase the burden on executive attention. They, like Tseng, McNeil, and Milenkovic (1993) and Murray, Holland, and Beeson, (1997a, b), hypothesized that a low proportion of incongruent stimuli (e.g., 20% incongruent stimuli condition) would require more executive attention compared to a high proportion of the incongruent conditions (e.g., 80% incongruent stimuli condition). Young normal participants showed the congruency proportion effect depending on their WM span. This result indicated that young normal people are sensitive to the probability structure of the color-word Stroop task and they engage their executive attentional system to complete the task (longer RT and larger error).

2.1.4.1 The Sensitivity of Proportion Structure in Persons with Aphasia

According to Kane and Engle's (2003) Stroop study, it is likely that normal participants can intuitively understand the proportion structure of the color-word Stroop task. However, given that there are many limitations in studying PWA due to their attentional ability, one of the most important considerations in an experimental study including proportion effect might be whether PWA completely understand the proportion structure within the experiment task. Therefore, to do the PWI task with the effect of congruency proportion to examine executive attention in an interference condition, it should be confirmed that PWA can understand the proportion structure of congruency and perform the PWI task based on that information.

Arvedson (1986) examined the effect of varied task proportions in dual-task conditions. In this study, 10 left hemisphere-damaged, 10 right hemisphere-damaged, and 10 normal controls participated in a task in which they engaged a semantic judgment and a lexical decision dual task, with varied proportions (100% semantic:0% lexical, 50%:50%, 0%:100%) dictated by the instructions. Both the accuracy and RT were measured for both the semantic judgment and lexical decision tasks under each of the three varied proportion conditions. In the accuracy analysis, a three-way repeated measure [3 (group) × 3 (proportion) × 2 (task)] ANOVA revealed that there was a significant group effect ($p < .05$), a significant proportion effect ($p < .05$), and a significant task effect ($p < .05$). In addition to the main effects, there was a significant interaction between the proportion and the task indicating that all three groups showed the attention trade-off across the varied proportions. In the RT analysis, a three-way repeated measure [3 (group) × 3 (proportion) × 2 (task)] ANOVA revealed that there was a significant proportion effect ($p < .05$), but there were no significant group and task effects. Although there was no significant task effect, there was a significant interaction between proportion and task. Arvedson concluded that there was an attentional trade-off between the two tasks according to the proportion of emphasis. The results of this study supported the notion that PWA are able to intuitively understand the probability structure and perform the dual tasks.

McNeil and colleagues (2011) investigated the effects of several color-word congruent and incongruent “Stroop” tasks, within the context of self-paced sentence reading comprehension in PWA (N=25) and normal adults (N=29). Each participant read a sentence (e.g., “Touch the red circle") under a normal reading condition, with the color word replaced with a colored polygon (neutral condition), and with the colored word printed in a font color different from the lexical item (incongruent condition) and with the colored word printed in a font color that was the same as the lexical item (congruent condition). The incongruent condition was delivered in 100% and 30% proportions. Dependent measures included reading times and error for the color words, font colors or polygons. The results relative to the proportion manipulation revealed that there were significant reading time differences for both NA ($p<0.001$) and PWA ($p<0.041$) between the 30% and 100% congruent condition, with the lower proportion yielding longer reading times. This result was consistent with Arvedson's (1986) in which PWA also demonstrated significant probability effects.

2.2 SUMMARY AND STATEMENT OF PURPOSE

Following the resource allocation hypothesis (McNeil, 1982; McNeil, Odell, & Tseng, 1991) that proposed a relationship between attentional deficits and the language ability in PWA, several researchers have investigated attentional resources in PWA. Because of the agreed upon role of attention in WM, many but not all of these studies have been conducted within that context. Several studies have focused on measuring individual's resource allocation strategies and their relationship to language deficits in PWA.

Since Baddeley and Hitch's (1974) first WM model, several WM models have been proposed while retaining basic components and assumptions of the original. The general WM models are considered to consist of three components; temporary memory stores, processing (computations), and executive attention. Most studies of WM have focused on STM and processing (Just & Carpenter, 1980; Caplan & Waters, 1995; Miyake, Just, & Carpenter, 1994). Caplan and Waters (1995) investigated the effects of the syntactic complexity and concurrent digit memory load across clinical groups to demonstrate separate verbal WM systems between two components. They have successfully replicated these results and have demonstrated the critical role of WMC for language processing and comprehension.

The main focus of Engle and colleagues' work, for the purposes of the current investigation, lies in the explanation of executive attention as a substantial component of WM in the face of interference or competition. They suggested that goal maintenance and conflict/competition resolution are two critical functions of the executive attentional component of WM for preventing inappropriate response tendencies from controlling behavior. In an attempt to directly examine the relationship between the WM capacity and executive attention, Engle and colleagues investigated interference tasks and found that individuals who performed in the lower ranges on WM tasks showed longer RT and higher error rates in incongruent conditions (Kane & Engle, 2003; Kane, Bleckley, Conway, & Engle, 2001). Interference tasks under congruency proportion manipulations have been shown to affect goal maintenance and conflict resolution, both critical components of executive attention. It is critical that a word-level interference task with congruency proportion be investigated in PWA to further examine the role of attentional mechanisms and impairments and their role in the language deficits that characterize aphasia.

The objective of the proposed research was to examine accuracy and response times under two different congruency ratio conditions (19% and 73%[5]) between PWA and NI groups using the Picture-Word Interference (PWI) paradigm. Within this experimental paradigm, it is possible to examine the role of two critical components of attention, conflict resolution and goal maintenance (Kane & Engle, 2003; Engle et al, 1999). The resolution of conflict in the face of interfering conditions requires the ability to resolve the competition and respond correctly when two competitive processes are activated by contradictory information. That is, increased resource demands for the incongruent conditions were expected to result in increased RT and/or a higher error rates on incongruent conditions compared to neutral and congruent conditions with a lower incongruent proportion. On the other hand, goal-maintenance ability is the capacity to maintain specific-task goals when the task context reinforces competing and more automatically achieved goals. Increased goal-maintenance burdens were hypothesized to cause an increased RT and Error percentage in NI when comparing incongruent trials between the 19% and 73% incongruent proportions. Conversely, PWA were predicted to have non-significantly different RTs and error rates in the two proportions due to proposed deficits of conflict resolution and goal maintenance resulting from impaired executive attention.

[5] The proportion of incongruent stimuli in this condition was exactly matched between Engle and Kane (2003) and the current study even though the numerical values of the proportion were different between studies. The 19% incongruent condition in the current study was the same with the 25% incongruent proportion by Kane and Engle (2003). The 73% incongruent proportion in this study is matched with the 100% incongruent proportion by Kane and Engle (2003). These differences in percentage between the two studies resulted from the calculation methods of the incongruent proportion in each task. The proportion in this study was calculated from that the trial number in the incongruent condition was divided by the trial number in the other conditions (congruent + neutral condition). However, Kane and Engle calculated the proportion from the ratio between the trial number in the incongruent condition versus the trial number in the congruent condition while ignoring the trial number of the neutral condition. See Appendix B for the specific structure of the proportions.

Prediction 1. A group of PWA will evidence significantly longer reaction times and higher error rates in the incompatible conditions of the PWI task as compared to the age-matched NI group due to executive attention deficits in the PWA. However, there will be no significant differences in performance between groups when the response times and the error rates of the PWI tasks are measured in the congruent and neutral conditions.

Prediction 2. There will be no significant proportion effect across the relevant PWI tasks for PWA. Specifically, PWA will show no significant difference in RTs or error rates between two different proportions of incongruent conditions due to executive attention deficits in the PWA. However, NI will reveal significantly longer RTs and more errors in the 19% incongruent proportion than in the 73% incongruent proportion. There will be a significant interaction between groups and proportions of congruency on the PWI tasks in the incongruent conditions.

2.3 SIGNIFICANCE

The proposed research will contribute to understanding the nature of cognitive attentional deficits in PWA by examining how the executive attention affects language processing. The theoretical background of the relationship between cognitive attention and language abilities was borrowed from the WM literature. By manipulating the STM (storage) and the linguistic processing of WM, several WM studies has examined WMC and language capability of individuals with aphasia (Water & Caplan, 1996; Berndt, Haendiges, & Wozniak, 1996; Friedman & Gvion, 2003; Kolk & Weijts, 1996; Schwartz et al., 1987) and without aphasia (Miyake & Shah, 1994, 1995; Shah & Miyake, 1996; Kane & Engle, 2003). The results have revealed a positive relationship between WMC and language processing ability. On the other approach with WM, executive attention has been suggested as a critical component of WMC in many studies with NI groups. Studies from the WM literature have demonstrated attentional differences. However, no one has demonstrated goal maintenance and conflict resolution deficits in PWA - especially the proportion effects with the PWI task and at the word-level. By controlling STM and linguistic processing effects in the level of a single word, the finding may inform not only the pure characteristics of executive attention in PWA but also the degree of its significance in PWA.

3.0 RESEARCH DESIGN AND METHODS

3.1 PARTICIPANTS

Ten PWA (4 females, 6 males) and Twenty NI (3 females, 17 males) participated in the study. They were recruited through the VA Research Registry approved by the VA Pittsburgh Healthcare System. All participants met the following inclusion criteria: American English as their native language; aged 30 to 80 years old; vision screening with the reduced Snellen chart with 20/40 or better visual acuity (with correction if necessary); performance on the immediate/delayed story retell task of the Assessment Battery of Communication in Dementia (ABCD) (Bayles & Tomoeda, 1993) yielding a ratio (the delayed recall/immediate recall × 100) greater than 70% on the delayed recall compared to the immediate recall; Lexical and semantic test greater than 60% accuracy based on PWI stimuli (picture and word). The NI participants also self-reported no history of communication disorder, learning disability, neurological illness, head injury, and psychiatric illness. Two potential PWA were excluded from participation due to the failure to meet the 60% or greater lexical and semantic test criterion. Two NI were withdrawn from the study because they didn't want to complete all subtests. The remaining 10 PWA (4 female and 6 male) and 20 NI (3 female and 17 male) whose data were submitted to analysis ranged in age from 47 to 70 years old (mean = 58.0; SD = 8.5) for PWA and 40 to 74 years old (mean = 65.4; SD = 7.9) for NI. The averaged time post onset of the PWA group was 115.5 with the range of 36 to 384.

3.2 SCREENING AND DESCRIPTIVE MEASURES

Both groups were administered the following descriptive and screening measures: a) the *Porch Index of Communicative Ability* (PICA) (Porch, 2001) as a test of general language performance, b) *the Computerized Revised Token Test* (CRTT) (McNeil, Pratt, Szuminsky et al., 2008) as a test of auditory sentence comprehension, c) *a modified Stroop version of the CRTT* presented using self-paced word-by-word reading (CRTT-R-$_{\text{WF-stroop}}$) (McNeil, Pratt et al., 2010) as a test of reading sentence comprehension in an interference context, d) *the Assessment Battery of Communication in Dementia* (ABCD) as a test of verbal memory (Bayles & Tomoeda, 1993), e) *forward digits span task* as a short-term memory span measure *and backward digits span tas*k as a working memory span measure, f) *the Raven Coloured Progressive Matrices* (Raven, 1956) as a non-verbal cognitive skill test, g) *the Edinburgh Handedness Inventory* (Oldfield, 1971) as a test of handedness, h) *sentence (cleft-subject and cleft-object) reading span , Alphabet span, and Subtract-2* (Waters & Caplan, 2003) as tests of working memory, i) *Trail Making Test* (TMT; Amieva et al, 1998) and *Symbol Trail Making test* (STMT) as a test of inhibitory processing, j) *Pyramids and Palm Trees test* (PPT) as a test of semantic ability, k) a modified version of *lexical decision test* (LDT, Arvedson, 1986) as a test of participants' ability to classify stimuli as words or non-words, l) *Iowa gambling test* (Bechara, Damásio, Damásio, & Anderson, 1994) as a test of sensitivity of proportion structure. Individuals' performance on each of these measures (from a through l) is summarized in Table 1 and for PWA group and Table 2 for the NI group. A t-test revealed that there were no significant differences between the groups for age, ABCD, Cleft-Subject reading span tests, TMT, STMT, Raven, PPT, LDT, CRTT-Stroop (overall score), IOWA gambling test (ps≥.05). However, PWA performed significantly worse than NI in the

Object-Subject reading span tests, Alphabet span test, Subtract-2 span test, and Digit Span (*p*s<.05). The handedness survey revealed that nine PWA were pre-morbidly right-handed, and one was ambidextrous. Nineteen NI were right-handed, and one was ambidextrous.

Table 1. Performance on descriptive and screening measures in persons with aphasia.

			WM				TMT		STMT								
ID	PICA	CRTT_a	CS	OS	Alph	Subt-2	Num	Alter	circle	Alter	PPT	LDT	CRTT_s	Gambling	F-D	B-D	Raven
101	13.33	14.30	2	1.5	4	2.5	42	165	8	57	51	92.5	14.40	1925	5	4	24
103	13.44	13.67	1.5	1	3.5	4	44	154	17	41	47	90	11.80	1250	6	3	31
104	10.68	11.77	1	1	1.5	1	84	244	15	63	49	95	14.40	1750	4	1	31
105	13.02	14.10	1.5	1	2	3	66	176	6	64	49	62.5	12.39	650	4	2	28
106	13.85	13.85	2	1	3	4	44	87	6	34	47	85	12.93	2300	7	4	34
108	13.93	13.94	1	1	4	4	28	67	9	29	52	100	12.80	1050	6	3	33
109	13.71	13.82	2	1.5	3.5	3.5	31	114	6	20	50	85	13.63	3000	6	2	34
110	12.28	10.48	1	1	2	1	182	388	9	67	49	80	10.64	2525	2	2	29
111	11.04	12.11	1	1	1.5	1	53	136	29	54	48	85	12.03	1725	2	2	28
112	9.58	11.41	1	1	1.5	1	184	366	15	96	45	70	11.34	2700	3	2	24
Mean	12.49	12.94	1.40	1.10	2.65	2.50	75.80	189.70	12.00	52.50	48.70	84.50	12.64	1887.50	4.50	2.50	29.60
SD	1.53	1.37	0.46	0.21	1.06	1.37	58.81	110.37	7.26	22.24	2.06	11.35	1.25	757.21	1.78	0.97	3.69

ID= subject number
PICA= Porch Index of Communicative Ability (PICA) (Porch, 2001)
CRTT-a= Computerized Revised Token Test ($CRTT\text{-}_{Stroop}$) (McNeil, Pratt, Szuminsky et al., 2008)
CS= Cleft-subject reading span test (Waters and Caplan, 2003)
OS= Cleft-object reading span test (Waters and Caplan, 2003)
Alph= Alphabet span test (Waters and Caplan, 2003)
Subt-2= Subtract-2 WM span test (Waters and Caplan, 2003)
TMT-Num= the number of Trail Making Test (Amieva et al, 1998)
TMT-Alter= = the alternative of Trail Making Test (Amieva et al, 1998)
STMT-circle= the number of Symbol Trail Making test (Barncord and Wanlass, 2001)
STMT-Alter= the alternative of Symbol Trail Making test (Barncord and Wanlass, 2001)
PPT= Pyramids and Palm Trees test
LDT= lexical decision test (Arvedson, 1986)
CRTT-s = Stroop version of Computerized Revised Token Test (CRTT) (McNeil, Pratt, Szuminsky et al., 2010)
Gambling = Total response time of Iowa Gambling Test (ms)
F-D= Forward digit pointing span task
B-D= Backward digit pointing span task
Raven= The Raven Coloured Progressive Matrices (Raven, 1956)
SD = Standard Deviation

Table 2. Performance on descriptive and screening measures in normal individuals.

