

CENTRAL EXECUTIVE FUNCTION IN INDIVIDUALS WITH APHASIA

By

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ABSTRACT

Individuals with aphasia (IWA) have been shown to encounter deficits in attention and working memory (WM). Although there is growing evidence demonstrating deficits in WM processing, there is less information regarding the abilities of the central executive (CE) of the WM system in IWA. Individuals with fluent and nonfluent aphasia were administered tasks that isolated the four fractions of the CE, and qualitative, descriptive analyses were conducted to determine performance on tasks that fractionate different CE functions. Additionally, the impact of variables such as age, time post-onset of injury, and aphasia severity on CE task performance was explored. Results suggest that CE dysfunction of the participants in this study cannot be predicted by aphasia type. Rather, aphasia severity and age may be more predictive indicators of CE abilities. Overall, there may be several factors that contribute to CE deficits in aphasia, indicating that attention may be affected differently amongst IWA.

INDEX WORDS: Aphasia, Attention, Stroke, Working Memory System, Central Executive, Executive Deficits

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CHAPTER 1

INTRODUCTION

Individuals with aphasia (IWA) have demonstrated deficits in cognitive abilities, such as reductions in attention and verbal working memory (WM) span. There has been a call to expand investigation into these cognitive abilities by examining executive functions after acquired brain injury or stroke (Keil & Kaszniak, 2007). Baddeley and Della Sala (1996) stated that individuals may present with executive deficits following a lesion to a part of the brain that is not frontally located and introduced the concept of the central executive (CE) in attempt to separate executive function from its typically associated frontal lobe localization. The CE is an integral component to the WM system that directs attentional resources to allow for the processing of verbal and spatial information (Baddeley, 1996). The integrity of the CE depends on an interconnected network of both frontal and posterior brain regions (Collette & Van der Linden, 2002), meaning that CE dysfunction can occur following damage to various locations. Murray and colleagues (Murray, Holland, & Beeson, 1997a) argued that despite the location of damage in individuals with different types of aphasia, a reduction in input and feedback throughout anterior and posterior attention networks is likely. Subsequently, these disruptions can lead to similar reductions in the attentional abilities of individuals with different types of aphasia, and may indicate that a common attention network is affected in aphasia (Murray et al., 1997a). Because the CE relies on an interconnected network of attention resources, if a common attention network is indeed affected in aphasia, then

individuals with different types of aphasia should experience similar reductions in the CE.

There are conflicts in the literature regarding the idea that CE abilities of IWA draw upon a common network of attentional resources. This has been suggested by the results of other studies that have shown differential performance by individuals with different types of aphasia on tasks that require the CE (e.g., Glosser & Goodglass, 1990). Given these conflicting findings, further examination of CE performance in IWA is warranted, as attention deficits and reductions in WM have been shown to be present in individuals with different types of aphasia (Glosser & Goodglass, 1990; Murray et al., 1997a). In addition, it has been suggested that onset of injury (Pohjasvaara et al., 2002) and age (Fisk & Sharp, 2004) may play a role in the abilities of the CE.

The current study was designed to explore the CE of the WM system, and its relationship to a common attentional system in individuals with fluent and nonfluent aphasia. Fluent and nonfluent IWA were assessed on tasks that isolate the four “fractions” of CE function (i.e., set switching, inhibition, dual-task processing, and updating information in WM; Baddeley, 1996). Each individual’s performance was compared across tasks, and to that of the other participants. In addition to performance as related to aphasia type (fluent or nonfluent), factors including aphasia severity, age, and time post-onset of injury were evaluated to determine if these variables may explain task performance. The aim of the current study was to provide important information regarding CE function in IWA, as some researchers are beginning to examine how executive functions may be related to linguistic abilities (see Keil & Kaszniak, 2007 for review). Furthermore, there is increasing interest in explaining the cognitive deficits

encountered in aphasia. For example, researchers are trying to find the source of resource allocation deficits (Hula & McNeil, 2008; Murray et al., 1997a) and reductions in WM (Beeson et al., 1993; Caspari, Parkinson, LaPointe, & Katz, 1998). The CE is implicated in both resource allocation and WM. Therefore, examination of CE function in fluent and nonfluent individuals may provide information regarding whether the source of these deficits can be explained by reductions in a common attentional system affected in aphasia. In addition, as speech-language pathologists begin to consider attention and WM as part of treatment strategies for aphasia (Murray, 2004), determining the CE's relation to a common attentional system may be important when devising ways to target these variables in the treatment of different types of aphasia.

CHAPTER 2

REVIEW OF THE LITERATURE

Aphasia is defined as a loss of language following brain damage incurred to the language processing areas of the brain. Aphasia is the result of acquired brain damage, not the result of sensory or intellectual deficits (Hallowell & Chapey, 2008). One or more aspects of communication can be affected in aphasia; including deficits in reading, writing, speaking, and listening abilities. Broadly, different types of aphasia can be categorized as being either fluent or nonfluent. One of the more popular and traditional approaches to classifying aphasia type is to associate communication profiles with a corresponding lesion (Helm-Estabrooks & Albert, 1991). For example, in right-handed individuals, fluent aphasias are typically associated with retrolandic lesions to the left parietal and/or temporal lobes, and nonfluent aphasias are often associated prerolandic lesions of the left frontal lobe (George, Vikingstad, Silbergleit, & Cao, 2007).

The view that aphasia is a “loss” assumes that an individual with aphasia no longer possesses the rules and representations of language (Hula & McNeil, 2008). This view has prevailed from a clinical standpoint, as aphasia treatment typically focuses on the habilitation of an individual’s deficits (Hallowell & Chapey, 2008). Alternatively, in 1991, McNeil and colleagues (McNeil, Odell, & Tseng, 1991) suggested that aphasia might be better explained as a reduction in the processing resources that subserve linguistic capacities. Their conclusion was drawn with support from a number of studies suggesting that aphasia may not be a problem with linguistic competence, as commonly

thought, but rather a problem with linguistic performance. This idea was based partly on the distinctions that Chomsky (1975) made between linguistic competence and linguistic performance, as well as growing evidence of the preservation of linguistic competence in individuals with aphasia (IWA). According to Chomsky, linguistic competence is the underlying knowledge of language that a speaker possesses, while linguistic performance is the speaker's actual use of language. These two constructs can be separable in that it is possible for an individual to possess linguistic competence, yet demonstrate performance errors. If IWA suffered from a loss of linguistic competence, then they would be expected to have a loss of the components of language: phonology, morphology, syntax, semantics, and pragmatics (Hymes, 1972). On the contrary, IWA have been shown demonstrate semantic priming (Blumstein, Milberg, & Shrier, 1982; Milberg & Blumstein, 1981; Milberg, Blumstein, & Dworetzky, 1988), and possess syntactic rules, but reductions in automatic processing for syntax (Kilbourn & Fredericci, 1989). Furthermore, the belief that linguistic abilities are not completely lost in aphasia has been demonstrated by variability in linguistic performance (Caplan, Waters, Dede, Michaud, & Reddy, 2007; Crisman, 1971; Freed, Marshall, & Chulantseff, 1996; Howard, Patterson, Franklin, Morton, Orchard-Lisle, 1984; Kolk, 2007; Kreindler, & Fradis, 1968), and that language performance can be stimulated by the use of nonlinguistic stimuli (Hula & McNeil, 2008).

Even though the aforementioned results indicated that some aspects of linguistic competence are preserved, others (Blumstein, 1988; Gardner, 1985; McClelland, 1987) argued that language is "computationally modular;" that language processing units are separate from and do not interact with other cognitive systems. The aforementioned

researchers (Blumstein, 1988; Gardner, 1985; McClelland, 1987) suggested that individuals could have a deficit in semantic processing, yet may have intact abilities in other aspects of language. In contrast, McNeil and colleagues noted that IWA experience deficits across linguistic domains (e.g., Darley, 1982; Schuell, Jenkins, & Jimenez-Pabon, 1964), and therefore they believed that it was unlikely that more than one module could be damaged. Instead, they argued that a mechanism connecting these modules is impaired. They furthered this hypothesis by demonstrating that multiple domains of language appear to draw upon similar processing resources (Arvedson & McNeil, 1986)¹.

McNeil and colleagues (1991) hypothesize that to account for performance deficits across the different domains of language, presence of reduced cognition in aphasia, variability, and stimulability, the deficits experienced in aphasia are more likely the result of reductions in the “computational units” for these processes. Thus, McNeil and colleagues proposed a framework for resource allocation to account for the deficits in aphasia. This framework opposes the view that different aspects of a modular linguistic system are affected in IWA. Instead, it is based on the idea that the linguistic system is relatively intact in aphasia, but that processing resources that subserve linguistic capacities are disrupted. According to this framework, both attention and attentional control are necessary for a variety of mental activities, language included. McNeil and colleagues (1991) postulated that language might require greater amounts of attentional

¹ Arvedson and McNeil (1986) used a dual-task procedure in which IWA had to complete lexical decision and semantic judgment tasks either in isolation or simultaneously. Individuals demonstrated intact performance when tasks were completed in isolation, but decreased performance when both tasks were completed simultaneously. If both aspects of language did not draw upon the same processing resources, performance should not have decreased on both tasks in dual-task conditions. Thus, through this dual-task procedure, the authors demonstrated that different aspects of language might not be computationally modular.

allocation than other cognitive domains and that inefficient allocation of attentional resources to meet these demands may better explain the deficits that IWA experience.