			WM				TMT		Symbol T								
ID	PICA	CRTT_a	CS	OS	Alph	Subt-2	Num	Alter	circle	Alter	PPT	LDT	CRTT_s	Gambling	F-D	B-D	Raven
201	14.2	14.8	1.2	1.2	3.5	5	37	122	16	38	50	92.5	12.70	25	7	4	27
202	14.7	14.3	3.5	1.5	5	6.5	25	48	8	26	50	100	14.70	1375	8	4	33
203	14.6	13.7	2	1	4	4	25	74	2	4	49	77.5	12.72	1350	7	4	28
204	14.7	14.7	3	2	4	6.5	28	56	4	17	50	80	14.39	2225	8	3	29
205	14.7	15.0	1.5	1.5	2.5	6.5	25	44	6	15	50	92.5	14.64	2675	8	5	33
206	14.5	14.5	2	2	5.5	5.5	20	77	4	16	51	97.5	14.40	1500	8	7	32
207	14.4	14.4	2	2	3.5	3.5	50	111	9	18	50	100	13.53	2675	5	3	29
208	14.2	14.8	2	2	3	6	17	58	6	33	48	95	13.55	3075	6	5	27
209	14.0	14.4	1	1	4	5	33	82	6	26	50	90	12.62	2175	6	3	31
210	14.2	14.6	2.5	2	4	4.5	27	56	5	64	51	92.5	12.84	2250	6	4	32
213	14.0	13.9	1	1	3.5	3.5	33	67	6	24	47	77.5	12.64	1575	6	5	30
214	14.1	13.9	1	1.5	3.5	4	18	53	4	12	50	85	12.79	100	6	4	22
215	13.9	12.9	1	1	3.5	4.5	53	227	7	72	42	70	11.94	2250	6	4	25
216	14.1	14.0	1	1	3	5	40	75	6	25	45	82.5	14.20	1425	8	3	27
217	14.1	13.8	2	2	3	4	40	10	8	22	49	90	13.86	1525	6	4	27
218	13.9	14.2	2.5	1	3	3.5	19	69	5	22	51	90	13.90	1625	5	4	34
219	14.1	12.9	2.5	1.5	4	5	31	74	4	24	49	90	14.51	2125	7	3	36
220	14.4	14.0	2	2	4	3.5	28	68	6	13	51	85	13.92	1900	7	4	32
221	14.2	14.0	2	2	4.5	5	43	133	10	62	50	82.5	12.66	1975	4	3	25
222	14.5	13.6	3.5	1.5	4	6.5	22	46	4	16	52	92.5	13.92	1025	8	6	32
Mean	13.68	13.73	1.77	1.39	3.38	4.08	45.73	114.90	8.20	35.80	49.07	86.92	13.23	1790.83	5.90	3.57	29.57
SD	1.23	1.05	0.75	0.42	0.98	1.63	40.14	89.42	5.45	22.74	2.21	9.21	1.06	758.30	1.71	1.28	3.53

ID= subject number
PICA= Porch Index of Communicative Ability (PICA) (Porch, 2001)
CRTT-a= Computerized Revised Token Test (CRTT-$_{\text{Stroop}}$) (McNeil, Pratt, Szuminsky et al., 2008)
CS= Cleft-subject reading span test (Waters and Caplan, 2003)
OS= Cleft-object reading span test (Waters and Caplan, 2003)
Alph= Alphabet span test (Waters and Caplan, 2003)
Subt-2= Subtract-2 WM span test (Waters and Caplan, 2003)
TMT-Num= the number of Trail Making Test (Amieva et al, 1998)
TMT-Alter= = the alternative of Trail Making Test (Amieva et al, 1998)
STMT-circle= the number of Symbol Trail Making test (Barncord and Wanlass, 2001)

STMT-Alter= the alternative of Symbol Trail Making test (Barncord and Wanlass, 2001)
PPT= Pyramids and Palm Trees test
LDT= lexical decision test (Arvedson, 1986)
CRTT-s = Stroop version of Computerized Revised Token Test (CRTT) (McNeil, Pratt, Szuminsky et al., 2010)
Gambling = Iowa Gambling test
F-D= Forward digit pointing span task
B-D= Bacward digit pointing span task
Raven= The Raven Coloured Progressive Matrices (Raven, 1956)
SD = Standard Deviation

3.3 APPARATUS AND STIMULI

Data were collected in a sound-attenuated booth and a Dell desktop computer was used to present the stimuli on a Super VGA high-resolution color monitor and record the responses. The binocular viewing distance was 100 cm. E-PRIME 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) was used to control the presentation of stimuli, timing operations, and data collection. Manual reaction times and errors were collected via a Dell keypad board.

The stimuli for the Picture-Word Interference task consisted of the 10 well-known words (See Appendix A) from two semantic categories (animal and non-animal). One-category set included animals consisting of five exemplars, and one non-animal category set consisted of mixed items from five other categories. The experimental stimuli for the PWI task were created by placing each of these words within a background line-drawn picture that was of high typicality and discriminability[6]. To create the stimuli (animals and non-animal), line drawings as picture stimuli were chosen from a previous PWI study (Dunbar, 1986), in which all stimuli were taken from the Snodgrass and Vanderwart's (1980) normed stimuli. In the congruent condition of the PWI tasks, each picture appeared with its corresponding name superimposed. In the incongruent condition, the pictures were paired with words from different categories. In the neutral condition, the stimuli consisted of each word surrounded by a polygon, used for controlling possible interference caused by lateral masking (Lupker & Katz, 1981).

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[6] Background line-drawn pictures were taken from the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997) and Pyramids and Palm Trees test (PPT; Howard & Patterson, 1992).

3.4 PROCEDURE

All data were collected in two separate sessions for each participant requiring approximately 90 - 120 minutes per session. In the first session, participants completed the informed consent process, screening tasks and several descriptive measures described above. In the second session, participants started with the experimental PWI tasks (practice condition, 19% incongruent condition, and 73% incongruent condition in order) and then completed the rest of descriptive measures.

Participants were seated 100cm distance in front of a Dell Desktop computer with a 19-inch color screen with an attached keyboard placed on the table between the computer and the participant. Participants were required to press two buttons on the right-side of the keyboard; the number “1” (for animal) and the number “2” (for non-animal categories). Participants were instructed to indicate whether the string of letters that appeared on the screen was an animal or non-animal by depressing the appropriate button with their non-dominant (left) hand. Throughout the task, participants rested one finger on each of the two buttons. In all conditions, a trial started with the presentation of a “*READY?*” signal at the center of the screen. The ready signal remained on screen until the participant press either button (“1” or “2” button) on the response keyboard. This response was followed by a 1,000 ms. blank screen. A black fixation cross-hair then appeared for 500 ms. at the center of the screen. The cross-hair was replaced by one of the target stimuli. The stimulus appeared on the monitor until the participant responded. Each stimulus remained in view for 5,000 ms. if the participants did not press a response within that time frame (See Appendix E). The E-PRIME 2.0 program presented the stimuli in bold

Times Roman font at size 64 point superimposed on the pictures and recorded the manual response latency and accuracy data.

All participants were individually tested in a quiet room. The experimenter remained in the room for the entire session. The two proportions (19% and 73%; see Appendix B) of the incongruent stimuli were presented in separate blocks. For each proportion, the instructions were first presented on the screen and read aloud by the examiner. Participants were told that they would be seeing a series of words superimposed on pictures, and that their job would be to classify each word as to whether it was an animal or not. They were also instructed to respond as rapidly and accurately as possible in all experimental tasks. The participants then responded to each of the randomly presented 280 stimuli. Onset of the stimulus started the timer and the subject's key press stopped the timer.

3.4.1 Picture-Word Interference task

The task began with three practice blocks. The first practice block of 30 trials was designed to familiarize the participants with the keypad and experimental stimuli of words and pictures. Participants pressed the number 1 key for animal words and the number 2 key for non-animal words, which were all superimposed with their correct labels and displayed in black. The second practice block of 30 trials was designed to familiarize participants with the unclassified line-drawing picture (a polygon) and with the animal or non-animal names imbedded within the unclassified line drawing. Each word string and picture appeared equally often in practice blocks 1 and 2. The third practice block was designed to familiarize participants with incompatible word and picture stimuli.

In the experimental condition, the two experiment blocks consisted of two proportions of the PWI task with 280 trials in each proportion, as described above (See Appendix B). The 19% incongruent PWI task was presented first. The 73% incongruent proportion task was always presented as the final task. This procedure was used to minimize any possible learning in the interference conditions (Kane & Engle, 2003).

The experimenter explicitly instructed all participants to ignore the picture on every trial in the PWI task, even if the word and picture matched on some or many trials. As well, the experimenter instructed all participants that they would be observed to determine that they never look away from the word or squint their eyes during the task. Finally, all participants were instructed and encouraged to respond as quickly and as accurately as possible.

3.5 DESIGN

The design was a 2 × 2 × 3 mixed-model factorial, with group (aphasia and normal) as between-subjects variables, incongruency proportion (19% and 73%) and condition (congruent, neutral and incongruent) as within-subjects variables. The presentation order of proportion conditions was fixed such that the 19% incongruent proportion condition was followed by 73% incongruent proportion.

3.6 ANALYSES AND HYPOTHESES

The accuracy and time of the manual response were used as the two dependent measures for each trial. Any response trial that exceeded the participant's mean response time for that condition by more than three standard deviations and any trial with a latency less than 200 ms. were deleted as outliers. To correct for non-normalcy in the distribution of RTs and error rates, all RT values were inverse transformed to approximate a normal distribution and error rates were transformed with aligned rank transform (Wobbrock, Findlater, Gergle, & Higgins, 2011). After the mean errors and response times for each condition were calculated, interference effects were calculated by subtracting the incongruent from the neutral conditions, and the facilitation effect was calculated by subtracting the congruent from the neutral. These manipulated data were entered into the statistic software package (SPSS 18) as dependent measures.

Two mixed models were conducted. The first mixed model for testing interference was calculated (alpha ≤ 0.05), with two independent factors: Group (PWA and NI) and Conditions (incongruent, neutral and congruent). The second mixed model for testing goal maintenance effects was calculated (alpha ≤ 0.05), with two independent factors: Group (PWA and NI) and incongruency proportion (19% and 73%). The following hypotheses were of primary interest to investigate executive attention in PWA resulting from hypothesized impaired conflict resolution and goal maintenance.

Hypothesis 1: PWA will show no significant difference in error rates and RTs from the NI for congruent and neutral conditions in 19% incongruent proportion of the PWI tasks. However, the PWA will show significantly larger error rates and longer response times than the NI in the incongruent condition of 19% incongruent proportion.

Hypothesis 2: PWA will show no significant difference in RTs and error rates in the incongruent conditions of the PWI tasks between the 19% and 73% incongruent proportions.

However, NI will demonstrate significantly longer RTs and more errors in the 19% incongruent proportion than in the 73% incongruent proportion.

Hypothesis 3: Language and executive attention performance will show a significant negative correlation with RTs in the incongruent condition of PWI task.

Hypothesis 4: WM capacity and executive attention performance will show a significant negative correlation with RTs in the incongruent condition of PWI task.

4.0 RESULTS

Mean RT was chosen as the primary dependent variable for this investigation. RTs were determined individually for each correct response (thus excluding errors, no response, responses less than 200ms and exceeding 3 standard deviations from the participant's own mean for that condition), under each congruency proportion (Pretest, 19%, and 73% Incongruent proportions) and for each condition (congruent, incongruent, and neutral). Error rates were also used as an additional dependent variable. Error percentage was calculated for each congruency proportion and for each condition after excluding response time outliers.

Hypothesis 1 (the interference effect) was analyzed with a 2 (group) × 3 (condition) mixed model ANOVA that compared RTs and error rates among congruent, neutral, and incongruent conditions of the 19% incongruent proportion task. Hypothesis 2 (the goal-maintenance effect) was assessed with a 2 (group) × 2 (proportion) mixed model ANOVA, comparing incongruent conditions between the 19% and 73% incongruent proportions. All RTs and error rates violated the normality assumption (See Appendix M[7]). In order to normalize the distribution for RT, an inverse transform (1/response time) was conducted for each condition and proportion for each group separately. The results of the inverse transform yielded a normal distribution for most RTs. Contrary to the normalization for the RTs, all of the inverse transformed error rates violated the normality assumption. Therefore, the aligned rank transform (Wobb et al., 2011) for the analysis of error rates was conducted and two mixed models were

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[7] Four Normalcy tests were conducted with Raw RTs, Raw Error Rates, Inverse Transformed RTs and Inverse Transformed Error Rates.

compute at an alpha level of.05. Hypotheses 3 and 4 were analyzed with nonparametric Spearman correlations at an alpha level of .05.

4.1 PRELIMINARY ANALYSIS

As a preliminary analysis, mean RTs from the neutral condition of the practice trials was used to determine significant RT slowing for the PWA. If there was a significant group effect on the neutral trials of the pretest condition, response speed would be used as a covariate in the following analyses in order to separate the participants' inhibition capacities from generally slowed information processing.

A one-way ANOVA using Group (NI and PWA) as a between-factor was computed on the inverse transformed RTs of the neutral trials from the practice condition. While the PWA (mean = 849.33; SD = 193.39) produced slower average RTs than NI (mean = 763.57; SD = 153.05), the difference was not significant; $F(1, 29) = 1.364$, $p = 0.252$, Effect Size (ES; η^2 [8]) = 0.21. Thus, the following analyses that assess the interference and facilitation effects on RT did not consider speed of response as a covariate.

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[8] Partial eta squared (η^2) was used for Effect Size of F-test (one-way ANOVA).

4.2 ANALYSIS OF PICTURE-WORD INTERFERENCE TASKS AND OTHER DESCRIPTIVE TESTS.

4.2.1 Response Times

Response errors (2.8%) and RT outliers (1.5%) were excluded from the reaction time analyses. The mean reaction times for each group and condition in the 19% and 73% incongruent proportion tasks are displayed in Table 3 and are contrasted in Figure 3. The results for each hypothesis are presented below:

Hypothesis 1: *PWA will show no significant difference in RTs from the NI for the congruent and neutral conditions in the 19% incongruent proportion of the PWI task. However, the PWA will show significantly longer response times than the NI in the incongruent condition of 19% incongruent proportion of the PWI task.*

The analysis revealed significant main effects for Group, F(1, 50.409) = 7.559, $p < 0.008$, ES (r[9]) = 0.45, and Condition, F(2, 141.742) = 173.393, $p < 0.0005$, ES (r) = 0.85, but no significant Group × Condition interaction, F(2, 141.742) = 0.134, $p = 0.874$, ES (r) = 0.00.

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[9] To calculate Effect Size from F-test in the mixed model analysis, r = $\sqrt{F \div (F + df)}$ was used.

Table 3. Mean Response Latencies (in Milliseconds) and Standard Deviations, by proportion (19% and 73%), condition (congruent, neutral, and incongruent) and group (NI and PWA).

Probability	Group	Condition					
		Congruent		Neutral		Incongruent	
		Mean	SD	Mean	SD	Mean	SD
73%_IC	NI	.	.	708.49	132.86	763.57	153.05
	PWA	.	.	849.33	193.39	977.70	311.42
19%_IC	NI	712.02	144.02	725.49	142.10	808.65	156.51
	PWA	882.91	272.94	942.17	347.30	1097.12	446.52

Decomposition of the group effect within each trial type with a Bonferroni alpha adjustment (p = 0.017) was conducted. The simple effect analysis indicated that the PWA were significantly longer than NI in the incongruent, F(1, 28) = 6.772, p < 0.015, ES (r) = 0.29 and the neutral conditions, F(1, 28) = 8.379, p < 0.007, ES (r) = 0.31, but the groups were not significantly different in the congruent condition, F(1, 28) = 6.246, p = 0.019, ES (r) = 0.29 (See Figure 3).

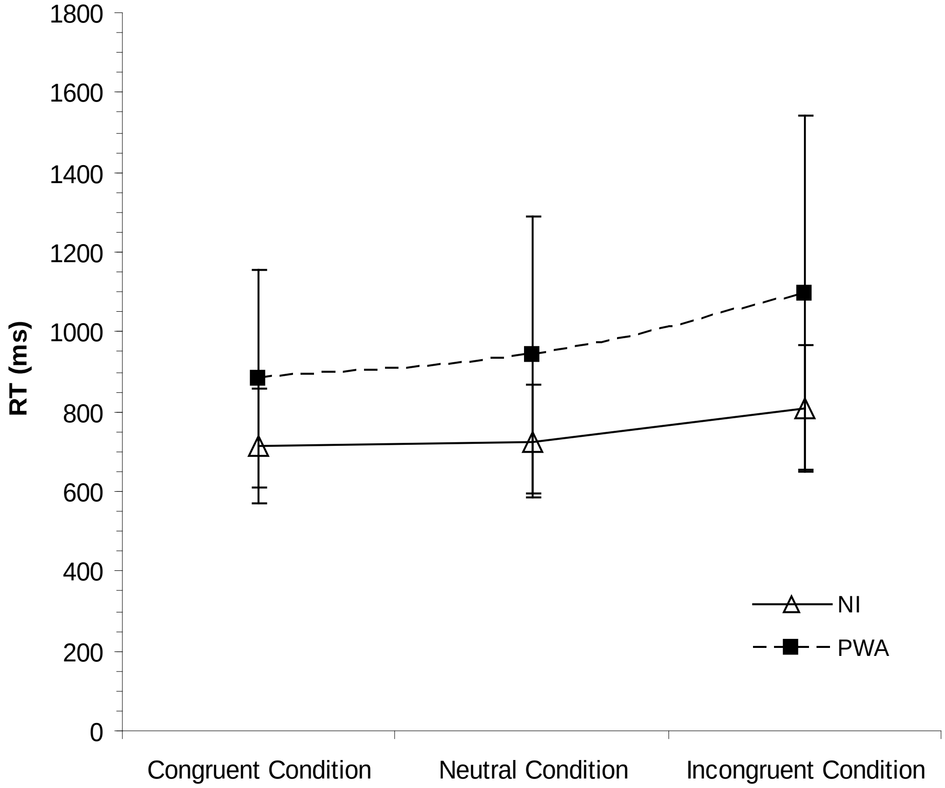

Figure 3. Mean Response Times for PWA and NI across three conditions in the 19% incongruent proportion of the PWI task.

Decomposition of the condition effect for each group using a mixed model with a Bonferroni adjustment (p=0.025) was conducted. The simple effect analysis indicated that there was a significant condition effect for the NI group, F(2, 157.70) = 124.151, p < 0.0005, ES (r) = 0.83, and the PWA group, F(2, 18) = 100.00, p < 0.0005, ES (r) = 0.92. Pairwise comparisons among conditions for each group indicated that the incongruent RTs were significantly longer than the neutral RTs for both NI (t = 11.18, df = 157.70, *p* < 0.0005, ES (*r*[10]) = 0.91) and PWA (t = 10.16, df = 157.70, *p* < 0.0005, ES (*r*) = 0.95). The incongruent RTs were also significantly longer than the congruent RTs for both NI (t = 2.739, df = 38, *p* < 0.009, ES (*r*) = 0.93) and PWA (t = 1.837, df = 18, *p* < 0.99, ES (*r*) = 0.98). Additionally, the RTs for the congruent condition were not significantly different from the neutral condition for the PWA (t = .344, df = 157.70, *p* = 0.99, ES (*r*) = 0.76), but they were significantly different for the NI (t = 4.03, df = 157.70, p < 0.0005, ES (*r*) = 0.72).

Hypothesis 2: *PWA will show no significant difference in RTs between the 19% and 73% incongruent proportions in the incongruent condition of the PWI tasks. However, NI will demonstrate significantly longer RTs in the 19% incongruent proportion than in the 73% incongruent proportion.*

A 2 (group) × 2 (proportion) mixed model comparing RTs between the 19% and the 73% incongruent proportion was conducted (Table 3). The analysis revealed a significant main effect for Group, F(1, 65.397) = 9.000, *p* < 0.004, ES (*r*) = 0.35, and proportion, F(1, 66.731) = 176.067, *p* < 0.0005, ES (*r*) = 0.85, but no significant Group × Proportion interaction, F(1, 66.731) = 0.101, *p* = 0.752, ES (*r*) = 0.04 (see Figure 4).

[10] To calculated Effect Size from t-test in the mixed model analysis, r = $\sqrt{t \div (t + df)}$ was used.

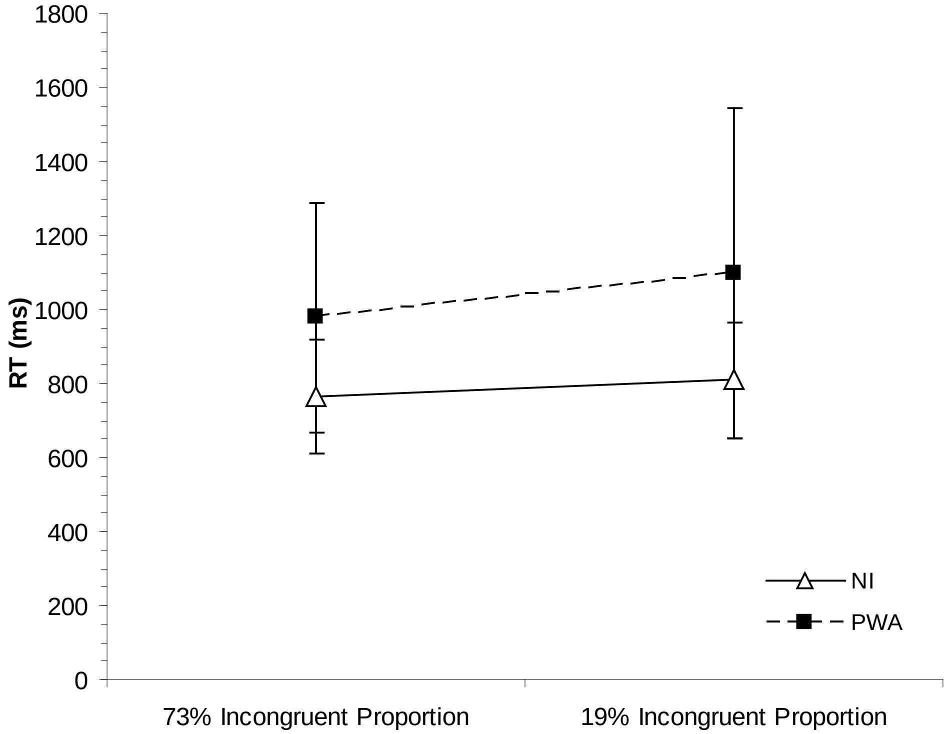

Figure 4. Response time for PWA and NI on the 19% and 73% incongruent proportions.

Group effects for each condition were examined using a mixed model with a Bonferroni adjusted alpha (p=0.025). Results revealed that the PWA group produced significantly longer RTs in both the 19%, $F(1, 28) = 8.379$, $p < 0.007$, ES (r) = 0.48, and the 73% incongruent proportions, $F(1, 28) = 7.674$, $p < 0.010$, ES (r) = 0.46, than the NI. Additionally, the RTs were significantly longer in the 19% incongruent proportion than the 73% incongruent proportion for both groups. (PWA, $F(1, 46.881) = 54.404$, $p < 0.0005$, ES (r) = 0.73, and the NI, $F(1, 29.936) = 183.868$, $p < 0.0005$, ES (r) = 0.86). While this effect was larger in PWA than NI, the difference was not significant.

4.2.2 Error Rate

The mean error rates for all conditions for both incongruent proportions are displayed in Table 4 for both groups. Aligned rank transformed data were analyzed with a mixed model. The results are presented below for each hypothesis.

Hypothesis 1: *The PWA will show no significant difference in error rates from the NI for congruent and neutral conditions from the 19% incongruent proportion of the PWI tasks. However, the PWA will show significantly larger error rates than the NI in the incongruent condition of the 19% incongruent proportion of the PWI tasks.*

Mixed model analysis revealed a significant main effect for condition, $F(2, 56) = 27.628$, $p < 0.0005$, ES (r) = 0.49, but no significant main effect of Group, $F(1, 28) = 1.225$, $p = 0.278$, ES (r) = 0.29, and no significant Group × Proportion Interaction, $F(2, 56) = 2.307$, $p = 0.109$, ES (r) = 0.08.

Table 4. Mean Error Rates (Percentage), with Standard Deviations, by Group, across conditions in the 19% and 73% incongruent proportions.

Proportion	Group	Condition					
		Congruent		Neutral		Incongruent	
		Mean	SD	Mean	SD	Mean	SD
73%_IC	NI	.	.	3.01	2.94	3.29	3.03
	PWA	.	.	3.80	2.27	7.81	6.71
19%_IC	NI	3.00	3.23	2.13	2.31	6.68	4.59
	PWA	2.72	2.44	2.73	3.62	10.04	9.47

Decomposition of the condition effects for each group, using a mixed model with a Bonferroni adjusted alpha ($p = 0.017$) was conducted. The simple effect analysis indicated that there was a significant condition effect for the NI, F(2, 38) = 30.258, $p < 0.0005$, ES (r) = 0.61, and the PWA, F(2, 18) = 6.261, $p < 0.009$, ES (r) = 0.41. Pairwise comparisons among the conditions for each group indicated that error rate for the incongruent condition was significantly higher than for the neutral condition for both the NI (t = 6.00, df = 38, $p < 0.0005$, ES (r) = 0.79) and PWA (t = 3.06, df = 18, $p < 0.013$, ES (r) = 0.64) groups. Error rates for the incongruent condition were significantly higher than for the congruent condition for the NI (t = 7.29, df = 38, $p < 0.000$, ES (r) = 0.91) and for PWA (t = 3.035, df = 18, $p < 0.013$, ES (r) = 0.71) groups. Error rates for the congruent trials were not significantly different from the neutral trials for the NI ($p = 0.406$ and ES (r) = 0.25) or PWA ($p = 0.999$ and ES (r) = 0.00) groups.

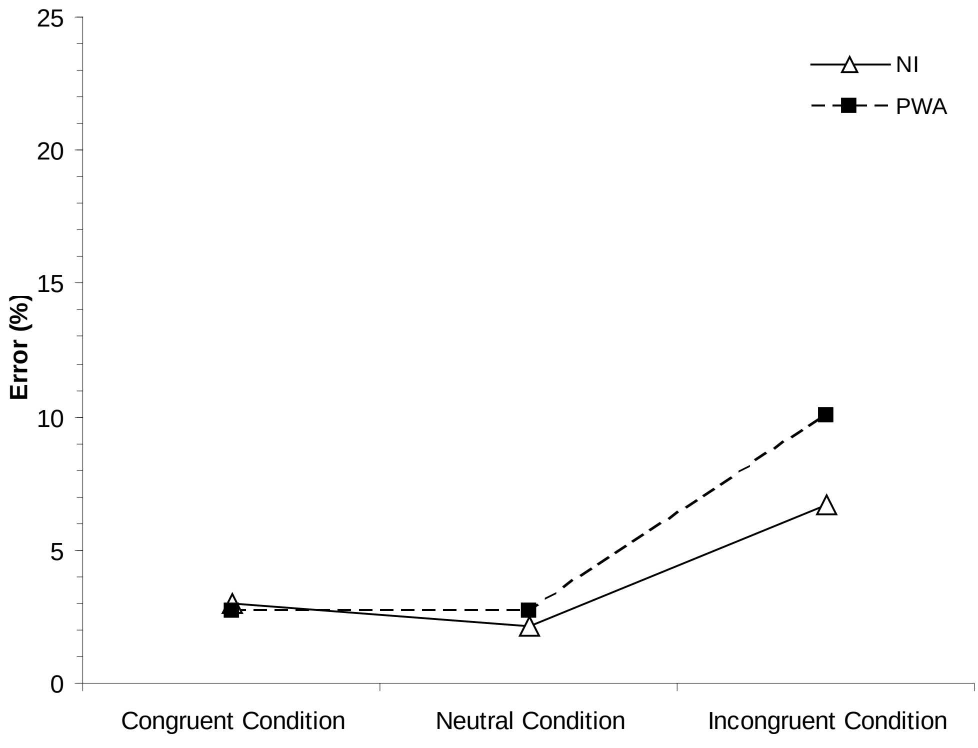

Figure 5. Error rates for PWA and NI across three conditions in the 19% incongruent proportion of the PWI task.