In the years following McNeil and colleagues' paper (1991), the study of nonlinguistic cognitive processes in IWA has become an increasingly important area of research in the field of aphasiology. Specifically, much of the current research is based on evidence demonstrating that attention deficits may be related to linguistic performance in IWA (McNeil et al., 1991).

There is growing evidence demonstrating that the capacity of attention itself may be decreased, or the ability to allocate attentional resources may be inefficient in IWA (Erickson, Goldinger, & LaPointe, 1996; LaPointe & Erickson, 1991; McNeil & Kimelman, 1986; McNeil et al., 1991; Murray, Holland, & Beeson, 1997a, 1997b, 1998; Slanksy & McNeil, 1997; Tseng, McNeil, & Milenkovic, 1993). IWA have been assessed for their performance on sustained attention tasks (Glosser & Goodglass, 1990; Laures, Odell, & Coe, 2003), dual-task abilities for linguistic (Murray et al., 1997a, 1997b; 1998) and nonlinguistic stimuli (Erickson et al., 1996), as well as working memory (Beeson et al., 1993; Caspari, Parkinson, LaPointe, & Katz, 1998; Downey et al., 2004; Friedmann & Gvion, 2003; Laures-Gore, Marshall, & Verner, 2011; Ronnberg et al., 1996). IWA have demonstrated decreased performance relative to controls (neurologically intact, left brain damage with no aphasia, or right brain damage with no aphasia) in all of these studies.

As the field expands to consider the impact of attention deficits on language performance, there has been a call to investigate the presence and role of attention and executive deficits in the abilities of this population (Keil & Kaszniak, 2007). Executive

abilities are necessary for WM, self-monitoring, self-regulating, the ability to inhibit irrelevant stimuli and switch between tasks or concepts, the creation of problem solving strategies, resource allocation, and the coordination and integration of multimodal information in the brain (Keil & Kaszniak, 2007). The Central Executive (CE) of the WM system has been credited with the responsibility of initiating and executing these behaviors and is thought to be the interface between attention and WM (Baddeley, 1996). Studying aspects of the WM system, and perhaps more specifically, the CE, may provide information regarding the cognitive variables that may underlie the linguistic deficits experienced by IWA (Hula & McNeil, 2008).

The Working Memory System.

The WM system, as proposed by Baddeley and Hitch (1974), is a tripartite model that explains the storage and manipulation of verbal and spatial material. The system is composed of a phonological loop (responsible for processing verbal and articulatory information), a visuospatial sketchpad (for visual and spatial memory), and the CE. The CE is the “attentional control” center of the WM system, and serves to communicate between long-term memory and each of the slave systems (the phonological loop and visuospatial sketchpad; Baddeley, 1996). The phonological loop is thought to be localized in the left hemisphere, with storage of phonological information in the area of Broadmann 44 and subvocal rehearsal in Broadmann’s areas 6 and 40 (Baddeley, 2003). Both the phonological loop and CE are necessary for verbal memory, as the CE “allocates” and “coordinates” information to the phonological loop, while also retrieving information from long-term storage (Gathercole & Baddeley, 1993). Once capacity limits

in the phonological loop are reached, attentional control from the CE is required for WM processes (Rypma, Prabhakaran, Desmond, Glover, Gabrieli, 1999).

Both frontal and parietal areas have been shown to be necessary in verbal WM (Jonides et al., 1998), highlighting the importance of fronto-parietal attention circuits in verbal processing. Specifically, Rypma and colleagues (1999) have found that the left inferior prefrontal, parietal, and temporal lobes are necessary for verbal WM, and as task demands increase, the CE is recruited for further information processing. Frontal lobe activations are typically seen in tasks that require information updating, maintenance, selection, manipulation, and monitoring (for review, see Fletcher & Henson, 2001). More recent research suggests that the parietal lobe is also implicated in manipulating information in WM, as individuals with parietal damage are unable to manipulate information in working memory, despite demonstrating intact storage and retrieval (Koenigs, Barbey, Postle, & Graffman, 2009). These results demonstrate that the integrity of the WM system as a whole, and its ability to process verbal information, is dependent on the abilities of each of its components (i.e., phonological loop and CE), served by different brain areas recruited to meet task demands.

The CE system is the component of the WM system that has been less extensively studied than either the phonological loop or visuospatial sketchpad (Baddeley, 1986; 1996). It is believed that the abilities of the CE can be “fractionated” into four components, making the CE responsible for dual-task processing, task switching, inhibition, and the manipulation of information into WM (Baddeley, 1996). Baddeley likens the CE system to the Supervisory Attentional System of Norman and Shallice (1980) in that it is responsible for attending to relevant information while rejecting

irrelevant information. Executive abilities have been thought of as “frontal” functions (i.e., located in the anterior regions of the brain; Vogt, Finch, & Olson, 1992), but more recent imaging research has shown that executive function relies on activations of neural networks throughout the brain (see Collette & Van der Linden, 2002 for review).

Because not all executive function is localized in the frontal lobes (Andrés, 2003; Collette & Van der Linden, 2002 for review), Baddeley (1996) stated that describing the CE system as a “frontal” function limits the role of the CE. According to Baddeley (1996), the failure to define certain behaviors as executive simply because they might not be supported by frontal lobe activations could potentially exclude processes that can be considered executive functions from being attributed to the CE. Baddeley argues further that deficits in executive performance may be related to brain damage in non-frontal areas of the brain (Baddeley, 1996; Baddeley & Della Sala, 1996; Baddeley & Wilson, 1988).

Because CE function relies on an interconnected network of brain structures, and is important to the functioning of the WM system as a whole, it follows that WM may be affected after part of the system is compromised. In fact, WM appears to be decreased in IWA (Beeson et al., 1993; Caspari et al., 1998; Downey et al., 2004; Friedmann & Gvion, 2003; Laures-Gore et al., 2011; Ronnberg et al., 1996; Yasuda & Nakamura, 2000) as compared to neurologically intact controls (Beeson et al., 1993; Friedmann & Gvion, 2002; Ronnberg et al., 1996), as well individuals with right hemisphere damage (Laures-Gore et al., 2011). The source of WM deficits, however, is still debated. The phonological loop has been studied in IWA because of its role in linguistic processing (Caspari et al., 1998). Previous research has speculated that the break down in the WM

systems can be attributed to storage reductions in the phonological loop (Caspari et al., 1998), the abilities of the central executive (Beeson et al., 1993), or resource allocation (Murray et al., 1997a; Tseng et al., 1993). That is, some argue that reductions in the abilities of the phonological loop (Caspari et al., 1998), reduced executive control (Beeson et al., 1993), or the inability to allocate resources necessary to meet task demands (Murray et al., 1997a; Tseng et al., 1993) may underlie the decreased WM performance in IWA. Investigating the cause of reduced WM in aphasia is important, as WM appears to be related to comprehension (Caplan & Waters, 1990; Daneman & Carpenter, 1980) and aphasia severity (Laures-Gore et al., 2011).

It has been argued that the CE is involved in reduced WM spans in aphasia (Ronnberg et al., 1996). Ronnberg and colleagues (1996) tested individuals on digit span, short-term and long-term word recall tasks (including free and cued recall), a reading span task, “subject performed tasks” (i.e., executing a task by following an imperative command), and the Tower of Hanoi (TOH; to test both CE and WM abilities). The long-term free recall tasks, “subject performed” tasks, and TOH were considered to require the CE, while the digit span and short-term word recall tasks were tests of the phonological loop. The authors found that performance on the executive tests, rather than performance on tests of the phonological loop, appeared to be more predictive of performance on the reading span tasks. Therefore, Ronnberg et al. concluded that disruptions in CE functions underlie reductions in WM by leading to reductions in semantic and phonological abilities. The results indicate that the CE may indeed be the source of WM span reductions in IWA, and it further appears that reductions in CE function might reduce the abilities of the phonological loop in aphasia.

Moreover, others (Awh, Vogel, & Oh, 2006; Cowan, 1995; Engle, Kane, & Tuholski, 1999) have shown that attention is implicated in verbal WM tasks, so it is possible that damage to the CE disrupts the direction of attentional resources that serve verbal WM processes, in turn leading to reductions in WM abilities.

Attention

Attention has been referred to as the “gatekeeper” of the WM system (Awh et al., 2006). Just as WM utilizes multiple brain regions, attentional capacities also rely on an “interconnected” network of regions in the brain (Mesulam, 1981, 1990; Posner & Petersen, 1990 for review). Attention can be defined as a “selective process that occurs in response to the limited processing capacity of the brain” (Banich, 1997, p. 236). Three separate attention networks have been described to support this process, all relying on different parts of the brain (Posner & Fan, 2004; Posner & Petersen, 1990; Posner & Raichle, 1996). Broadly, there is an anterior network responsible for traditionally labeled executive abilities that are thought to be responsible for overall control of the attentional system (Posner, 1994), a posterior network that works to orient attention to sensory information and locations in space (Treisman & Gormican, 1988), and a network for the maintenance of an alert state (Raz, 2004). The anterior executive network is localized in the anterior cingulate gyrus, and the prefrontal cortex, and the posterior network located in the superior parietal lobe and temporal parietal junction (Posner & Dehaene, 1994). Maintaining an alert state appears to be the responsibility of the thalamus and surrounding areas, locus coeruleus, and cortical areas (for review, see Raz, 2004).