Hypothesis 2: *PWA will show no significant difference in error rates between the 19% and 73% incongruent proportions in the incongruent conditions of the PWI tasks. However, NI will demonstrate significantly larger error rates in the 19% incongruent proportion than in the 73% incongruent proportion.*

A 2 (Group) × 2 (Proportion) mixed model with error rates for incongruent conditions in the 19% and the 73% incongruent proportion was conducted (Figure 6). The analysis revealed a significant main effect for proportion, $F(1, 28) = 34.631$, $p < 0.0005$, ES (r) = 0.74, but no significant Group effect, $F(1, 28) = 1.287$, $p = 0.266$, ES (r) = 0.21, or Group × Proportion Interaction, $F(1, 28) = 0.620$, $p = 0.15$.

Decomposition of the proportion effect for each group with a Bonferroni adjusted alpha ($p = 0.025$) indicated that there was a significant proportion effect for the NI, $F(1, 19) = 42.379$, $p < 0.0005$, ES (r) = 0.83, but not for the PWA group, $F(1, 9) = 6.670$, $p = 0.030$, ES (r) = 0.65. Consistent with the hypothesis, the NI committed significantly more errors when responding to the incongruent conditions in the 19% incongruent proportion than in the 73% incongruent proportion, but the PWA did not.

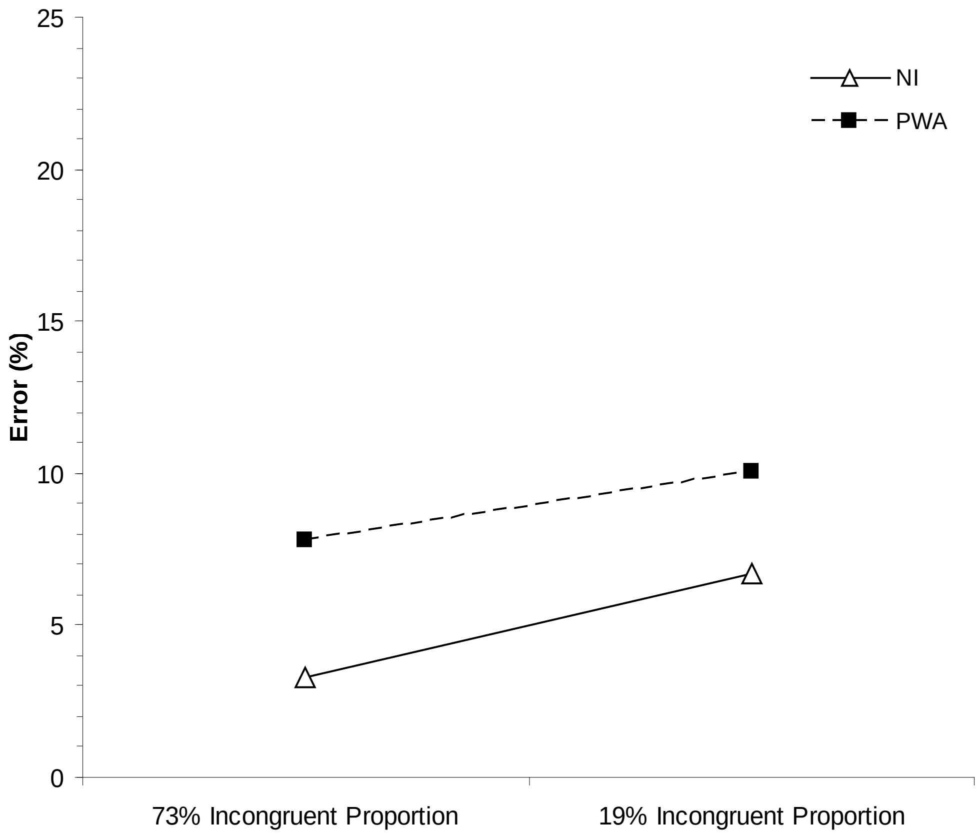

Figure 6. Error rates for PWA and NI on the incongruent conditions in the 19% and 73% incongruent proportions of the PWI task.

4.2.3 Analyses of correlation between Executive Attention and Language Severity/Working Memory Capacities

Correlation coefficients were computed in order to examine the relationships among the measures of aphasia severity and response time on the PWI task (Table 5), and between the independent measures of working memory capacity and response time on the PWI task (Table 6).

Given that the data were not normally distributed, non-parametric correlation coefficients were computed using Spearman's rank correlations.

Hypothesis 3: *Language and executive attention tests will show significant negative correlations with RTs in the incongruent condition of the PWI task.*

Table 5. Correlation coefficients between the response time on the incongruent condition of PWI task and Language Severity as measured by the PICA and the CRTT.

	Language Tests		
	PICA	*CRTT_Score*	*CRTT_Efficiency*
PWI_RT	-.494**	-.436*	-.413*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
PICA = Porch Index of Communicative Ability (PICA) (Porch, 2001).
CRTT-Score = Overall Mean score in the Auditory version of the *Computerized Revised Token Test (CRTT)* (McNeil, Pratt, Szuminsky et al., 2008).
CRTT-Efficiency = Efficiency Score in the Auditory version of the *Computerized Revised Token Test (CRTT)* (McNeil, Pratt, Szuminsky et al., 2008).

The RT in the incongruent condition of PWI task (PWI_RT) was significantly and negatively correlated with *PICA* score (r = -0.49, $p < .006$), the mean score of the *CRTT-R* (r = -.44, $p < .016$), and the efficiency score of the *CRTT-R* (r = -.41, $p < .023$).

Hypothesis 4: *WM capacity and executive attention will show a significant negative correlation with RTs in the incongruent condition of PWI task.*

The PWI RT in the incongruent condition was significantly, moderately, negatively correlated with the Subtract-2 Working Memory Test, the Waters and Caplan average WM Measure, the STM Forward (r=-.55, *p*<.001), and STM Backward (r=-.49, *p*=<.01) tests.

Table 6. Correlation coefficients among the Short Term memory, Working Memory and Language Severity/Executive Attention

	Working Memory					Short Term Memory	
	CS sentence	*OS sentence*	*Alpha*	*Sub-2*	Mean WM	*Forward*	*Backward*
Executive Attention Test							
PWI_RT	-.319	-.209	-.285	-.521**	-.468**	-.546**	-.489**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
CS sentence= *Cleft-Subject sentence reading Working Memory test* (Waters & Caplan, 2003).
OS sentence= *Cleft-Object sentence reading Working Memory test* (Waters & Caplan, 2003).
Alpha= *Alphabet Working memory test* (Craik, 1986).
Sub-2= *Subtract -2 Working Memory test* (Salthouse, 1988).
Mean WM= the average of four working memory span (Waters & Caplan, 2003).
Forward= *Forward digit pointing span task*.
Backword= *Backward digit pointing span task*.
TMT_Time= Time in *the Trail Making Test B* (Amieva et al, 1998).
STMT_Time= Time in *the Symbol Trail Making Test B* (Barncord & Wanlass, 2001).
PWI_RT= response time of incongruent trials in the 25% incongruent condition.

4.2.4 Analysis of interference and facilitation

In order to determine whether the two groups showed significant interference (incongruent minus neutral condition) and facilitation (congruent minus neutral trial) effects, non-parametric tests were conducted among the RTs derived from the neutral, incongruent, and congruent conditions within the 19% incongruent proportion of PWI task within each group. Mean facilitation and interference scores for each group are summarized in Table 7.

Table 7. Facilitation and interference reaction times (Msec.) from the 19% incongruent condition for NI and PWA.

	Facilitation		Interference	
	Mean	SD	Mean	SD
NI	-26.24	29.89	90.23	45.62
PWA	-54.12	78.19	184.97	157.05

A Wilcoxon Signed Rank Test was conducted with RTs for comparing the incongruent condition versus the neutral condition and the congruent versus the neutral condition from the 19% incongruent proportion. PWA showed significant facilitation, Z = 2.50, N-Ties = 0, $p < 0.01$, two-tailed, ES = 0.56, and interference effects, Z = 2.80, N-Ties = 0, $p < 0.002$, two-tailed, ES = 0.63. Likewise, NI showed significant facilitation, Z = 3.21, N-Ties = 0, $p < 0.001$, two-tailed, ES = 0.51, and interference effects, Z = 3.88, N-Ties = 0, $p < 0.001$, two-tailed, ES = 0.61.

To assess group differences, a Mann-Whitney Test was conducted with RTs from the facilitation and interference contrasts derived from the 19% incongruent proportion. A simple comparison showed that PWA showed a significantly larger interference effect than the NI, U=55, N1 = 20, N2 = 10, $p < 0.049$, two-tailed, ES = 0.36, but no significant difference in facilitation between two groups, U=80, N1 = 20, N2 = 10, $p < 0.40$, two-tailed, ES = 0.16 (See Figure 7).

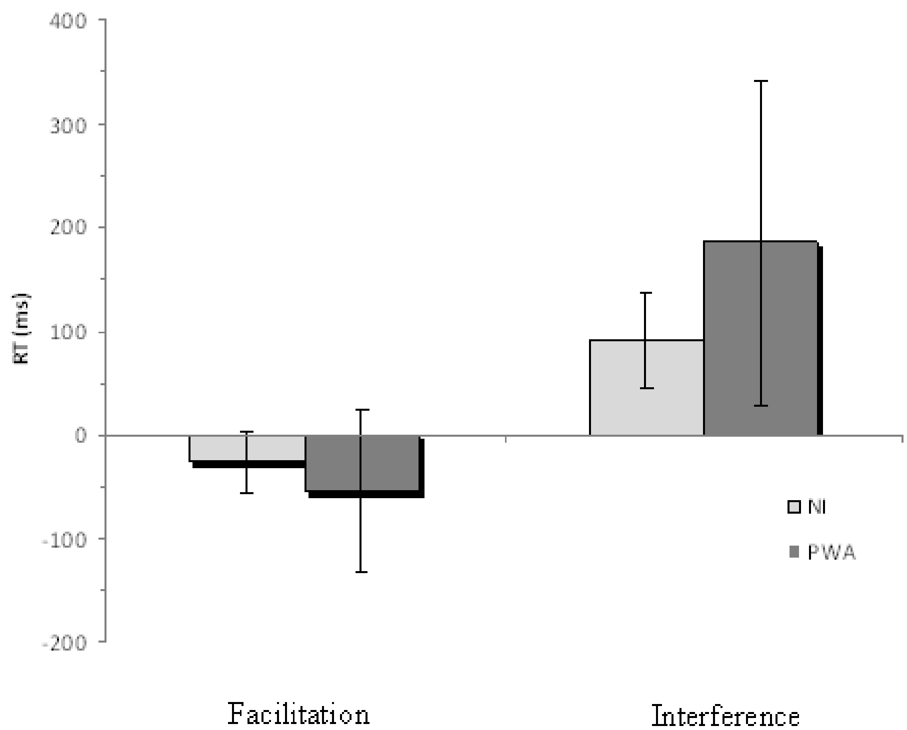

Figure 7. Facilitation and interference effects in the 19% incongruent proportion.

4.2.5 Analysis of sensitivity to proportion structure on the Iowa Gambling Test

In order to determine whether the two groups had different sensitivity of proportion structure, a Mann-Whitney Test was conducted with total response time and the amount of earned money in the *Iowa Gambling Test*. There was no significant group difference on the Iowa gambling test for total response time (Z = 0.70 and ES = 0.13) and amount of money (Z = 0.48 and ES = 0.09).

4.2.6 Analysis of RTs of Error in the incongruent condition of the 19% incongruent proportion

In order to determine whether the two groups had different error patterns that resulted from loss of goal, a Mann-Whitney Test was conducted with the error percentage in which the RTs from the Error responses in the incongruent condition were less than those from the correct congruent condition derived from the 19% incongruent proportion. There was no significant group difference (Z = 0.31 and ES (*r*[11]) = 0.06).

4.2.7 Analysis of Skew of the correct response in the incongruent condition of the 19% incongruent proportion

In order to inspect the difference of goal maintenance ability between the two groups, a Mann-Whitney Test was conducted with the value of skew in the correct incongruent condition of the 19% incongruent proportion. The results revealed that the PWA group had a significantly more positive skew (skew=2.43) than the NI group (skew=1.36) (U=39, N1=10, N2=20, $p<.006$, two-tailed, ES (*r*) = 0.49).

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[11] To calculate Effect Size from non-parametric analysis, r = $Z \div \sqrt{N}$ was used.

5.0 DISCUSSION

The primary purpose of this study was to examine the role of executive attention in PWA. To examine this, Picture-Word Interference tasks were employed in which visually presented words were superimposed on congruent, neutral, or incongruent pictures in 19% and 73% incongruent proportions. RTs and error rates for the two groups in the 19% incongruent proportion across congruent, neutral, and incongruent conditions assessed the conflict resolution effects of executive attention revealed within the PWI task. Executive attentional goal maintenance effects were tested by comparing RTs and error percentages between the two incongruent conditions in the 19% and 73% incongruent proportions.

The PWI tasks produced significant condition (congruent, neutral, and incongruent) and proportion (19% and 73% incongruent) effects for the NI group. The notable outcome in the condition and proportion effects was in accordance with results obtained in previous interference studies. These studies reported that healthy non-impaired individuals responded reliably more slowly to incongruent than neutral and congruent conditions and they also responded more slowly and committed more errors in the less frequent incongruent conditions than in more frequently occurring incongruent conditions (Engle et al., 1999; Kane & Engle, 2003; Belanger et al., 2010). This finding is interpreted to reflect increased resource demands on conflict resolution in the interference context (incongruent conditions vs. neutral/congruent conditions) and on goal maintenance in the lower incongruent proportion (19% vs. 73% incongruent proportions). Based on the consistency of results between the previous studies and the current study, the data from the NI confirmed the empirical finding that the PWI tasks in the current study provided sufficient demands on both conflict resolution and goal maintenance.

Conflict Resolution:

Analyses of the RTs in the 19% incongruent proportion revealed that PWA also produced a significant interference effect. Thus, both groups demonstrated significantly longer RTs when a word was superimposed on an incompatible picture compared to the congruent or neutral conditions. The group comparison between NI and PWA revealed significant differences in the latency of response in the 19% incongruent condition with the PWA group producing significantly longer RTs than the NI group on both the incongruent and neutral conditions but not on the congruent condition; in spite of the fact that the RT difference between PWA and NI on the incongruent condition was larger than on the neutral condition. This finding indicates that the PWA group was relatively more sensitive than the NI group to the incongruent stimuli than to the neutral and congruent stimuli. The longer RTs for the PWA group on the incongruent conditions are consistent with the hypothesis that PWA have an impairment of executive attention that is attributable to the resolution of linguistic conflict between response relevant lexical information of a word and response irrelevant semantic information of a picture.

PWA and NI produced a facilitation effect. That is, they responded significantly faster on the congruent than on the neutral conditions in the 19% incongruent proportion. This finding is consistent with Glaser's two route processing model of semantic and lexical information processing in the Picture-Word Interference paradigm (Glaser & Glaser, 1999). Glaser and Glaser (1989) proposed a model that has a semantic system containing all semantic knowledge and a lexicon that contains only linguistic word knowledge. The two systems are assumed to have different input and output functions. The semantic system controls the perception of pictures and the action of physical objects. In contrast, the lexicon is thought to be responsible for the comprehension and production of spoken and written language. Within this conceptualized architecture, the response modality is critical for the production of facilitation or interference effects. In the PWI task, two dimensions of the stimulus are simultaneously activated and the privileged access will depend on the response modality. If the required response of PWI task is spoken, a word superimposed on a picture has the privileged access to the response. In contrast, if the required response is categorization, a picture has the privileged access. Therefore, when a word superimposed with a picture has to be read, participants will directly activate their word nodes within the lexicon. A picture, however, will first have to activate its concept nodes within the semantic system followed by activation of the corresponding word nodes. Therefore, picture naming will take longer than word naming. Conversely, when semantic information is required (e.g., determining the category to which an item belongs), a picture will not have to make the detour through the lexicon. Therefore, if the dimensions of the PWI stimuli are matched (e.g., a word “dog” and a picture of dog), a facilitation effect will be observed because the response relevant picture (picture of a dog) has privileged access to the system that leads to faster selection of the response compared to a word. When the category to which a picture belongs is the required response, Glaser and Glaser assumed that the semantic system is relevant for its selection. In this case, there will be a facilitation effect through semantic processing activated by the picture. Because the picture has privileged access to the semantic system, a picture will accelerate the categorization response. The finding that PWA gained a significant benefit from the congruent stimuli suggests that the individuals with aphasia in this study were able to use a relatively more intact or less resource demanding semantic processing network compared to the two stages, more resource demanding lexical processing system. That is, when the PWA encountered the congruent picture/word stimuli, they did not need to depend on the lexical processing, but rather activated the semantic node that is one step shorter than single word lexical processing.

Analyses of the error rates extracted from the 19% incongruent proportion revealed significantly more errors in both groups on the incongruent than on the neutral and congruent conditions. The high error rates on the incongruent conditions are consistent with the expected interference effect for both groups. It was interpreted as that the error rates were also useful for the measurement of conflict resolution. However, the two groups did not differ significantly in errors across the three conditions. This suggests that the measurement of error rates is not particularly sensitive for capturing differences found with the measurement of RT between the NI and PWA groups.

Goal Maintenance:

Analyses of RTs between the incongruent proportions revealed that the NI group demonstrated significantly longer RTs on the incongruent conditions under the 19% incongruent proportion than under the 73% incongruent proportion. This finding is consistent with the theoretical view that an interference task with a smaller proportion of incongruent conditions increases goal maintenance demands (Kane & Engle, 2003; Belanger et al, 2010). Participants should ignore distracting picture information, inhibit semantic information and activate lexical information to achieve a correct and rapid response on the incongruent conditions of PWI task. Theoretically, the 19% incongruent proportion requires a greater demand on goal maintenance compared to the 73% incongruent proportion due to the fact that participants receive task goal cues on more trials under the 73% incongruent proportion. That is, the frequent incongruent trials in the 73% incongruent proportion remind participants of the task goal to inhibit the picture information and activate the lexical information of the word superimposed on picture. Contrary to the prediction, the PWA also demonstrated the significantly longer response times between the two proportion conditions. In addition, the PWA group showed significantly longer RTs than the NI group on both the 19% and 73% incongruent proportions.

Analyses of error rates on the incongruent conditions between the 19% and 73% incongruent proportions revealed that the PWA did not commit more errors than the NI. However, the NI participants did produce significantly more errors on the incongruent conditions of the 19% incongruent proportion than the 73% incongruent proportions. This finding is interpreted as evidence that the NI group was sensitive to the incongruent proportion, whereas the PWA had impaired ability to keep the goal of the PWI task in both proportions that resulted in no difference in error rates between two incongruent proportions. To the degree that goal maintenance is captured through the error rates on the PWI task, the PWA demonstrated an impairment in their ability to maintain the task goal of ignoring the semantic information and activating the lexical information. The PWA group showed a larger response-time facilitation effect relative to NI (RT on neutral trials minus RT on congruent trials) in the 19% incongruent proportion. This result supports the interpretation that the PWA were impaired in the goal maintenance component of executive attention. That is, the PWA lost the goal of the PWI task in which they were required to categorize the response irrelevant word stimulus instead of response relevant picture stimulus, and they responded to the picture stimulus that lead to a correct and fast response on the congruent conditions. MacLeod (1998) and MacLeod & MacDonald (2000a; 2000b) argued that facilitation reflects a convergence of the two dimensions of the congruent conditions while interference reflects conflict and competition between task-relevant aspects and task-irrelevant aspects of stimuli. They proposed that RTs (in normal populations) on congruent conditions in the color-word Stroop task reflects the combined RTs of slower (response irrelevant) color-naming and faster (response relevant) word reading. Because there was no discrimination between “goal maintaining” color naming and “goal neglecting” word reading, the RT of color word reading reduced the mean latency on the congruent conditions. In the case of the PWI task, facilitation effects reflected the combination of slower (response irrelevant) word categorization and faster (response relevant) picture categorization. Therefore, the fast RTs for pictures reduced the mean RTs on the congruent conditions and resulted in the facilitation effect. The larger facilitation effect in PWA for the 19% incongruent condition supports the interpretation that the PWA demonstrated an impairment of goal maintenance.

Analyses of the PWI latency distribution for the correct responses in the 19% incongruent proportion revealed that the PWA group had a significantly more positive skew than the NI group. This resulted from a larger proportion of fast responses. Kane and Engle (2003) argued that an increased skew of RT distribution on incongruent conditions provided evidence for periodic neglect of the goal. Given that failures in goal maintenance may not be all-or-none (Kane & Engle, 2003), very slow response time reflects that the goal of PWI task was more likely lost but then recovered before an overt error was committed. The larger positive skew for PWA is viewed as confirmatory evidence that PWA group had impaired goal maintenance in the 19% incongruent proportion compared to the NI.

The analyses of performance on the *Iowa Gambling Test* revealed that there was no significant group difference on either the time or the amount of money allocated. Both groups demonstrated non-significant differences in decision-making ability based on the proportions structure. Given the fact that there was no group difference on the proportion structure, the different pattern of RTs and error rates between PWA and NI on the PWI tasks is not likely due to group difference in the sensitivity of the proportion structure, but rather to impaired goal maintenance in the PWA. This finding is consistent with the effect of priority manipulation by Tseng, McNeil, and Milenkovic (1993). These researchers required PWA and NI to detect phonetic and semantic targets simultaneously while listening to word lists. Tseng and colleagues varied the target occurrence probability (e.g., phonetic-to-semantic target ratio of 80:20, 50:50, or 20:80) under the premise that participants would allocate greater attentional resources to the more infrequently occurring targets in order to maximize performance accuracy. As the probability of target occurrence increased, the NI performed the detection tasks as predicted. In contrast, PWA failed to show this probability effect, regardless of instruction explicitness. They failed to utilize the probability information whether instructed to do so or through deduction. This is interpreted as external evidence to support an executive attention impairment rather than an inability to understand or utilize probability structure per se.

With respect to latencies of errors in the 19% incongruent proportion, it was predicted that error latencies under the incongruent conditions should be similar to RTs of the congruent condition when the goal is lost. Loss of goal errors was 62% for the PWA and 56% for the NI. Although the group difference was in the predicted direction with PWA making more goal lost errors, it did not reach statistical significance (p = 0.94). Given that both groups committed more than half of goal lost error in the incongruent condition of PWI task, the effect is interpreted as support for the notion that goal maintenance is a critical component of executive attention under interference contexts and it was evident for both groups.

Both groups were also tested on a variety of independent language, WM and executive attention measures. Correlation analyses of these data revealed that the language abilities measured by *PICA* and *CRTT* were significantly correlated with the measures of executive attention. The participants with poor *PICA* scores, *CRTT* scores and *CRTT* efficiency scores showed longer response times on the interference conditions of the 19% incongruent proportion. In addition, executive attention performance was also significantly and negatively correlated with WM and STM. The participants who had longer RTs on the 19% incongruent proportion (proposed to be a measure of one component of executive attention) showed lower WM capacity and shorter STM. This finding is consistent with a working memory model by Engle and colleagues (1998). They claimed that WM consists of three components, STM, processing/computation, and executive attention. In this conceptualization, WM capacity is determined by executive attention that is composed primarily of conflict resolution and goal maintenance in the face of interfering contexts. Therefore, the significant correlations of WM with RTs in the incongruent condition support the critical role of execution attention in WM. While the averaged WM score from the four WM tests (Water & Caplan, 2003), showed that participants with lower WM took longer time to resolve conflicts in the interference condition, RTs in the 19% incongruent proportion was not significantly correlated with the CS, OS, and Alphabet WM span measures. The low correlations for some individual WM tests resulted from a floor effect in which those three tests were too hard to obtain a valid span for the PWA. More than half of PWA produced the lowest WM span (1 span) on the test. These results support earlier findings in normal individuals that participants with low WMC generally produce longer RT on executive attention demanding tasks (Kane & Engle 2003; Engle et al. 1999; Conway et al., 2001).

Study Limitations:

Results for this study were relatively straightforward and most comparisons of interest were significant and followed the predictions based on the previous literature and on its theoretical underpinnings. However, it is critical to identify some of the limitations of the current study.

First, the study included a relatively small number of participants, especially for the PWA group. Group (NI and PWA) × proportion (19% and 73% incongruent proportions) interactions for error rates were not significant. Low power (power = 0.118) diminished the possibility of finding an effect of impaired goal maintenance for this measure for the PWA and the possibility that these persons with aphasia actually have impaired goal maintenance remains likely; especially in light of the error findings. The power analysis modeled on G power estimated that at least 73 PWA would be required in this experiment to reach a power of .8.

A second limitation involves the fixed order of condition presentation that was used. That is, the 19% incongruent proportion was always presented as the first experimental task, followed by the 73% incongruent proportion. Given previous findings by Kane and Engle (2003), the order used in the current study may have little influence over the RTs or errors on the PWI task. Kane and Engle (2003) demonstrated that when the more frequently occurring incongruent condition repeatedly reinforced the goal of the task by presenting the incongruent condition first, the task goal appeared to transfer to the next lower incongruent proportion task. They argued that a lower incongruent context should be presented first to minimize the interference transition effect created by the alternative condition presentation order. However, there still remains the possibility that the less frequently occurring incongruent condition had some, even if small, effect on goal maintenance affecting the next more frequently occurring incongruent condition.

A third limitation involves the structure of the proportion conditions. In order to maximize goal maintenance effects, the current study chose the 19% and 73% incongruent proportions. Whereas the 19% incongruent proportion was composed of all three conditions (neutral, congruent, and incongruent conditions), the 73% incongruent proportion was composed of 23% neutral conditions and 73% incongruent conditions. That is, there was no congruent condition in the 73% incongruent proportion (See Appendix B). The question arises as to whether no congruent conditions in the 73% incongruent proportion would lead to a unique result compared to the 19% incongruent condition that included instances of all three (incongruent, neutral, and congruent) conditions. Kane and Engle (2003) examined whether the low congruent proportion would lead to results similar to those in no congruent condition. The result from the low congruent condition closely matched the no congruent condition in which the low congruent condition yielded a significant span difference in RT for the incongruent conditions. Therefore, this does not appear to be a source of bias in the data. However, this effect has not been investigated in detail in the current study and cautious interpretation of results in the PWI task with this participant population is warranted.

6.0 CONCLUSION

The major purpose of this study was to examine whether PWA have impaired executive attention in terms of conflict resolution and goal maintenance as assessed in PWI tasks. The PWA group demonstrated impaired conflict resolution as evidenced from RTs and error rates. They also evidenced impaired goal maintenance from error rates under the incongruent conditions (relative to performance by the NI group). The fact that the PWA group was vulnerable to both demands of conflict resolution and goal maintenance suggests that the PWA group demonstrated impaired executive attention.

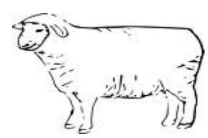
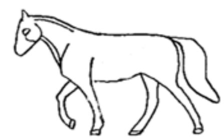
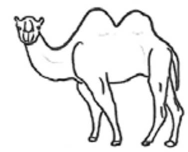
When performance profiles on the PWI tasks for the PWA were compared to the NI in the PWI tasks, the data converged to indicate deficits of executive attention in the PWA group. That is, when RTs and error rates on the incongruent conditions were analyzed, the PWA group demonstrated impaired conflict resolution and goal maintenance relative to NI group. This outcome was expected based on the results from previous studies, which have increasingly supported the idea that PWA have attentional deficits that are related to their language processing impairments. Furthermore, the correlations between PICA score and PWI performance are consistent with this interpretation.

The review of the literature, along with the findings from this study, suggests that the PWA group demonstrate attentional deficits in interference contexts. The performance of the PWA compared to the NI in these PWI tasks, demonstrating longer latency in the congruent conditions of the 19% incongruent proportion along with no difference of error rate on the incongruent conditions between the two incongruent proportions, is interpreted as evidence for deficits of conflict resolution revealed by interference and deficits of goal maintenance revealed by proportion. However, there are limits to generalizing and applying these findings to the general clinical population of PWA. There was large performance variability among participants and the number of participants with aphasia was small. The study was also underpowered to show an interaction between group and condition in the confliction resolution analyses and in the group by proportion analyses for the goal maintenance effect.