Although WM appears to direct attention (de Fockert, Rees, Frith, & Lavie, 2001), attention appears to influence the information that can be stored and manipulated into WM by encoding information that best suits that which is needed for WM processing (Awh, Vogel, & Oh, 2006). The WM system also appears to be involved in the control of selective attention (de Fockert et al., 2001), and imaging research reveals that the neural networks supporting WM and attention often overlap (LaBar, Gitelman, Parrish, & Mesulam, 1999). Further, frontal and posterior cortical areas are likely to be active during WM processes, and broadly, the frontal areas are responsible for synthesizing different types of information into WM, and the posterior areas select the type of information to be stored (Prabhakaran, Narayanan, Zhao, & Gabrieli, 2000). Because attention and WM appear to share similar fronto-parietal networks, it has been said that attention works to serve WM (Awh & Jonides, 2001). Thus, the breakdown in WM abilities may be attributed to a decrease in attention, or a failure of the CE to sufficiently allocate attention or resources to a task.

The overlap of networks that subserve attention and WM has been thought to support the idea of a more general network, what Baars (1988, 2002) and Newell (1994) referred to as a “global workspace.” That is, the overlap of neural networks that support attention, WM, and perception allow for information to be spread from one element of the system to another. Further, because attention and working memory are supported by activations in a common fronto-parietal network, it appears that a common neural network supports these cognitive constructs (see Naghavi & Nyberg, 2005 for review). Specifically, Baars (2002) used WM as evidence to support the notion of a global workspace. He cites a study by John and colleagues (2001) that found that posterior-

anterior network activations in WM demonstrate the interaction between perception and executive function, a “right-to-left” network activation for inner speech, and that activity in the anterior cingulate supported effort necessary for WM task execution (Baars, 2002; John et al., 2001).

Damage to either the anterior or posterior attention network may result in damage to a common attention system (Posner & Petersen, 1990; Mesalun, 1981), and it is possible that lesions to frontal or posterior areas will affect attention similarly (Murray et al., 1997a). Murray et al. (1997a) theorized that disruptions in posterior input or feedback influence frontal lobe processes and attentional control abilities. Accordingly, because both the CE and the WM system as a whole rely on the integrity of interconnected attentional networks, if a common attention system is indeed damaged, then reductions in the abilities of both constructs appear to be possible, regardless of site of damage within this network. Understanding CE function and its relationship to this common attention system will provide information regarding how damage to different parts of this attention system affects the CE, and in turn lead to reductions in the overall function of the WM system.

Executive Function and Dysfunction

As previously mentioned, executive performance has typically been attributed to frontal brain locations. Baddeley originally explained executive functions as frontal (Baddeley, 1986), but later, he and his colleagues began to move away from defining executive functions by their anatomic location (Baddeley, 1996; Baddeley & Della Sala, 1996; Baddeley & Wilson, 1988). According to Baddeley and Della Sala (1996),

“... ‘frontal’ behaviour may occur in the absence of frontal [lesion] localization” (p. 1397). The concept of CE was introduced and further defined in order to move away from the characterization of dysexecutive syndrome as “frontal dysfunction” (Baddeley & Della Sala, 1996). Therefore, the introduction of the CE concept underscores the importance of considering the role of multiple neural networks to support CE abilities, as it was Baddeley and colleagues' attempt to introduce the possibility of executive dysfunction from lesions to either frontal and/or nonfrontal areas.

Individuals may suffer from executive dysfunction after acquired brain damage or stroke, even without the presence of aphasia (Pohjasvaara et al., 2002; Vataja et al., 2003; Zinn, Bosworth, Hoenig, & Swartzwelder, 2007). Specifically, these studies have demonstrated that executive dysfunction was most likely to occur following left hemisphere stroke (Vataja et al., 2003), and that executive deficits may occur after insult to either frontal or nonfrontal areas (Pohjasvaara et al., 2002; Vataja et al., 2003). When individuals were given assessments commonly used to test CE function (e.g., Trail Making Test, Delis-Kaplan Executive Function System test), there was evidence of reduced processing speed, WM, and cognitive flexibility in some post-stroke individuals (Zinn et al., 2007). Furthermore, for individuals that did present with post-stroke executive dysfunction, these deficits appeared to be related to reductions in the abilities to carry out activities of daily living (e.g., dressing, feeding, continence; Fillenbaum, 1988; Pohjasvaara et al., 2002). Given these findings, the literature reports a need of further investigation of executive abilities of post-stroke individuals or those with acquired brain damage (Keil & Kaszniak, 2006; Zinn et al., 2007). However, some investigators (Pohjasvaara et al., 2002; Vataja et al., 2003) have excluded individuals with “severe”

aphasia. If IWA were included, their executive abilities were not examined separately, and results from these individuals contributed to an overall analysis (Pohjasvaara et al., 2002; Vataja et al., 2003; Zinn et al., 2007). Therefore, because IWA were not considered separately within these studies, there is not much information regarding how executive abilities in aphasia differ from those of individuals with left hemisphere damage and no aphasia. Further, Zinn and colleagues (2007) state that the presence of aphasia in some of their participants is a limitation to the interpretation of their results. Taken together, these findings (Pohjasvaara et al., 2002; Vataja et al., 2003; Zinn et al., 2007) suggest that the executive deficits in IWA should be considered separately from individuals that have suffered left hemisphere damage (no aphasia) as it is possible that IWA experience greater reductions in executive function (Keil & Kaszniak, 2002).

Studying CE function in IWA may be important in fully understanding the attention networks affected in aphasia. Hula and McNeil (2008) hypothesized that “it is the attentional component of WM that can satisfy the conditions under which aphasia is manifested” (p. 173). Moreover, McNeil and colleagues (1991) have hypothesized that attention is needed for language processing abilities, and inefficient allocation of attentional resources for language underlies the linguistic difficulties that IWA experience. The attentional component of the WM system is the CE, and thus, with regards to Hula and McNeil’s hypothesis, studying the CE may lead to a better understanding of how attention is related to linguistic performance in IWA.

Executive Function in Aphasia

Glosser and Goodglass (1990) were some of the earliest researchers to document how IWA perform on tasks that require CE processing (Wisconsin Card Sorting Test, Nonverbal Continuous Performance Test, Graphic Pattern Generation Test, Sequence Generation Test, and Tower of Hanoi). Glosser and Goodglass found that IWA with prerolandic lesions were more likely to experience reductions in executive performance compared to IWA who had lesions in other locations. These results suggest that CE abilities may not be supported by a common attention network in aphasia, as the individuals with more frontally located lesions demonstrated decreased performance on tests of CE abilities when compared to individuals with lesions in other locations. These results suggest that anterior and posterior brain areas may contribute to CE function differently, and that a common attention network might not subserve the CE in IWA. Although both aphasia groups exhibited decreased performance when compared to neurologically intact controls, from Glosser and Goodglass's results alone it appears that CE functioning in different types of aphasia may not be associated with disruptions to a common attention network.

In another study examining an aspect of CE abilities, Murray and colleagues (1997a) compared individuals with frontal and posterior lesions on a dual-task procedure to determine if task performance was correlated with location of damage. According to Baddeley (1996), dual-task processing abilities represent one of the four fractions of the CE, therefore studying dual-task performance provides information regarding the abilities of the CE. Murray et al. hypothesized that damage to the frontal attention network (associated with nonfluent aphasia) would result in greater attention deficits when

compared to damage to the posterior network (associated with fluent aphasia) because frontal areas are traditionally assumed to be responsible for executive control. Results did not reveal significant group differences, and the authors concluded that a “common network” of attention was affected because the participants in each group experienced lesions to different areas of the brain (i.e., frontally or posteriorly located), yet did not perform significantly different. Murray et al. interpreted these findings as indication that damage to the posterior attention system might lead to reduced input to the frontal system, or the inability to maintain proper feedback throughout the frontal-posterior network. According to Murray and colleagues, the disruption in input/feedback appears to affect the “frontal circuit” in individuals with posterior lesions (Murray et al., 1997a), meaning that both groups of IWA performed as though they experienced similar reductions in attentional abilities.

If reductions in posterior activity do indeed affect the abilities of the frontal circuit as Murray and colleagues proposed, then this finding raises questions regarding the findings of Glosser and Goodglass’s study. It has been argued that dual-task processing is carried out by the CE and recruits activity from the anterior cingulate cortex; the frontal, parietal, temporal, and occipital cortices; and subcortical areas (Collette & Van der Linden, 2002). Similarly, both frontal and parietal interactions are necessary for the other aspects of CE function that were assessed by Glosser and Goodglass (i.e., inhibition, set switching, updating; Collette & Van der Linden, 2002). This evidence indicates that the CE’s ability to coordinate dual-task processing, as tested by Murray et al. (1997a) likely relies on multiple neural networks, just as it is thought that other aspects of CE function appear to be subserved by widespread neural networks

(Collette & Van der Linden, 2002). Therefore, if the tasks implemented by Murray et al. and Glosser and Goodglass both rely on widespread neural activations, it is noteworthy that Murray and colleagues did not find group differences while Glosser and Goodglass did. If multiple brain regions contribute to executive function and a common attention network is affected regardless of aphasia type (Murray et al., 1997a), then according to Murray et al.'s conclusions, the CE should have been affected similarly in both aphasia groups assessed in Glosser and Goodglass's study. However, because neither study assessed all four aspects of CE function, no definitive conclusions can be made regarding why Glosser and Goodglass found group differences and Murray et al. did not.