Although a number of questions have been raised with respect to confirming and refining characteristics and knowledge of impaired executive attention and its application to aphasia, the current study encourages both researchers and clinicians to consider executive attentional deficits as a possible source of language processing difficulties in PWA. These findings support a relatively long history of identifying attentional impairments as a source of language deficits in PWA. The findings make clear that there are many more questions to be generated and much more research to be accomplished in order to determine how conflict resolution and goal maintenance are linked to language processing in PWA. It is hoped that this experimental study initiates and stimulates theoretical and clinical discussion of executive attentional issues in the assessment and treatment of aphasia.

APPENDIX A

The Stimuli of Picture-Word Interference task

Category	Word	Picture
Animal	Whale	
	Sheep	
	Horse	
	Moose	
	Camel	

Non-Animal	Apple	
	Table	
	Glass	
	Piano	
	Onion	

APPENDIX B

The Proportion of Picture-Word Interference task (items numbers)

Condition / Proportion	Incongruent Condition	Neutral Condition	Congruent Condition	Total
19% Incongruent Proportion	52	72	156	280
73% Incongruent Proportion	204	76	0	280

APPENDIX C

The Lexical Decision Task Stimuli

Lexical	Concrete & Frequency	word	length
Word	High	chair	5
		mountain	8
		picture	7
		forest	6
		woman	5
		street	6
		newspaper	9
		army	4
		college	7
		star	4
	Low	savant	6
		spree	5
		concept	7
		satire	6
		interim	7
		boredom	7
		dalliance	9
		clemency	8
		forethought	11
		gist	4
Nonword	High	capin	5
		mapazine	8
		makhine	7
		nalley	6
		woney	5
		hollar	6
		gentlezan	9
		cipy	4
		teabher	7
		boty	4
	Low	doible	6
		truwe	5

		qallacy	7
		upreep	6
		perzury	7
		contept	7
		sozriety	9
		tlandness	8
		wistsulness	11
		Kact	4

APPENDIX D

Edinburgh Handedness Inventory

Participant # _________ Date: ___________

Please indicate your preferences in the use of hands in the following activities by putting a check in the appropriate column.

1) Where the preference is so strong that you would never try to use the other hand, unless absolutely forced to, put ***2*** checks.

2) If in any case you are really indifferent, put a check in ***both*** columns.

Some of the activities listed below require the use of both hands. In these cases, the part of the task, or object, for which hand preference is wanted is indicated in parentheses.

Please try and answer all of the questions, and only leave a blank if you have no experience at all with the object or task.				Right	Left
1	Writing			☐ ☐	☐ ☐
2	Drawing			☐ ☐	☐ ☐
3	Throwing			☐ ☐	☐ ☐
4	Scissors			☐ ☐	☐ ☐
5	Toothbrush			☐ ☐	☐ ☐
6	Knife (w/o fork)			☐ ☐	☐ ☐
7	Spoon			☐ ☐	☐ ☐
8	Broom			☐ ☐	☐ ☐
9	Striking Match			☐ ☐	☐ ☐
10	Opening box (lid)			☐ ☐	☐ ☐

TOTAL					
Difference (Rt – Lt)-(1)		Cumulative Total (Lt.+Rt.)-(2)	Result : (1)/(2) x 100		

Scoring:

Add up the number of checks in the "Left" and "Right" columns and enter in the "TOTAL" row for each column. Add the left total and the right total and enter in the "Cumulative TOTAL" cell. Subtract the left total from the right total and enter in the "Difference" cell. Divide the "Difference" cell by the "Cumulative TOTAL" cell (round to 2 digits if necessary) and multiply by 100; enter the result in the "Result" cell.

Interpretation (based on Result):

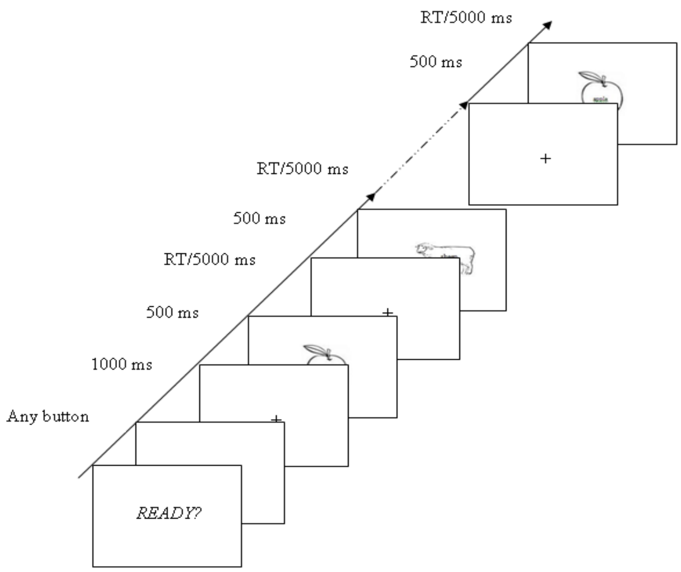
below -40 = left-handed

between -40 and +40 = ambidextrous

above +40 = right-handed

APPENDIX E

Depiction of Picture-Word Interference experiment



* 500 ms: The fixation hair-cross remains visible for 500 ms and then is replaced by one of the stimuli

** RT/5000 ms: The stimuli will appear on the computer monitor and stay on until the participant responds. Each stimulus will remain in view for 5000 ms if the participants do not press a response within that time frame.

APPENDIX F

Introduction of the PWI task for participants

"In this task, you will see a word superimposed within a picture. The word in the picture either matches with the picture or differs from the picture. Your job is to judge whether each superimposed word is animal or non-animal while consistently ignoring the picture on every trial. You should press the left button "1" for animal words or the right button "2" for non-animal words.

For example, the word "sheep" may appear in a picture of sheep, or it can appear in a picture of apple. Then you are supposed to press the left button 1. If you see the word "apple" in a picture of sheep or a picture of apple, you are supposed to choose the right button 2.

"You should respond to the targets as quickly and accurately as you can. Please note that whether or not you look away from the word or squint your eyes during the task will be monitored."

APPENDIX G

Raw and Inverse transformed RTs in the 19% incongruent proportion of the Picture-word Interference Tasks

Subject	19% Incongruent Proportion					
	Neutral Condition		Incongruent Condition		Congruent Condition	
	Raw	Transformed	Raw	Transformed	Raw	Transformed
101	821.81	0.0012168	1009.54	0.0009906	798.43	0.0012525
103	893.94	0.0011186	1072.72	0.0009322	857.29	0.0011665
104	692.68	0.0014437	865.34	0.0011556	709.33	0.0014098
105	868.99	0.0011508	954.38	0.0010478	792.81	0.0012613
106	864.94	0.0011561	965.92	0.0010353	824.86	0.0012123
108	646.41	0.0015470	714.52	0.0013995	629.03	0.0015897
109	700.75	0.0014270	817.98	0.0012225	646.96	0.0015457
110	1156.00	0.0008651	1442.61	0.0006932	1162.70	0.0008601
111	804.94	0.0012423	869.90	0.0011496	749.46	0.0013343
112	1692.00	0.0005910	2279.24	0.0004387	1430.43	0.0006991
201	931.43	0.0010736	1067.17	0.0009371	902.54	0.0011080
202	635.13	0.0015745	727.74	0.0013741	602.34	0.0016602
203	661.04	0.0015128	824.17	0.0012133	635.69	0.0015731
204	595.49	0.0016793	701.76	0.0014250	543.94	0.0018384
205	652.99	0.0015314	724.14	0.0013809	637.82	0.0015678
206	607.51	0.0016461	723.05	0.0013830	613.24	0.0016307
207	1026.78	0.0009739	1141.96	0.0008757	960.01	0.0010417
208	541.83	0.0018456	616.32	0.0016225	519.76	0.0019240
209	694.41	0.0014401	783.04	0.0012771	629.36	0.0015889
210	572.75	0.0017460	622.37	0.0016068	539.21	0.0018546
213	675.59	0.0014802	722.58	0.0013839	668.91	0.0014950
214	692.21	0.0014446	785.55	0.0012730	672.76	0.0014864
215	842.65	0.0011867	937.75	0.0010664	822.53	0.0012158

216	629.96	0.0015874	650.36	0.0015376	613.61	0.0016297
217	829.75	0.0012052	1025.63	0.0009750	895.35	0.0011169
218	613.58	0.0016298	674.57	0.0014824	586.26	0.0017057
219	754.72	0.0013250	873.73	0.0011445	716.69	0.0013953
220	789.56	0.0012665	789.08	0.0012673	722.82	0.0013835
221	991.00	0.0010091	1084.36	0.0009222	937.31	0.0010669
222	621.83	0.0016082	689.46	0.0014504	615.28	0.0016253

APPENDIX H

Raw and Inverse Transformed RTs in the 73% incongruent proportion of the Picture-word Interference Tasks

Subject	73% Incongruent Proportion			
	Neutral Condition		Incongruent Condition	
	Raw	Transformed	Raw	Transformed
101	838.88	0.0011921	868.95	0.0011508
103	899.96	0.0011112	953.99	0.0010482
104	721.93	0.0013852	727.32	0.0013749
105	838.90	0.0011920	885.21	0.0011297
106	816.09	0.0012254	854.98	0.0011696
108	641.69	0.0015584	674.06	0.0014835
109	665.96	0.0015016	689.53	0.0014503
110	916.78	0.0010908	976.50	0.0010241
111	847.41	0.0011801	825.78	0.0012110
112	1503.57	0.0006651	1647.74	0.0006069
201	907.99	0.0011013	949.76	0.0010529
202	578.80	0.0017277	628.69	0.0015906
203	724.70	0.0013799	767.74	0.0013025
204	560.92	0.0017828	616.81	0.0016212
205	660.49	0.0015140	663.23	0.0015078
206	636.97	0.0015699	636.98	0.0015699
207	1021.37	0.0009791	1027.42	0.0009733
208	551.11	0.0018145	572.52	0.0017467
209	687.36	0.0014548	700.09	0.0014284
210	532.80	0.0018769	556.28	0.0017977
213	681.23	0.0014679	694.50	0.0014399
214	695.64	0.0014375	672.95	0.0014860

215	783.73	0.0012759	779.70	0.0012825
216	581.58	0.0017195	590.72	0.0016928
217	767.83	0.0013024	849.53	0.0011771
218	600.61	0.0016650	617.00	0.0016207
219	741.76	0.0013481	826.77	0.0012095
220	667.24	0.0014987	692.25	0.0014446
221	944.85	0.0010584	975.74	0.0010249
222	596.58	0.0016762	606.45	0.0016489

APPENDIX I

Raw and Aligned Rank Transformed error rates of the Picture-word Interference Tasks in 19% incongruent Proportion (Normal participants)

Condition	Subject	Error	Aligned			ART		
			Group	Condition	Group× Condition	Group	Condition	Group× Condition
Neutral Condition	201	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	202	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	203	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	204	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	205	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	206	3	1.011	-0.406	1.739	66.0	64.0	70.0
	207	4	2.011	0.594	2.739	73.5	68.5	75.5
	208	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	209	3	1.011	-0.406	1.739	66.0	64.0	70.0
	210	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	213	1	-0.989	-2.406	-0.261	38.5	43.5	47.5
	214	1	-0.989	-2.406	-0.261	38.5	43.5	47.5
	215	3	1.011	-0.406	1.739	66.0	64.0	70.0
	216	4	2.011	0.594	2.739	73.5	68.5	75.5
	217	3	1.011	-0.406	1.739	66.0	64.0	70.0
	218	3	1.011	-0.406	1.739	66.0	64.0	70.0
	219	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	220	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
	221	6	4.011	2.594	4.739	81.0	72.0	82.0
	222	0	-1.989	-3.406	-1.261	19.5	21.5	31.0
Incongruent Condition	201	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	202	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	203	6	-1.089	3.494	-1.261	36.0	74.0	31.0

	204	18	10.911	15.494	10.739	89.0	89.0	89.0
	205	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	206	10	2.911	7.494	2.739	76.5	83.5	75.5
	207	14	6.911	11.494	6.739	83.5	85.5	84.5
	208	15	7.911	12.494	7.739	86.0	87.0	87.0
	209	8	0.911	5.494	0.739	62.5	77.5	63.5
	210	4	-3.089	1.494	-3.261	14.0	70.0	14.0
	213	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	214	10	2.911	7.494	2.739	76.5	83.5	75.5
	215	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	216	14	6.911	11.494	6.739	83.5	85.5	84.5
	217	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	218	6	-1.089	3.494	-1.261	36.0	74.0	31.0
	219	6	-1.089	3.494	-1.261	36.0	74.0	31.0
	220	2	-5.089	-0.506	-5.261	7.0	57.0	7.0
	221	8	0.911	5.494	0.739	62.5	77.5	63.5
	222	0	-7.089	-2.506	-7.261	2.0	31.0	2.0
	201	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	202	0	-1.589	-3.439	-0.828	27.0	14.0	43.0
	203	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	204	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	205	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	206	0	-1.589	-3.439	-0.828	27.0	14.0	43.0
	207	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	208	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	209	1	-0.589	-2.439	0.172	49.0	37.0	56.0
Congruent Condition	210	2	0.411	-1.439	1.172	59.5	50.5	65.5
	213	0	-1.589	-3.439	-0.828	27.0	14.0	43.0
	214	2	0.411	-1.439	1.172	59.5	50.5	65.5
	215	0	-1.589	-3.439	-0.828	27.0	14.0	43.0
	216	3	1.411	-0.439	2.172	71.0	61.0	73.0
	217	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	218	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	219	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	220	1	-0.589	-2.439	0.172	49.0	37.0	56.0
	221	5	3.411	1.561	4.172	80.0	71.0	80.0
	222	0	-1.589	-3.439	-0.828	27.0	14.0	43.0

APPENDIX J

Raw data and Aligned Rank Transformed error rates of the Picture-word Interference Tasks in 19% incongruent Proportion (Aphasic participants)