In another study exploring executive abilities in IWA, Purdy (2002) compared IWA to neurologically intact (NI) controls on accuracy, efficiency, and speed when completing a battery of assessments commonly used to test CE functioning. Purdy's assessment of accuracy, efficiency, and speed were based on the rationale that aside from accuracy, *how* an individual performs on executive tasks may provide more information regarding their executive abilities (Lezak, 1995). Purdy compared the performance of IWA to NI controls in order to see the extent that IWA experience reductions in cognitive flexibility when compared to those who have not experienced brain damage. The tasks included the Wisconsin Card Sorting Test (WCST), Porteus Maze (PM; tests planning and plan switching) test, Tower of London (TOL; planning), and the Tower of Hanoi (TOH; planning and inhibition). When compared to the NI controls, IWA demonstrated significantly reduced accuracy on the WCST and TOH, efficiency on the PM and WCST, and decreased speed on the PM, TOL, and WCST. These results suggest that reductions

in CE functioning, as demonstrated by the IWA, might affect qualitative aspects of performance (i.e., *how* IWA complete tasks).

Purdy interpreted that the IWA's reduced performance was related to a "deficit in cognitive flexibility," or that a reduction in WM prevented the participants from completing the task while keeping the rules of the task in mind. Purdy did not obtain measures of the participants' WM spans, and therefore no firm conclusions can be drawn regarding if the participants had reduced WM spans, or how WM span was related to performance on the tasks of executive function. Purdy noted, however, that because there was great variability among the participants, it is possible that the deficits demonstrated were related to the cerebral locations that were affected.

Because lesion location might influence linguistic abilities, and is related to aphasia type, Purdy's conclusion suggests that examining CE performance by aphasia type might provide valuable information regarding how executive abilities are affected in IWA. This conclusion cannot be made firmly because aphasia type or lesion location were not considered in Purdy's analysis, and because of conflicting findings regarding differences in executive abilities within aphasia (Glosser & Goodglass, 1990; Murray et al., 1997a). Regardless, Purdy's results demonstrated not only that IWA have executive deficits, but also that these deficits are associated with reductions in cognitive flexibility and goal-directed behavior. Purdy argues for the importance of considering the role of executive deficits on language abilities in aphasia, as nonlinguistic cognitive processes (attention, sequencing, self-monitoring, and selecting and switching efficacious communication strategies; Ramsberger, 1994) are necessary for communication (Purdy, 2002). Given Purdy's results, it is possible to conclude that the CE in IWA is less

efficient at employing the cognitive processes necessary for language. Subsequently, this inefficiency might partly explain some the linguistic deficits with which an IWA presents.

Fridriksson and colleagues (2006) elaborated on the findings of Purdy (2002) to determine how reduced executive function might be related to functional communication and language impairment. Because Purdy found that IWA demonstrate reduced accuracy and efficiency in executive processes, it is possible that these deficits will manifest in the reduced ability to employ cognitive processes for linguistic performance. Fridriksson et al. (2006) measured executive functioning in IWA by using the WCST and the Color Trails Test (CTT). Performance on these tasks was compared to scores on the ASHA Functional Assessment of Communication Skills for Adults (ASHA-FACS) and a measure of language impairment, the Bedside Evaluation Screening Test-2 (BEST-2). More than half of the individuals were unable to complete the WCST, and the authors concluded that this was likely due to reductions in WM abilities, not because they did not understand the procedures of the WCST². Thus, very limited conclusions can be drawn between WCST performance and functional communication or language impairment. Results, therefore, were based on correlation findings from CTT scores. The authors argued that their results showed that executive abilities in aphasia (measured by the CTT) are related to functional communication (ASHA-FACS), but not predictive of language impairment (BEST-2). Although there was no control group to compare performance, the data suggest that greater performance on the CTT was related to “more intact”

² Fridriksson et al. established comprehension of the task to be getting a string of at least four items correct. The authors reported that there was a 0.004 probability that this would happen by chance. IWA were able to achieve this level of performance, indicating test comprehension.

functional communication abilities. Based on these results, the authors concluded that because the CTT tests sequencing, inhibition, planning, cognitive flexibility, working memory, and sustained and divided attention, these abilities are likely necessary for functional communication in IWA. When considering the results from Purdy's (2002) study, it is possible that the individuals who demonstrated reduced performance were unable to efficiently coordinate the cognitive processing resources needed for functional communication. This finding supports the theory that IWA have a reduction in the processing resources for linguistic abilities (McNeil et al., 1991), and that examination of the CE may provide valuable support to this theory. Despite overall correlation analyses between executive function and functional communication abilities, the authors noted some variability in the relationship between these two constructs in some of the participants. It appeared that executive performance was not indicative of communication abilities for all participants. The characteristics of these participants (e.g., aphasia type) were not mentioned as possible reasons for that finding.

In another study of executive functioning, Proios et al. compared individuals with Broca's, Wernicke's, global, anomic, and "unclassified" aphasia, (as classified by the Greek *Aachen Aphasia Test*; Proios et al., 2006) on performance of the random number generation (RNG) test. Random item generation (RIG) tasks have been shown to require inhibition and updating of WM (Miyake et al., 2000), and are therefore a test of CE abilities. In IWA, decreased performance on the RNG task may be related to the executive functions of inhibition and updating (Proios et al., 2008). Results did not reveal a difference in performance among individuals with different types of aphasia, and showed that all performed "satisfactorily" on the task. That is, although the IWA did

exhibit more stereotyped responses than the controls, they were still able to generate random sequences of numbers. This finding further suggests that these CE abilities (updating items in WM, inhibition) might draw upon a similar network of attention in different types of aphasia.

Implications for Language

The relation of executive and linguistic abilities should be further investigated, considering hypotheses that executive processes are needed for language abilities (Alexander, Benson, & Stuss, 1989). In the literature, there appears to be conflicting evidence regarding how executive impairments are related to linguistic abilities. Glosser and Goodglass (1990) found that performance on executive tasks was related to naming, and Fridriksson and colleagues (2006) demonstrated that impaired executive function was related to decreased functional communication. In contrast, Helm-Estabrooks et al. (1995) found executive performance may not be related to language deficits, because performance on tasks that require CE abilities (i.e., tasks that assessed planning, organization, conceptualization, and execution) was not predictive of language impairment (Helm-Estabrooks, Bayles, Ramage, & Bryant, 1995). Nevertheless, investigation in to the executive abilities of IWA is needed due to the evidence that suggests it is possible that executive abilities do indeed play a role in some of the language and communicative processes of IWA (e.g., Fridriksson et al., 2006; Keil & Kaszniak, 2002; Kolk, 2007; Purdy, 2002). Keil and Kaszniak (2002) argued that executive deficits often co-occur with linguistic deficits, and that these deficits contribute to the limitations one experiences after a loss of language. Accordingly, it appears that

executive performance is needed to plan linguistic outputs, and that deficits in planning may have implication in linguistic deficits (Burgess & Shallice, 1996; Costello & Warrington, 1989; Keil & Kaszniak, 2002). Although the focus of Keil and Kaszniak's review relates to selecting appropriate assessments for executive function in IWA, the authors believe that further understanding of the processes related to executive attention must be further investigated before the construct of executive function can be fully understood. Thus, Keil and Kaszniak have called for study of the executive abilities of IWA in order to better understand executive function.

Purpose

In the current study, in order to determine if CE abilities rely on a common attention system affected in aphasia, individuals with different types of aphasia (fluent and nonfluent) were tested on tasks that isolated the four functions of the CE (i.e., set switching, inhibition, updating items in WM, and dual-task processing). As previously mentioned, IWA have been shown to have decreased attention (Erickson et al., 1996; LaPointe & Erickson, 1991; Laures et al., 2003; McNeil & Kimelman, 1986; McNeil et al., 1991; Murray et al., 1997a, 1997b, 1998; Slanksy & McNeil, 1997; Tseng, McNeil, & Milenkovic, 1993) and decreased WM (Beeson et al., 1993; Caspari et al., 1998; Downey et al., 2004; Friedmann & Gvion, 2003; Laures-Gore et al., 2011; Ronnenberg et al., 1996). If the CE is a factor in attention and WM deficits, then it would be expected that IWA would demonstrate decreased performance on tests of the CE. If IWA do in fact present with reductions in CE abilities, based on past research (Murray et al., 1997a) it can be predicted that this would be due to reductions in a general attention network, and

therefore, both fluent and nonfluent individuals would be affected similarly. In addition, the relationship between CE task performance and aphasia severity, age, and time post-onset of injury may be variables that can further explain CE abilities, as these factors have been shown to be influential in the executive abilities of IWA (Fisk & Sharp, 2004; Pohjasvaara et al., 2002).

Summary and the Present Study

There is growing evidence detailing WM deficits in IWA. There is less evidence concerning the role of the CE itself after disruptions to brain areas involved in attention. The proposed study contributes to literature concerning WM deficits in IWA by exploring CE function and its relationship to the “common” attentional system in individuals with fluent and nonfluent aphasia (Murray et al., 1997a). Because the CE has been considered as the source of some WM deficits in aphasia (Beeson et al., 1993; Ronnberg et al., 1996), the presence of CE deficits in fluent and nonfluent IWA may provide further information regarding WM performance in aphasia. Furthermore, with the CE designated as the “attentional control center” of the WM system (Baddeley, 1996), its functioning is related to the integrity of an intact attention system. To date, however, there appears to be a lack of conclusive evidence regarding CE function in aphasia (Keil & Kaszniak, 2002), and whether it is supported by a common attention network (Glosser & Goodglass, 1990; Murray et al., 1997a; Proios et al., 2008).