Condition	Subject	Error	Aligned			ART		
			Group	Condition	Group× Condition	Group	Condition	Group× Condition
Neutral Condition	101	0	-1.122	-3.856	-2.578	32.0	4.0	17.0
	103	0	-1.122	-3.856	-2.578	32.0	4.0	17.0
	104	10	8.878	6.144	7.422	87.0	79.0	86.0
	105	3	1.878	-0.856	0.422	72.0	52.0	62.0
	106	1	-0.122	-2.856	-1.578	55.0	27.0	24.0
	108	0	-1.122	-3.856	-2.578	32.0	4.0	17.0
	109	0	-1.122	-3.856	-2.578	32.0	4.0	17.0
	110	2	0.878	-1.856	-0.578	61.0	45.0	46.0
	111	0	-1.122	-3.856	-2.578	32.0	4.0	17.0
	112	4	2.878	0.144	1.422	75.0	67.0	67.0
Incongruent Condition	101	12	3.078	6.344	3.422	78.5	80.5	78.5
	103	4	-4.922	-1.656	-4.578	11.5	48.5	11.5
	104	27	18.078	21.344	18.422	90.0	90.0	90.0
	105	4	-4.922	-1.656	-4.578	11.5	48.5	11.5
	106	2	-6.922	-3.656	-6.578	3.0	11.0	3.0
	108	13	4.078	7.344	4.422	82.0	82.0	81.0
	109	12	3.078	6.344	3.422	78.5	80.5	78.5
	110	5	-3.922	-0.656	-3.578	13.0	53.0	13.0
	111	0	-8.922	-5.656	-8.578	1.0	1.0	1.0
	112	19	10.078	13.344	10.422	88.0	88.0	88.0
Congruent Condition	101	0	-0.622	-3.789	-2.144	41.5	8.5	21.5
	103	0	-0.622	-3.789	-2.144	41.5	8.5	21.5
	104	8	7.378	4.211	5.856	85.0	76.0	83.0

105	0	-0.622	-3.789	-2.144	41.5	8.5	21.5
106	0	-0.622	-3.789	-2.144	41.5	8.5	21.5
108	1	0.378	-2.789	-1.144	57.0	29.0	39.0
109	1	0.378	-2.789	-1.144	57.0	29.0	39.0
110	2	1.378	-1.789	-0.144	69.5	46.5	49.5
111	1	0.378	-2.789	-1.144	57.0	29.0	39.0
112	2	1.378	-1.789	-0.144	69.5	46.5	49.5

APPENDIX K

Raw and Aligned Rank Transformed error rates of the incongruent Conditions between 19% and 73% incongruent Proportions (Normal Participants)

Proportion	Subject	Error	Aligned			ART		
			Group	Proportion	Group× Proportion	Group	Proportion	Group× Proportion
73% Incongruent Proportion	201	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	202	0	-3.325	-4.500	-2.275	14.0	6.5	19.0
	203	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	204	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	205	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	206	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	207	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	208	3	-0.325	-1.500	0.725	35.5	36.5	40.5
	209	5	1.675	0.500	2.725	43.0	40.0	47.0
	210	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	213	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	214	6	2.675	1.500	3.725	49.0	42.5	53.0
	215	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	216	5	1.675	0.500	2.725	43.0	40.0	47.0
	217	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	218	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
	219	3	-0.325	-1.500	0.725	35.5	36.5	40.5
	220	2	-1.325	-2.500	-0.275	31.5	24.5	36.5
	221	5	1.675	0.500	2.725	43.0	40.0	47.0
	222	1	-2.325	-3.500	-1.275	20.0	15.0	25.0
19%	201	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	202	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	203	6	-1.675	1.550	-0.675	27.0	45.0	30.0

Incongruent Proportion	204	18	10.325	13.550	11.325	57.0	59.0	58.0
	205	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	206	10	2.325	5.550	3.325	47.5	52.5	50.5
	207	14	6.325	9.550	7.325	54.5	54.5	54.5
	208	15	7.325	10.550	8.325	56.0	56.0	56.0
	209	8	0.325	3.550	1.325	38.5	47.5	42.5
	210	4	-3.675	-0.450	-2.675	13.0	38.0	17.0
	213	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	214	10	2.325	5.550	3.325	47.5	52.5	50.5
	215	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	216	14	6.325	9.550	7.325	54.5	54.5	54.5
	217	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	218	6	-1.675	1.550	-0.675	27.0	45.0	30.0
	219	6	-1.675	1.550	-0.675	27.0	45.0	30.0
	220	2	-5.675	-2.450	-4.675	7.0	32.0	11.0
	221	8	0.325	3.550	1.325	38.5	47.5	42.5
	222	0	-7.675	-4.450	-6.675	2.0	8.0	3.0

APPENDIX L

Raw and Aligned Rank Transformed error rates of the incongruent Conditions between 19% and 73% incongruent Proportions (Aphasic Participants)

Proportion	Subject	Error	Aligned			ART		
			Group	Proportion	Group× Proportion	Group	Proportion	Group× Proportion
73% Incongruent Proportion	101	5	1.75	-2.50	-0.35	45.5	24.5	32.5
	103	0	-3.25	-7.50	-5.35	15.0	2.0	6.0
	104	9	5.75	1.50	3.65	53.0	42.5	52.0
	105	4	0.75	-3.50	-1.35	40.5	15.0	20.5
	106	1	-2.25	-6.50	-4.35	24.5	3.5	15.5
	108	5	1.75	-2.50	-0.35	45.5	24.5	32.5
	109	4	0.75	-3.50	-1.35	40.5	15.0	20.5
	110	1	-2.25	-6.50	-4.35	24.5	3.5	15.5
	111	3	-0.25	-4.50	-2.35	37.0	6.5	18.0
	112	21	17.75	13.50	15.65	59.0	58.0	59.0
19% Incongruent Proportion	101	12	4.25	4.40	2.25	50.5	49.5	44.5
	103	4	-3.75	-3.60	-5.75	11.5	9.5	4.5
	104	27	19.25	19.40	17.25	60.0	60.0	60.0
	105	4	-3.75	-3.60	-5.75	11.5	9.5	4.5
	106	2	-5.75	-5.60	-7.75	3.0	5.0	2.0
	108	13	5.25	5.40	3.25	52.0	51.0	49.0
	109	12	4.25	4.40	2.25	50.5	49.5	44.5
	110	5	-2.75	-2.60	-4.75	16.0	20.0	7.0
	111	0	-7.75	-7.60	-9.75	1.0	1.0	1.0
	112	19	11.25	11.40	9.25	58.0	57.0	57.0

APPENDIX M

Normalcy Tests of RT, Error Rate, Inverse RT and Inverse Error Rate from PWI task

A normalcy test of RTs with Shapiro-Wilk

Condition	Group	Congruent Statistic	Congruent df	Congruent Sig.	Neutral Statistic	Neutral df	Neutral Sig.	Incongruent Statistic	Incongruent df	Incongruent Sig.
73% Incongruent Proportion	NI				0.90	20	0.04	0.89	20	0.03
	PWA				0.73	10	0.00	0.72	10	0.00
19% Incongruent Proportion	NI	0.87	20	0.01	0.89	20	0.02	0.89	20	0.02
	PWA	0.80	10	0.02	0.75	10	0.00	0.72	10	0.00

A normalcy test of Error Rates with Shapiro-Wilk

Condition	Group	Congruent Statistic	Congruent df	Congruent Sig.	Neutral Statistic	Neutral df	Neutral Sig.	Incongruent Statistic	Incongruent df	Incongruent Sig.
73% Incongruent Proportion	NI				0.75	20	0.00	0.83	20	0.00
	PWA				0.75	10	0.00	0.74	10	0.00
19% Incongruent Proportion	NI	0.81	20	0.00	0.80	20	0.00	0.89	20	0.03
	PWA	0.62	10	0.00	0.71	10	0.00	0.90	10	0.23

A normalcy test of Inverse RTs with Shapiro-Wilk

Condition		Condition								
		Congruent			Neutral			Incongruent		
	Group	Statistic	df	Sig.	Statistic	df	Sig.	Statistic	df	Sig.
73% Incongruent Proportion	NI				0.96	20	0.62	0.95	20	0.33
	PWA				0.91	10	0.25	0.91	10	0.29
19% Incongruent Proportion	NI	0.93	20	0.18	0.95	20	0.38	0.94	20	0.26
	PWA	0.93	10	0.43	0.93	10	0.43	0.94	10	0.50

A normalcy test of Inverse Error Rates with Shapiro-Wilk

Condition		Condition								
		Congruent			Neutral			Incongruent		
	Group	Statistic	df	Sig.	Statistic	df	Sig.	Statistic	df	Sig.
73% Incongruent Proportion	NI				0.77	20	0.00	0.92	20	0.11
	PWA				0.84	10	0.05	0.82	10	0.03
19% Incongruent Proportion	NI	0.88	20	0.02	0.72	20	0.00	0.69	20	0.00
	PWA	0.86	10	0.09	0.78	10	0.01	0.64	10	0.00

APPENDIX N

Correlation coefficients between Executive Attention and Language Severity tests

	Language Tests		
	PICA	*CRTT_Score*	*CRTT_Efficiency*
Executive Attention Tests			
TMT_Time	-.707**	-.426*	-.477*
Symbol_Time	-.669**	-.267	-.304
PWI_RT	-.494**	-.436*	-.413*
CRTT_Stroop_RT	-.620**	-.529*	-.556*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
PICA = *Porch Index of Communicative Ability* (PICA) (Porch, 2001)
CRTT_Score = Overall Mean score in the Auditory version of *the Computerized Revised Token Test* (CRTT) (McNeil, Pratt, Szuminsky et al., 2008)
CRTT_Efficiency = Efficiency Score in the Auditory version of *the Computerized Revised Token Test* (CRTT) (McNeil, Pratt, Szuminsky et al., 2008)
TMT_Time= Time in *the Trail Making Test* B (Amieva et al, 1998)
STMT_Time= Time in *the Symbol Trail Making Test* B (Barncord and Wanlass, 2001)
PWI25_RT= response time of incongruent trials in the 25% incongruent condition
CRTT-R-Stroop_RT = Response Time of Incongruent Trial in the Stroop version of *the Computerized Revised Token Test* (CRTT) (McNeil, Pratt, Szuminsky et al., 2010)

APPENDIX O

Correlation coefficients among the Short Term memory and Working Memory and Executive Attention tests

	Working Memory					Short Term Memory	
	CS sentence	*OS sentence*	*Alpha*	*Sub-2*	Mean WM	*Forward*	*Backward*
Executive Attention Tests							
TMT_Time	-.475**	-.487**	-.354	-.613**	-.596**	-.636**	-.631**
Symbol_Time	-.363*	-.382*	-.353	-.371*	-.422*	-.622**	-.469**
PWI_RT	-.319	-.209	-.285	-.521**	-.468**	-.546**	-.489**
*CRTT-R-Stroop*_RT	-.52*	-.57**	-.53*	-.47*	-.62*	-.44*	-.49*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
CS sentence= *Cleft-Subject sentence reading Working Memory test* (Waters & Caplan, 2003)
OS sentence= Cleft-Object sentence reading Working Memory test (Waters & Caplan, 2003)
Alpha= *Alphabet Working memory test* (Craik, 1986)
Sub-2= *Subtract -2 Working Memory test* (Salthouse, 1988)
Mean WM= the average of four working memory span (waters and Kaplan, 2003)
Forward= Forward digit pointing span task.
Backword= Backward digit pointing span task.
TMT_Time= Time in *the Trail Making Test* B (Amieva et al, 1998)
STMT_Time= Time in *the Symbol Trail Making Test* B (Barncord and Wanlass, 2001)
PWI_RT= response time of incongruent trials in the 25% incongruent condition
*CRTT-R-Stroop*_RT = Response Time of Incongruent Trial in the Stroop version of the *Computerized Revised Token Test* (*CRTT*) (McNeil, Pratt, Szuminsky et al., 2010)

BIBLIOGRAPHY

Aboitiz, Z., Garcia, R. R., Bosman, C., & Brunetti, E. (2006). Cortical memory mechanisms and language origins. *Brain and Language, 98 (1)*, 40-56.

Arvedson, J. C. (1986). *Effect of lexical decisions on auditory semantic judgments using divided attention in adults with left and right hemisphere damage.* Unpublished Doctoral Dissertation, University of Wisconsin-Madison.

Baddeley, A., & Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory Recent advances in learning and motivation* (Vol. 8, pp. 47-90). New York: Academic Press.

Baddeley, A.D. (1986). *Working Memory*, Oxford: Oxford University Press.

Barncord, S.& Wanlass, R. (2001). The symbol trail making test: test development and utility as a measure of cognitive impairment. *Applied Neuropsychology, 8(2)*, 99-103.

Bayles, K. A., & Tomoeda, C. K. (1991). *Arizona battery for communication disorders of dementia*. Tucson, AZ: Canyonlands.

Bayliss, D. M., Jarrold, C., Gunn, D. M., & Baddeley, A. D. (2003). The complexities of complex span: Explaining individual differences in working memory in children and adults. *Journal of Experimental Psychology: General, 132*, 71-92.

Bechara, A., Damásio, A. R., Damásio, H., & Anderson, S. W. (1994). "Insensitivity to future consequences following damage to human prefrontal cortex". *Cognition 50 (1–3)*: 7-15.

Belanger, A., Belleville, S. & Gauthier, S. (2010). Inhibition impairments in Alzheimer's disease, mild cognitive impairment and healthy aging: Effect of congruency proportion in a Stroop task. *Neuropsychologia, 48,* 581-590.

Berndt, R. S., Haendiges, A., & Wozniak, M. (1997). Verb retrieval and sentence processing: Dissociation of an established symptom association. *Cortex, 33,* 99-114.

Biggs, T. C., & Markmurek, H. H. C. (1990). Picture and word naming is facilitation due to processing overlap? *American Journal of Psychology, 103*, 81-100.

Caplan, D., & Waters, G. (1995). Aphasic disturbances of syntactic comprehension and working memory capacity. *Cognitive Neuropsychology, 12,* 637-649.

Caplan, D., & Waters, G. (1999). Verbal working memory capacity and language comprehension. *Behavioral Brain Sciences, 22*, 114-126.

Caplan, D., & Waters, G. S. (1996). Syntactic processing in sentence comprehension under dual-task conditions in aphasic patients. *Language and Cognitive Processes, 11,* 525-551.

Caspari, I., Parkinson, S. R., LaPointe, L. L., & Katz, R. C. (1998). Working memory and aphasia. *Brain and Cognition, 37,* 205-223.

Cattell, R. B. (1973). *Measuring intelligence with the Culture Fair tests.* Champaigne, IL: Institute for Personality and Ability Testing.

Chapey, R. (2001). *Language intervention strategies in aphasia and related neurogenic communication disorders* (4th ed.). Baltimore, MD: Williams & Wilkins.

Cherry, E. C. (1953). Some experiments on the recognition of speech, with one and with two ears. *Journal of the Acoustical Society of America, 25,* 975-979.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Cohen, J. D., & Servan-Schreiber, D. (1992). Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychological Review, 99*, 45-77.