Regardless of frontal or posterior damage, Murray et al. (1997a) demonstrated that IWA present with similar attention profiles, suggesting that a common network of attention is affected in aphasia. Furthermore, the CE works to direct attention, relying on

intact connections of multiple brain areas (Baddeley, 1996; Baddeley & Della Sala, 1996; Baddeley & Wilson, 1988). Because fluent aphasia is typically associated with posterior lesions and nonfluent aphasia with anterior lesions, if individuals in the current study perform similarly on tests of the CE, then the abilities of the CE would appear to be related to this common attention network.

In addition to gaining a greater understanding of the attention network, descriptive analyses of age, aphasia, severity, and time post-onset of aphasia, and how these variables may affect CE functioning will provide additional information regarding the integrity of the CE in aphasia. It has been suggested that CE deficits may be predictive of aphasia severity (Fridriksson et al., 2006; Glosser & Goodglass, 1990), and that age and onset of injury may play a role in CE abilities (Fisk & Sharp, 2004; Pohjasvaara et al., 2002). Further research has suggested that the CE may underlie WM and phonological loop impairments in aphasia (Ronnberg et al., 1996). Because WM has been shown to be predictive of linguistic abilities (Caplan & Waters, 1999; Daneman & Carpenter, 1980) and related to aphasia severity (Laures-Gore et al., 2011), it should be expected that a deficit in the CE of the WM system would also contribute a decrease in linguistic performance. A conflict in the literature appears in that Helm-Estabrooks and colleagues (1995) argued that executive performance is not predictive of linguistic deficits, whereas others have demonstrated the possibility that CE deficits are predictive of other communication abilities (i.e., functional communication: Fridriksson et al., 2006; naming: Glosser & Goodglass, 1990). The extent that executive deficits are related to linguistic performance would add support to findings that executive deficits may in fact

be related to communication deficits in IWA (Fridriksson et al., 2006; Glosser & Goodglass, 1990; Keil & Kaszniak, 2002).

In order to determine how the CE of the WM system is affected in aphasia, individuals with fluent and nonfluent aphasia were assessed for performance on tasks that isolate the four “fractions” of CE function. Individual performance was assessed for each experimental task, and qualitative analyses were used to determine if individuals with different types of aphasia exhibited similar CE abilities. In addition, aphasia severity, time post-onset of injury, and age were also evaluated to determine the role of these variables on performance on tests of the CE. Based on previous research (Murray et al., 1997a), one expected finding is that fluent and nonfluent individuals will demonstrate similar reductions in CE abilities.

Hypotheses

It was hypothesized that:

1. There will be no qualitative differences in the performance of fluent and nonfluent individuals on CE tasks. This expected finding would indicate that there is a common network of attention that is disrupted in aphasia.
2. Individuals will demonstrate decreased performance on all tests of CE function, as given the hypothesized unity of the CE fractions (Baddeley, 1996), all aspects of CE performance should be affected in the case of CE damage.

3. CE abilities will be explained by aphasia severity, as it has been argued that executive abilities are related to the language abilities of IWA (Keil & Kaszniak, 2007).
4. Older participants, and those who have a shorter time post-onset of injury will demonstrate greater CE deficits, as age (Fisk and Sharp, 2004) and injury (Pohjasvaara et al., 2002) have been shown to influence executive functioning.

CHAPTER 3

METHOD

A qualitative description of individual performance was used to determine if the CE is related to a common attention network in aphasia. Fluent and nonfluent individuals' performance was evaluated on each task. Additionally, performance was evaluated according to differences in aphasia severity, time post-onset of injury, and age. These factors were used to describe variables that may have influenced task performance by the fluent and nonfluent individuals. Such design provided information regarding CE function in each IWA, and for a descriptive analysis of multiple factors that may influence executive abilities in aphasia, in addition to type of aphasia.

Participants

Five individuals (ages 53-73; mean age = 61.2, SD = 8.25) were recruited for the study. Participants were recruited through speech-language pathologists in area hospitals or clinics or through fliers. All individuals were native English speakers and had experienced a stroke within the past 11 years. Information regarding age, sex, date of birth, education, stroke location, date of stroke, substance use (drugs or alcohol), and medical history (e.g., medicines, history of head injuries, any other chronic illness) was collected. All individuals passed a hearing screening at 45dB bilaterally for 500, 1000, 2000, and 4000 Hz. Each individual's aphasia was assessed based on results from the

Western Aphasia Battery (WAB; Kertesz, 1982). All participants classified as having aphasia according to their WAB scores. See Table 1 for participant characteristics.

M.W. *M.W.*, a 53-year-old male, suffered a left hemisphere cerebrovascular accident (CVA) in 2000. The infarct was localized to the left middle cerebral artery and right frontal cortex. At the time of assessment, *M.W.* reported to taking the following medications: Metoprolol, Lanoxia, Spironolactone, Coumadin, Zocor, Glucotrol, Lasiz, and Lotrel. *M.W.* did not report any substance use (alcohol or drugs). *M.W.* has been receiving speech/language services through the UGA Speech and Hearing Clinic since 2002, with objectives to emphasize reading and spelling. *M.W.*'s highest level of education was a high school diploma. He was not employed at the time of assessment. Results from *M.W.*'s WAB reveal an aphasia quotient (AQ) of 91.1, and a diagnosis of mild anomia.

J.J. *J.J.*, a 61-year-old male, suffered a left hemisphere CVA in 2005 that resulted in mild expressive and receptive language deficits. *J.J.* was medicated for high blood pressure, and list of medications at time of assessment include: Nifedipine ER, Enalapril, and Clonidine. *J.J.* reported negatively to substance use. *J.J.* has received services from the UGA Speech and Hearing Clinic since 2007, with objectives to target naming, expressive language and formulation of sentences. *J.J.* received a high school diploma and worked as a car mechanic prior to his stroke. Results from *J.J.*'s WAB reveal moderate conduction aphasia (AQ = 59.8).

L.W. *L.W.*, a 65-year-old male, suffered a left hemisphere hemorrhagic stroke in 2007. *L.W.* reported to no premorbid chronic illness or dementia. He noted some memory loss following the stroke, but no symptoms of anxiety or depression. *L.W.* was

not enrolled in speech/language therapy at the time of assessment, and his only medication at the time was one Aspirin per day. L.W.'s history of substance use included tobacco and alcohol until 1987. L.W.'s highest level of education completed was a high school GED, and was not employed at the time of assessment. Results from L.W.'s WAB reveals severe Broca's aphasia (AQ = 41).

R.I.R.I., a 73 year old male, suffered a right hemisphere ischemic stroke in 2010 that resulted in global aphasia (R.I. is left-hand dominant). Premorbid history is positive for a heart transplant. R.I. did not report to any other premorbid illnesses (e.g., memory loss, dementia), but reported to post-stroke depression. A list of R.I.'s medications include Cyclosporine, Mag-Ox, Metamucil, Colace, Plavix, Foltx, Cozaar, Atenolol, Finasteride, Amlodipine, Trocor, Pravastatin, Prednisone, Imuran, Hydrochlorozide, and Klonopin. R.I. began receiving speech/language therapy at the UGA Speech and Hearing Clinic in 2010, with goals to improve his expressive speech and language. Results from R.I.'s WAB reveals severe global aphasia (AQ = 42.2).

R.E. R.E., a 54-year-old male, suffered a left hemisphere stroke in 2007. R.E. reported to 30 years of smoking, but did not report any premorbid health concerns (e.g., dementia or other chronic illnesses), nor any post-stroke anxiety or depression. R.E. noted some memory loss since his stroke. Medications included Plavix, Lipitor, and Altace. R.E.'s highest level of education was a college degree; however, he was not employed at time of assessment. R.E. was not enrolled in speech/language treatment at the time of assessment. WAB results reveal moderate Wernicke's aphasia (AQ = 63.6).

Materials

Executive function tests: Tests of executive performance assessed all four aspects of CE function: set switching, inhibition, and updating information in WM, and dual-task processing (Baddeley, 1996). Testing all four aspects of CE function allowed for a complete assessment of CE abilities in aphasia. The tests used for the current study included the Color Trails Test (CTT), Conner's Continuous Performance Test (CPT), a nonverbal N-back task, and a nonlinguistic dual-task procedure modeled from Erickson and colleagues (1996) (all discussed below). Selecting tasks that assess set switching, inhibition, updating, and dual-task abilities allowed for a full assessment of CE function in different types of aphasia, and therefore, the ability to determine the factors that influence CE abilities in aphasia. Detailed rationale for chosen tasks is as follows:

Color Trails Test (CTT; D'Elia, Satz, Uchiyama, & White, 1996). The CTT requires set shifting in order to complete the task. The CTT is sensitive in detecting cerebral dysfunction, tests visual attention, and requires the use of "perceptual tracking and sequencing" (D'Elia et al., 1996). This task was used by Fridriksson et al. (2006), and they found that performance on the CTT was highly correlated with functional communication (as measured by the ASHA-FACS). Test materials for the CTT were two test forms to be completed by each individual. One side of each test form contains a practice test that was used to instruct individuals on the procedures of the CTT, and to assess for their comprehension of the task. The task is a paper and pencil test that required individuals to connect a line from the numbers 1 to 25 in consecutive order. In the first test form, all odd numbers are pink and all even numbers are yellow; and individuals have to draw a line from one to 25. In the second test form, there is a yellow

and a pink version of every number and individuals have to alternate between different colors (yellow and pink) while drawing a line from one to 25. Set switching is tested when individuals are required maintain the sequence of numbers (one to 25), and to alternate between the yellow and pink targets.

Prior to beginning, individuals were required to count (either verbally or by writing, based on their communicative needs) from one to 25 to ensure that any potential errors on the test trials do not occur because of the inability to count. All individuals passed this prerequisite, and proceeded to complete both CTT test forms. Practice tests were administered prior to each CTT in order to provide task instructions and explanations to participants before moving on to the test trials. Participants were instructed to correct any mistakes made in the practice tests (in accordance with CTT test administration guidelines); hence, a 100% accuracy of the practice tests is not required to continue to the test trials.

Test-retest reliability for CTT time variables is $r = .644$ (CTT test 1) and $r = .787$ (CTT test 2), $p < .001$ for both. Validity of the CTT was determined by comparing CTT performance to performance on the Trail Making Test. The TMT, known as a sensitive measure of executive dysfunction, uses numbers and letters to test set switching (Tombaugh, 2004). Using a geriatric sample, it was shown that the CTT and the TMT have a high congruence coefficient ($r_c = 0.89$), meaning the CTT appears to be an appropriate test of set switching and sequencing. Additionally, construct validity for the CTT for a neurological population was determined by comparing performance on the CTT by a neurologically intact control group and a traumatic brain injury group (TBI).

Performance by these two groups was compared, and the TBI group exhibited significantly reduced performance on both the CTT1 and CTT2 ($p < 0.012$ for both tests).

Continuous Performance Test (CPT): Conners' CPT (2000) was designed for the assessment of attention, and specifically, can be used to assess inhibition and impulsivity. The CPT is a computerized program that presents individuals with letters at various interstimulus intervals (ISIs; 1, 2, or 4 seconds). Individuals are told to respond (by key press) to every letter except the letter 'X'. Experiment duration is 15 minutes. Although the CPT provides results for ten different dependent variables, only the variables related to inhibition were assessed. Additionally, hit reaction time (HRT) was inspected to provide information regarding processing speed. Thus dependent variables under investigation for the current study will included commission errors (failure to inhibit a response), omission errors (failure to respond to a target), and HRT. Test retest reliability correlation for these measures is as follows: a) omissions: $r = 0.84, p < .01$; b) commissions: $r = 0.65, p < .01$; c) hit reaction time: $r = 0.55, p < .05$. Construct validity for use of the CPT as a measure of attention deficits was determined by comparing CPT scores to performance on the Child and Adolescent Psychiatric Assessment (CAPA; Angold et al., 1995; Angold & Costello 1995; 2000; Epstein et al., 2003). Results showed that the ADHD symptoms of Inattention, Hyperactivity, Impulsivity, Hyperactivity + Impulsivity were highly correlated ($p < 0.01$ for all) with CPT Commission errors, consistency of reaction time, and d' values (measure of overall attentiveness). CPT omission errors were related ($p < 0.01$) to all domains of the ADHD, except for Inattention.

Construct validity for a neurological clinical group was determined based on results of an epidemiological study that compared CTT performance of a group of adults with diagnosed attention deficit/hyperactivity disorder (ADHD; based on the criteria established by the DSM-IV), as well as a group of Neurological and Non-clinical adults. Validity of assessing for reductions in attention was demonstrated by significantly reduced performance by the ADHD and Neurological groups when compared to the Non-clinical group ($p < 0.001$ for both comparisons). Comparisons between the ADHD and Neurological groups reveal that both performed similarly on commission errors, but that the Neurological group demonstrated significantly more omission errors and longer reaction times ($p < 0.001$). These epidemiological and experimental comparisons are indicative of the validity of the CTT for the assessment of attention deficits.

The CPT was administered with Conner's Continuous Performance Test II Version 5 software on a Dell laptop computer. All stimuli were presented and all responses were coded and stored using this software. Individuals were required to complete a 70-second practice test issued by CPT software prior to initiating the 15-minute experimental task. The practice test facilitated comprehension of task instructions by requiring participants to complete a shortened version of the task prior to progressing to the experimental task. All participants passed the practice test with fewer than 50% omission errors. Participants were able to pass the practice test with no more than two trials

N-Back task: When fractionating the CE, the CE is said to be responsible for updating WM representations (Baddeley, 1996). Nonlinguistic tasks like the *N-back* task isolate the updating function of the CE, as completion of these tasks does not appear to

rely on either slave system (phonological loop or visuospatial sketchpad; Morris & Jones, 1990). Imaging research (for review, see Collette & Van der Linden, 2002) has suggested that N-back tasks isolate the updating function of the CE by requiring participants to use “encoding, temporary maintenance and rehearsal, tracking of serial order, updating and comparison” to evaluate a picture presented in a sequence. Therefore, to isolate the updating function of the CE, an *N*-back task was used. Task presentation was modeled after Wright et al. 2007, and visual stimuli are modeled after Downey et al.’s (2004) “Fruit-back” task. Downey and colleagues (2004) found that IWA who completed their “Fruit-back” task demonstrated reductions in performance as task complexity increased, which they noted appears to be consistent within the *N*-back literature.

In the current task, individuals were tested on a 1-back and 2-back task. Along the lines of Wright et al. (2007), each task (1-Back and 2-Back) consisted of four blocks. Blocks for the 1-back task are as follows:

- Block 1: Practice. 10 items and 2 targets.
- Block 2: Practice. 12 items and 3 targets.
- Block 3: Test. 32 items and 10 targets.
- Block 4: Test. 33 items and 10 targets.

Experimental blocks for the 2-back test were similar in that individuals were given two practice blocks followed by two test blocks. There were the same number of targets presented in the 2-back task (20 total targets in the two test conditions), but the number of non-target items was different. That is, in the 2-back task, Practice Block 1 had 10 items, Practice Block 2 had 15 items, Test Block 1 had 37 items, and Test Block 2

had 39 items. This presentation ratio for the 1-back and 2-back tasks is as follows: 31% of the items were targets in the 1-back task, and 27% were targets in the 2-back task. Wright and colleagues (2007) used these percentages so that the tasks would be valid measures of *N*-back performance, without being long tasks.

The *N*-Back task was presented using SuperLab Pro for Windows software on a Dell laptop computer. For each set, individuals had to respond (by key press) to each item that is the same as the one that occurred either one or two items prior to the current item (as designated by stimulus condition). The use of a 1-back and 2-back design allowed for the ability to determine task performance as WM load increases. Items were presented at a stimulus onset asynchrony of 4000 ms (Wright et al., 2007) with stimulus duration of one and a half seconds. Task comprehension was experimenter defined (see below), and based on performance on the practice test sections. Practice tests were used as training criteria, and only to ensure that participants understood task instructions. Use of practice test for training purposes ensured that participants were not excluded from study due to possible deficiencies with CE updating, which could have surfaced during the practice test. As there are only two or three target items in the practice blocks, individuals were required to accurately respond to at least one of the targets in the practice test to demonstrate comprehension.

Dual Task Processing: A nonlinguistic dual-task modeled after that of Erickson, Goldinger, and LaPointes's (1996) was used to assess the CE's abilities for dual-task processing (i.e., divided attention). Dual-tasks require the simultaneous completion of two different tasks, and to do so, attentional allocation is needed for successful task completion. Dual-tasks are often used to assess attention and resource allocation because

if both tasks compete for a limited amount of attentional resources, performance on one or both tasks will result in reduced accuracy (Banich, 1997). There is a limited pool of attention resources that can be allocated to a task (Kahneman, 1973), and thus, if resource allocation is reduced it would be apparent in a divided attention task. Erickson et al. (1996) demonstrated this to be the case when IWA and neurologically intact (NI) controls completed a task in focused (only identifying a target tone) and divided (identifying a target tone while sorting cards) conditions. The IWA performed similarly to the NI controls in the focused conditions, but performed at significantly lower levels when completing the dual-task. Differences in dual-task performance by the IWA and NI controls demonstrate added support to theories that resource allocation is reduced or inefficient in IWA (Erickson et al., 1996).

In the current dual-task, individuals were required to sort cards (by the color, number, or shape of the items on the cards) and to identify a target tone amongst a series of non-target tones. Tones were created using ToneGen software at the following frequencies: 550, 580, 620, 680, 720, 780, 820, 920, and 980 Hz. The target tone is a harmonic comprised of frequencies at 500, 1000, 1500, 2000, 2500, and 3000 Hz. A Dell Laptop with Super Lab Pro for Windows was used to present the tones. The dependent variables in question were the percent of tones identified correctly and percent of cards sorted correctly. Individuals were required to pass a hearing screening at 45dB bilaterally at 500, 1000, 2000, and 4000 Hz prior to this task to rule out poor hearing acuity as a factor in performance.

A total of 120 tones (500 msec duration) were presented randomly every 2500 msec at a ratio of 1 to 6 target to non-target tones. Task duration was 10 minutes. In

order to ensure that individuals understood task requirements, individuals were required to complete a practice task (one minute in duration) prior to beginning the full dual-task. Tones were presented at the same ratio (1 target to 6 non-targets), and individuals were required to sort cards by the predetermined method (e.g., color, number, or shape of items on the cards). Experimenter-defined task comprehension was considered the identification of at least one target tone and sorting at least five cards correctly.

Western Aphasia Battery (WAB): The WAB was administered to the IWA to determine the type and severity of aphasia. WAB scores have been shown to be correlated with measures of WM, as measured by the digit span task (Laures-Gore et al., 2011) and therefore the WAB was used to determine the role of aphasia severity on executive abilities. The WAB assessment is composed of eight subtests, and individuals were required to complete 32 short tasks over the course of these eight subtests. Within these tasks, language content, fluency, auditory comprehension, repetition, naming, reading, writing and calculation were assessed.