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review, 97*, 332-361.

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review, 8,* 331-335.

Conway, A. R. A., Kane, M. J., & Engle, R. W. (2003). Working memory capacity and its relation to general intelligence. *Trends in Cognitive Science*, *7*, 547-552.

Cowan, N. (1995). *Attention and memory: An integrated framework*. Oxford: Oxford University Press.

Cowan, N. (1999). An embedded-processes model of working memory. In A. Miyake, & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 62–101). New York: Cambridge University Press.

Cowan, N. (2005). *Working memory capacity*. Hove, East Sussex, UK: Psychology Press.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.*), Human memory and cognitive capabilities* (pp. 409-421). Amsterdam: North-Holland.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 450-466.

Daneman, M., & Carpenter, P. A. (1983). Individual differences in integrating information between and within sentences. *Journal of Experimental Psychology: Learning, Memory, and Cognition. 9,* 561-584.

Dell'Acqua, R., Job, R., Peressotti, F., & Pascali, A. (2007). The picture-word interference effect is not a Stroop effect. *Psychonomic Bulletin & Review, 14(4),* 717-722.

Derrick, W. L. (1988). Dimensions of operator workload. *Human Factors, 30*, 95-110.

Duffy, J., Keith, A. & Minnesota, R. (1980). Performance of Non-Brain Injured Ajults on the PICA: Descriptor Data and a Comparison to Patients with Aphasia. *Aphasia-Apraxia-Agnosia, 2,* 1-30.

Dunbar, K. N. (1986). *Multiple sources of interference in a picture-word analogue of the Stroop task.* Unpublished doctoral dissertation, University of Toronto.

Dunn, L.M., & Dunn, L.M. (1997). *Peabody Picture Vocabulary Test*, Third Edition. Circle Pines, MN: American Guidance Service.

Engle, R. (2002). Working memory as executive attention. *Current Directions in Psychological Science, 11(1),* 19-23.

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.), *The psychology of learning and motivation* (pp. 145-199). New York: Academic Press.

Engle, R. W., Kane, M. J., & Tuholski, S. W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In Miyake, A. & Shah, P. (Eds.), *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control* (pp.102-134). London: Cambridge Press.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory and general fluid intelligence: A latent variable approach. *Journal of Experimenta*l *Psychology: General, 128,* 309-331.

Field, A (2005*). Discovering Statistics Using SPSS*. London: SAGE publications Ltd.

Friedmann, N., & Gvion, A. (2003). Sentence comprehension and working memory limitation in aphasia: A dissociation between semantic-syntactic and phonological reactivation. *Brain and Language, 86,* 23–39.

Fuentes, L. J., Vivas, A. B., & Humphreys, G. W. (1999). Inhibitory mechanisms of attentional networks: Spatial and semantic inhibitory processing. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 1114- 1126.

Glaser, W. R. (1992). Picture naming. *Cognition, 42*, 61-105.

Glaser, W. R., & Düngelhoff, F. J. (1984). The time course of picture–word interference. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 640-654.

Glaser, W. R., & Glaser, M. O. (1989). Context effects in Stroop-like word and picture processing. *Journal of Experimental Psychology: General, 118*, 13-42.

Gopher, D., & Braune, R. (1984). On the psychophysics of workload: Why bother with subjective measures? *Human Factors, 26*, 519-532.

Gutbrod, K., Cohen, R., Mager, B. & Meier, E. (1989). Coding and recall of categorized material in aphasics. *Journal of Clinical and Experimental Neuropsychology, 11*, 821-839.

Helm-Estabrooks, N. (2001). *Cognitive Linguistic Quick Test*. San Antonio, TX: The Psychological Corporation.

Helm-Estabrooks, N. (2002). Cognition and aphasia: a discussion and a study. *Journal of Communication Disorders, 35*, 171-186.

Houwer, J., Fias, W., & d'Ydewalle, G. (1994). Comparing color-word and picture-word Stroop-like effects: A test of the Glaser and Glaser (1989) model. *Psychological Research, 56*, 293-300.

Howard, D., & Patterson, K. (1992). *The Pyramids and Palm Trees Test*. Bury St. Edmunds, UK: Thames Valley Test Company.

Jarrold, C. & Towse, J.N. (2006). Individual differences in working memory. *Neuroscience, 139,* 39-50.

Just, M. A., & Carpenter, P. A. (1992). A Capacity Theory of Comprehension: Individual Differences in Working Memory. *Psychological Review, 99,* 122-149.

Just, M.A., & Carpenter, P.A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review, 87(4),* 329-354.

Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ: Prentice Hall.

Kane, M. J., & Engle, R. W. (2003). Working memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132,* 47-70.

Kane, M. J., Bleckley, K. M., Conway, A. R. A., & Engle, R. W. (2001). A controlled-attention view of working-memory capacity. *Journal of Experimental Psychology: General, 130,* 169-183.

Kane, M.J., Conway, A.R.A., Hambrick, D.Z., & Engle, R.W. (2007). Variation in working memory capacity as variation in executive attention and control. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake, and J. N. Towse (Eds.), *Variation in Working Memory* (pp. 21 - 48). NY: Oxford University Press.

Kay, J., Lesser, R., & Coltheart, M. (1992). *PALPA: Psycholinguistic Assessments of Language Processing in Aphasia*. Lawrence Erlbaum Associates, Hove.

Kertesz, A. (1982). *Western Aphasia Battery*. New York: Grune & Stratton.

Kolk, H.H.J., & Weijts, M. (1996). Judgments of semantic anomaly in agrammatic patients: Argument movement, syntactic complexity, and the use of heuristics. *Brain and Language, 54 (1),* 86-135.

La Heij, W. (1988). Components of Stroop-like interference in picture naming. *Memory and cognition, 16,* 400-410.

LaPointe, L. L., & Erickson, R. J. (1991). Auditory vigilance during divided task attention in aphasic individuals. *Aphasiology, 5,* 511-520.

Lupker, S. J., & Katz, A. N. (1981). Input, decision, and response factors in picture–word interference. *Journal of Experimental Psychology: Human Learning & Memory, 7,* 269-282.

Maanen, L. V., Rijn, H. V., & Borst, J. P. (2009). Stroop and picture–word interference are two sides of the same coin, *Psychonomic Bulletin & Review, 16 (6*), 987-99.

MacLeod, C. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological bulletin, 109 (2*), 163-203.

McNeil, M. R. & Pratt, S. R. (2001). A Standard Definition of Aphasia: Toward a general theory of aphasia. *Aphasiology, 15 (10/11)*, 901-911.

McNeil, M. R. (1988). Aphasia in the adult. In N.J. Lass, L. V. McReynolds, J. Northern, & D. E. Yoder (Eds.), *Handbook of speech-language pathology and audiology* (pp. 738-786). Toronto: D.C. Becker, Inc.

McNeil, M. R., Odell, K., & Tseng, C. H. (1991). Toward the integration of resource allocation into a general theory of aphasia. *Clinical Aphasiology, 20,* 21- 39.

McNeil, M. R., Pratt., S. R., Fassbinder, W., Dickey, M. W., Kendall, D., Lim, K., Kim, A., Pompon, R., Szuminsky, N., Krieger, D. (2011). Effects of linguistic complexity and executive attentional demands on sentence comprehension in persons with aphasia and normal controls: Exploring on-line and off-line measures with two reading versions of the Computerized Revised Token Test. *Poster presentation at Clinical Aphasiology Conference*, Ft. Lauderdale, FL.

McNeil, M.R., Pratt, S.R., Szuminsky, N., Fossett, T.R.D., Eberwein, D., Sung, J.E., & Doyle, P.J. (2008). *Conceptual, technical and psychometric development of the Computerized Revised Token Tests: Auditory (CRTT) and Reading (CRTT-R).* Manuscript in preparation. J. Miller & R. Chapman, 1998).

McNeil, M.R., Sung, J.E., Yang, D., Pratt, S., Pavelko, S., Fossett, T.R.D., Smolky, B., Doyle, P.J. (2007). Comparing connected language elicitation procedures in persons with Aphasia: Concurrent validation of the story retelling procedure. *Aphasiology*, *21*, 775-790.

Miyake, A., & Shah, P. (Eds.). (1999). *Models of working memory: Mechanisms of active maintenance and executive control*. New York: Cambridge University Press.

Miyake, A., Carpenter, P. A., & Just, M. A. (1994). A capacity approach to syntactic comprehension disorders: Making normal adults perform like aphasic patients. *Cognitive Neuropsychology, 11,* 671-717.

Miyake, A., Carpenter, P. A., & Just, M. A. (1995). Reduced resources and specific impairments in normal and aphasic sentence comprehension. Cognitive *Neuropsychology, 12*, 651-679.

Murray, L. L. (1999). Attention and aphasia: Theory, research and clinical implications. *Aphasiology, 13,* 91-112.

Murray, L. L., Holland, A. L., & Beeson, P. M. (1997a). Accuracy monitoring and task demand evaluation in aphasia. *Aphasiology, 11*, 401-414.

Murray, L. L., Holland, A. L., & Beeson, P. M. (1997b). Auditory processing in individuals with mild aphasia: a study of resource allocation. *Journal of Speech, Language, and Hearing Research, 40*, 792-808.

Norman, D. A. Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In Davidson R. J., Schwatz, G. E., Shapiro, D. E. *Consciousness and self-regulation.* New York: Plenum Press. 1-14.

O'Donnell, R.D., and Eggemeier, F.T. (1986). "Workload Assessment Methodology," (pp. 42/1-42/9). In K. Boff, L. Kaufman and J. Thomas (Eds.) *Handbook of Perception and Human Performance, Vol. II: Cognitive Processes and Performance*. New York: Wiley Interscience.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*, 97-113.

Porch, B. E. (2001). *Porch Index of Communicative Ability*. Palo Alto, CA: Consulting Psychologists.

Posner, M. I., & Raichle, M. E. (1994). *Images of mind*. New York: Freeman.

Raven, J. C. (1995). *Raven's coloured progressive matrices*. San Antonio, TX: The Psychological Corporation.

Raven, J. C., Court, J. H., & Raven, J. (1977). *Standard progressive matrices*. London: H. K. Lewis.

Repovs, G., & Baddeley, A.D. (2006) Multi-component model of working memory: explorations in experimental cognitive psychology. *Neuroscience Special Issue, 139,* 5-21.

Robin, D. A., & Rizzo, M. (1989). The effects of focal lesions on intramodal and cross-modal orienting of attention. *Clinical Aphasiology, 18,* 62–74.

Rochon, E., Waters, G. S., & Caplan, D. (2000) The relationship between measures of working memory and sentence comprehension in patients with Alzheimer's disease. *Journal of Speech, Language, and Hearing Research. 43 (2),* 395-413.

Rochon, E., Waters, G. S.,& Caplan, D. (1994). Sentence comprehension in patients with Alzheimer's disease*. Brain and Language, 46,* 329-349.

Ronnberg, J., Larsson, C., Fogelsjoo, A., Nilsson, L., Lindberg, M., & Anggquist, K. (1996). Memory dysfunction in mild aphasia. *Scandinavian Journal of Psychology, 37,* 46-61.

Salthouse, T. A. (1988b). The role of processing resources in cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood* (pp. 185-239). New York: Springer-Verlag.

Salthouse, T. A., & Meinz, E. J. (1995). Aging, inhibition, working memory, and speed, *Journal of Gerontology: Psychological Sciences, 50B,* 297-306.

Schwartz, M. F., Linebarger, M. C., Saffran, E. M., & Pate, D. (1987). Syntactic transparency and sentence interpretation in aphasia. *Language and Cognitive Processes, 2,* 85-113.

Shah, P., & Miyake A. (1996). The Separability of Working Memory Resources for Spatial Thinking and Language Processing: An Individual differences Approach. *Journal of Experimental Psychology: General, 125,* 4-27.

Smith, M. C., & Magee, L. E. (1980). Tracing the time course of picture–word processing. *Journal of Experimental Psychology: General, 109,* 373-392.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174-215.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643-662.

Thompson C. K., Shapiro, L. P., Tait, M. E., Jacobs, B., Schneider, S., & Ballard, K. (1995). A system of the linguistic analysis of agrammatic language production. *Brain and Language, 51*, 124-129.

Tompkins, C. A., Bloise, C. G. R., Timko, M. L., & Baumgaertner, A. (1994). Working memory and inference revision in brain-damaged and normally aging adults. *Journal of Speech and Hearing Research, 37,* 896-912.

Tseng, C. H., McNeil, M. R., & Milenkovic, P. (1993). An investigation of attention allocation deficits in aphasia. *Brain and Language, 45,* 276-296.

Vallar, G., Corno, M., & Basso, A. (1992). Auditory and visual verbal short-term memory in aphasia. *Cortex, 28,* 383–389.

Van mourikm M., Verschaene, M., Boon, P., Paquier, P. et. Al. (1992). Cognition in global aphasia: indicators for therapy. *Aphasiology, 6(5),* 491-499.

Vilkki, J. (1988). Probelem-solving deficts after focal cerebral lesions. *Cortex*, *24*, 119-127.

Warren, C., & Morton, J. (1982). The effects of priming on picture recognition. *British Journal of Psychology, 73*, 117-129.

Waters, G. S., & Caplan, D. (1996). The measurement of verbal working memory capacity and its relation to reading comprehension. *Quarterly Journal of Experimental Psychology, 49A*, 51-74.

Waters, G. S., Caplan, D., & Rochon, E. (1995). Processing capacity and sentence comprehension in patients with Alzheimer's disease. *Cognitive Neuropsychology, 12,* 1-30.

Wiener, D. A., Connor, L. T., & Obler, L. K. (2004). Inhibition and auditory comprehension in Wernicke's aphasia. *Aphasiology, 18 (5/6/7),* 599-609.

Wobbrock, J.O., Findlater, L., Gergle, D. and Higgins, J.J. (2011). The Aligned Rank Transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11). Vancouver, British Columbia (May 7-12, 2011).* New York: ACM Press, pp. 143-146.

Wright & Shisler, (2005). Working memory in aphasia: theory, measures, and clinical implications. *American Journal of Speech-Language Pathology, 14*, 107-118.

Wright, H. H., Newhoff, M., Downey, R., & Austermann, S. (2003). Additional data on working memory in aphasia. *Journal of International Neuropsychological Society, 9*, 302.

Yeh, Y. Y., & Wickens, C. D. (1988). Dissociation of performance and subjective measures of workload. *Human Factors*, *30*, 111-120.