Test-retest reliability for the WAB (based on adults with little recovery over a one-year time period) is $r = .99$, $p < .01$. Construct validity was based on WAB scores for IWA, neurologically intact controls, and a group of individuals with diffuse or subcortical brain damage. From this sample, a valid diagnosis of aphasia can be given for individuals with an AQ less than 93.8 (Kertesz, 1982).

Procedure

Testing took place at a location convenient for each participant (i.e., home or clinic setting). Efforts were taken to minimize distractions and extraneous noise. For

example, in some cases, caretakers requested to observe assessments, but they were instructed to remain quiet and refrain from interacting with the participant during each assessment.

After individuals were identified and qualified for inclusion (listed above), the purpose of the study was explained, and written consent was obtained. After consenting to participating in the study, all individuals were assessed for performance on the aforementioned tasks. The procedures of each experimental task were explained prior to each task. Individuals were assigned a presentation order (A, B, C, or D) for the CE tasks to ensure that all tasks were balanced among participants. Task presentation by order was as follows:

- Order A: CTT, CPT, N-Back task, and Dual-task
- Order B: CPT, Dual-task, CTT, N-Back task
- Order C: Dual-task, N-Back task, CPT, CTT
- Order D: N-Back task, CTT, Dual-task, CPT

Because of the length of WAB administration (30-45 minutes), and the fact that it is considered a stable measure of language abilities even if given when individuals are fatigued, it was administered last to all participants so that it did not induce fatigue effects that may have influenced performance on the CE tasks. Individuals were offered and granted breaks in between each assessment to avoid fatigue.

All assessments were videotaped, and video camera placement was arranged according to the assessment. That is, arrangements were as follows: 1) dual-task: video camera was placed diagonally behind the participant in order to record responses to the tone identification and card sorting. 2) CTT: video camera was focused on the CTT

record form, as scoring was based on participants' to draw lines from target to target. 3 and 4) CPT and N-Back: video camera was placed diagonally behind the participant so that responses and participant behavior were recorded. Because all CPT and N-Back scoring is done through either CPT software or based on responses recorded from SuperLab, video recording was used for qualitative purposes (i.e., if the participant got distracted in the middle of the task). 5) WAB: video camera was placed in front of the participant in order to record both the participant and WAB stimuli. Because individuals were instructed to write or manipulate stimuli, the video camera was placed to ensure that all aspects of the required behavior could be recorded. A research assistant was available at all assessments to help with camera placement and with assessment set-up. This assistant was not involved in assessment administration.

Data Analysis

Each individual's performance was assessed for all four experimental tasks. For the CTT, the primary measures of importance were number of errors (color and number), prompts to correct responses, and time to complete the task. In addition, participant CTT scores were compared to the CTT standardization sample to provide additional information regarding how participants performed relative to individuals in their age range. Primary measures of importance for the CPT were hit reaction time (HRT), total number of omission and commission errors. Important measures for the N-Back task were number of target items omitted, as well as commission errors. For the dual-task, percent accuracy for tone identification, percent accuracy for card sorting, rate of card sorting, and reaction time (RT) to the tone identification portions of the task were the

primary measures under investigation. Performance on each CE task was evaluated in order to compare fluent versus nonfluent aphasia, as well as the influence of aphasia severity. Additionally, the time post-onset of injury and participant age were analyzed due to the potential impact on CE performance (Fisk & Sharp, 2004; Pohjasvaara et al., 2002).

CHAPTER 4

RESULTS

Each individual's performance was inspected for each experimental task to examine CE abilities of each participant, and qualitative assessment of the group's scores as a whole was conducted to determine the presence of general trends in performance. Although individual variability within each task was noted, there were some trends in participant performance.

Results by Experimental Task

Color Trails Test (CTT). CTT test scores were analyzed for time taken to complete the task (in seconds), total number of errors, prompts, and performance compared to the test standardization sample (standard score and percentile rank). In accord with the CTT scoring guidelines, performance was considered atypical compared to the standardization sample when scores (time for task completion, prompts, or errors) fell below one standard deviation of normal performance. Each portion of the CTT was assessed (CTT1 and CTT2). See Table 2 for CTT performance across participants.

Performance on the CTT was variable, as reflected by participant standard scores and percentile rank. Comparisons of CTT1 and CTT2 performance indicate that participants had difficulty when the executive function of set switching was required, as only the CTT2 required participants to connect lines by selecting targets of alternating colors. Overall performance appears to be affected by age and/or severity, rather than

time post-onset, or aphasia type. The oldest and most severe participants, J.J. (age 61), L.W. (age 65), and R.I. (age 73) demonstrated poorer performance when compared to M.W. (age 53) or R.E. (age 54). Yet, it is not possible to determine which factor (age or aphasia severity) contributed most to a CE deficit with set switching.

Individuals in the CTT Standardization Sample between the ages of 60-69 completed the CTT1 with a mean time of 40.35 seconds ($SD=8.36$), and for the 70-79 year old age group, in a mean time of 53.91 ($SD= 22.63$). J.J., L.W., and R.I.'s completion times for the CTT1 were atypical for their age range, indicating performance that was comparatively worse than a neurologically intact standardization sample. Although J.J., L.W., and R.I. demonstrated poor performance on the CTT1 with regard to time to complete the task, their errors and number of prompts required fell within normal limits. Inspection of CTT2 standard scores indicates that J.J., L.W., and R.I. also demonstrated poor performance for the CTT2 test. J.J. and L.W. were unable to complete the task within the allotted time (240 seconds), and R.I.'s completion time was atypical when compared to the neurologically intact standardization sample. That is, mean task completion for individuals in the 70-79 age range is 105.5 ($SD=32.34$), and R.I. completed the task in 217 seconds. Although J.J., L.W., and R.I. required more prompts than the standardization sample to complete the task (between 3-5 prompts each), none of the three older participants demonstrated any errors with either number or color, indicating error scores within normal limits.

Inspection of the two younger participants' (M.W. and R.E.) scores also indicates performance that was not typical for individuals in their age range. Average time to complete the CTT1 for Caucasian individuals in the 50-59 year age range was 35.81

(SD=13.02). Because M.W. is an African American male, and a standardization sample for African Americans over 50 is not available, his scores were inspected according to age and education level. Average CTT1 performance for an individual between 45-59 years old with 12 years of education was 43.91 (SD=16.73). With these time scores considered, both R.I. and M.W.'s CTT1 performance was poor when compared to the neurologically intact standardization sample. However, inspection of CTT2 time scores for M.W. reveals that his performance was within normal limits for his comparison group. That is, average time completion for the CTT2 for individuals with 12 years of education was 101.43 (SD=31.32), and M.W. completed the CTT2 in 120.51 seconds, indicating that his score fell within average range. Although M.W.'s CTT2 time score was within normal limits, his number and color errors (two each) were not typical for his standardization sample. R.E.'s performance was not within normal limits for his age, as individuals in the 50-59 age range completed the CTT2 with an average time of 72.76 seconds (SD = 21.50), and R.E. completed the CTT2 in 149 seconds. Additionally, although R.E. required more prompts than the standardization sample, he did not make any errors on the task. See Figure 1 for CTT scores, standard scores, and percentile ranks for each participant.

In terms of time post-onset, J.J. and L.W. were both three years post-stroke, and R.I. was seven months post-stroke. These three individuals were either unable to complete the CTT2 in the time allotted (J.J. and L.W.), or performed below the first percentile of the standardization sample (R.I.). However, R.E., also three years post-stroke, and M.W., 10 years post-stroke, were able to complete both CTT tasks. Both M.W. and R.E. were the youngest participants (ages 54 and 53, respectively), and M.W.,

the mildest participant, achieved a higher percentile rank than R.E. In terms of aphasia type, although the two nonfluent individuals (R.I. and L.W.) demonstrated poor performance, J.J. (fluent aphasia), also demonstrated difficulties with the CTT, indicating that type of aphasia does not appear to be a factor in performance.

Inspection of standard scores for all participants indicates that when the executive function of set switching was required (CTT2), performance decreased. This pattern was consistent across participants, although some participants completed the CTT2 within the allotted time (M.W., R.I., R.E.), while others did not (L.W. and J.J.). These findings indicate that fluent or nonfluent type of aphasia may not predict difficulties with the CE function of set switching. Rather, the factors of age and aphasia severity may be more indicative of deficits in set switching within this population. Age is an influential factor for successful CTT completion (D'Elia et al., 1996), which was found with the current participants. However, age was a factor in the current study as the three oldest participants (J.J., L.W., and R.I.) performed below those in the standardization sample. Because these individuals were also the three most severe individuals, it is possible that aphasia severity was a concomitant to age, leading to a decline in the set switching abilities of the CE.

Continuous Performance Test (CPT). The CPT variables assessed were number of omission errors, commission errors, and hit reaction time. The number of omission errors ranged from zero (R.E.) to 26 (M.W.), with an average of 15 omission errors (SD = 9.63). Age, time post onset, aphasia type, and aphasia severity did not seem to explain number of omission errors. The youngest participant, with the longest time post onset, and mildest form of aphasia (M.W.) made the most omission errors (N= 26). All participants

(except for R.E.) made errors, but there were no clear error patterns based on the variables assessed when observing omission errors. This result indicates that fluent or nonfluent type of aphasia did not appear to predict performance in addition to any of the other variables assessed. Furthermore, all participants, except for R.E., demonstrated “markedly atypical” performance (according to the CPT) for omissions when percentile ranks were compared to the CPT standardization sample.

Commission errors ranged from five (R.E.) to 20 (L.W.), and averaged 12.2 commission errors for all participants ($SD = 6.5$). Although L.W., the most severe participant, made the most commission errors, there is no other evident pattern of performance, similar to findings for the omission errors. When compared to the CPT standardization sample, L.W. was the only participant to fall within the “mildly atypical” range. All other participants were within normal limits.

Inspection of reaction time reveals that L.W. demonstrated the slowest processing speed, in addition to the highest number of commission errors. The participants with the two lowest reaction times were J.J. and M.W. (453.84 msec and 481.36 msec, respectively). It is possible that J.J. and M.W. sacrificed accuracy for speed, as these two participants demonstrated high numbers of omission and commission errors.

Overall, the lack of a clear pattern of performance among the five participants indicates that fluent or nonfluent type of aphasia was not a factor in performance on a task requiring the CE function of inhibition. In addition, age, time post-onset, and aphasia severity were not predictive of performance for the individuals in the current study when tested on the CPT.

N-Back Task. Performance on the N-Back task was assessed for omission and commission errors as task difficulty increased. Because the manipulation of information is essential to the definition of WM updating (Miyake et al., 2000), results from the 2-Back task will be discussed, as this was the most complex portion of the task that required the most information processing. Overall, participants tended to make more errors (omission and commission) when task difficulty increased (from 0-Back to 2-Back), and participants tended to make more omission errors than commission errors. The two mildest participants (M.W. and R.E.) performed the best, with the highest number of responses to correct stimuli (M.W.: 20 correct, R.E.: 15 correct) and the fewest omissions (nine and five, respectively). Although the other participants (J.J., R.I., and L.W.) demonstrated few commission errors (less than 6 each), they omitted a considerable number of stimuli (average = 17.67, range = 15-19), suggesting that participants did not make frequent responses to task stimuli. Fluent or nonfluent aphasia did not appear to be predictive of performance, as both fluent and nonfluent individuals demonstrated difficulty with this task. Instead, performance on the 2-Back task suggests that age and/or aphasia severity were most predictive of performance. That is, the participants who made the most omission errors on the 2-Back task (J.J., R.I., and L.W.) were the three oldest participants, but also those with the most severe forms of aphasia. Therefore, it is difficult to determine the degree that either factor played in the CE deficits of these participants. See Figure 3 for N-Back task performance.

Dual-Task. Percent of cards sorted correctly and percent of tones identified correctly were assessed to determine dual-task performance. There was variability amongst participants on the tone identification portion of the dual-task, with only two

participants performing with greater than 90% accuracy. However, card sorting accuracy was similar across participants, as demonstrated by card sorting accuracy greater than 95% for all individuals. In addition, rate of cards sorted (number of cards sorted per minute), did not appear to differ significantly across participants, indicating similar speed of card sorting for all participants. See Figure 3 for task performance.

Aphasia type (fluent and nonfluent) appeared to be influential in task performance, in addition to aphasia severity. In particular, the two participants who demonstrated reductions in accuracy of tone identification (R.I. and L.W.) were the most severe (WAB AQ Scores were 42.2 and 41, respectively). Both participants had forms of nonfluent aphasia, R.I. presenting with global aphasia and L.W. with Broca's aphasia. Additionally, R.I. and L.W. demonstrated to greatest RTs to the tone identification portion of the task, indicating reduced processing speed for this portion of the task, as their card sorting rate did not appear to differ greatly from that of the other participants. Although R.I. and L.W. were the oldest participants (R.I. was 73 and L.W. 65), age does not seem to be a factor in performance, as L.W. and J.J. (age 61) are similar in age, yet J.J. performed better than L.W. Further, time post onset of stroke does not seem to be a primary contributing factor to performance. That is, R.I. demonstrated poor performance and was the only individual that participated within a year of his stroke (time post-onset was 7 months). However, L.W., J.J., and R.E. were all three years post-onset, and of the three, L.W. performed significantly worse than either J.J. or R.E.

Inspection of the M.W.'s performance (the mildest participant) revealed that although he performed at 83% on the tone identification portion of the task, he committed five false-positive errors. Therefore, even though M.W. was the mildest participant and

the one who was the furthest time post-onset at the time of testing (10 years), it appears that difficulties with divided attention may be persistent in IWA.

Assessment of task performance itself reveals that overall, participants tended to allocate greater amounts of attentional resources to the card-sorting portion of the task, resulting in reduced accuracy on tone identification. Additionally, false-positive errors (M.W. and L.W.) provide further evidence for difficulty allocating attentional resources to both portions of the task, with card sorting receiving greater cognitive resources.

Within-Subjects Comparisons.

M.W. M.W.'s greatest weaknesses were CPT and dual-task performance (inhibition and dual-task processing). M.W. omitted the most CPT stimuli (N=26, 8.05%) and made the second most commission errors (N = 18. 50%) when compared to the other participants. Although M.W.'s commission errors were considered to be within normal limits when compared to the CPT standardization sample, his omission errors were considered "markedly atypical" with regard to CPT scoring. An order effect does not appear to explain his performance on the CPT, as this was the second task he completed. Inspection of dual-task performance reveals the highest number of false positive errors (5) and target tone identification at 83%. Because the dual-task was the last task M.W. completed, it is possible that reduced performance was related to fatigue. Performance on the CTT and N-Back tasks were relative strengths for M.W. (set switching and WM updating), as he was able to complete the CTT within the allotted time period, and obtained the highest number of correct responses on the 2-Back task. Therefore, M.W.'s performance is indicative of difficulties with inhibition and dual-task processing.

J.J. *J.J.*'s overall performance suggests the greatest difficulties with the N-Back task and the CPT (WM updating and inhibition). *J.J.* made a correct response to only one of the 2-Back target stimuli, omitting 19, and making six commission errors. *J.J.*'s high rate of commission errors suggests that some of his omissions cannot be explained as failure to respond; rather, he was responding to incorrect targets. Because the N-Back task was the last task completed, it is possible that *J.J.*'s performance on the updating portion of the assessment was related to fatigue. CPT performance reveals "markedly atypical" performance on omission errors when compared to the standardization sample, as he omitted fourteen targets. The CPT was *J.J.*'s first task completed; therefore, performance is not likely related to an order effect. Performance on the two remaining tasks (CTT and dual-task; set switching and dual-task processing) were relative strengths for *J.J.* That is, he did not demonstrate any color or number errors on the CTT, and performed with above 90% accuracy on both the card sorting and tone identification portions of the dual-task. Therefore, it appears that *J.J.* had the greatest difficulties with WM updating and inhibition.

R.E. *R.E.* demonstrated relatively good performance on the dual-task, CPT, and CTT when compared to the other participants. Performance accuracy on the dual-task was 100% for both the card sorting and tone identification portions of the task. *R.E.* did not omit any stimuli on the CPT, and made the fewest number of commission errors (five) when compared to the other participants. When compared to the standardization sample, *R.E.*'s performance was categorized as "good," but with reaction time as "atypically slow." *R.E.* did not make any errors on the CTT. Although *R.E.* made the fewest number of commission errors on the 2-Back task, the number of responses to

correct stimuli was 15, second to M.W. However, because the N-Back task was the second task completed, it does not appear that an order effect is a likely explanation for his performance on this task. Overall, R.E.'s performance indicates relatively intact CE functioning, with the possibility of a mild weakness with working memory updating.

L.W. L.W., the most severe participant, demonstrated difficulties across all four experimental tasks. Although his card sorting accuracy was 100%, L.W. demonstrated the lowest accuracy of tone identification for the dual-task (33% of targets identified). L.W. was unable to complete the CTT, resulting in 17 color and number errors. Although L.W. did not demonstrate the poorest performance on the CPT and N-Back tasks, he demonstrated difficulty on these tasks. CPT performance reveals that although his commission errors were within normal limits when compared to the standardization sample, he made the second highest number of omission errors (19), which was considered "markedly atypical." Additionally, his reaction time was considered "atypically slow." 2-Back performance indicates five correct responses to target stimuli, but fifteen omission errors. Because L.W. demonstrated difficulties with all four tasks, the effect that order may have influenced task performance is not readily noticeable, as his he demonstrated difficulty with CE task performance from the beginning of the study. Overall, L.W.'s performance indicates difficulties with all four aspects of CE function (WM updating, set switching, inhibition, and dual-task processing).

R.I. R.I.'s performance indicates the greatest difficulties with the dual-task, the 2-Back task, and the CPT. Although card sorting accuracy was 100%, R.I. identified only 51.67% of target tones. Inspection of 2-Back performance reveals that R.I. identified the fewest number of target stimuli; only responding to one correct target. R.I. made two

commission errors on the 2-Back task, indicating that many omissions were related to lack of responding. Similar to the other participants, R.I.'s performance on the CPT was "markedly atypical" for omissions. Performance on the CTT reveals no errors for color or number, indicating relatively intact performance on the CTT. R.I. was the only individual who completed the study across two different appointment times due to time limitations. Therefore, an order effect may not completely explain his performance. Because the dual-task and CPT were completed at different appointment times than the N-Back and CTT, difficulties with these CE fractions may better explain his performance, rather than fatigue or an order effect. Overall, R.I. appears to demonstrate difficulties with working memory updating, dual-task processing, and inhibition.

Overall trends in the data appear to indicate the presence of CE deficits in aphasia; however, the degree of deficit and the extent that all four fractions were affected was variable. Although each participant experienced different deficits, the most common fractions affected were inhibition and WM updating. See Table 3 for a chart of each participant's performance for comparative purposes. Due to the limited sample size, it is difficult to determine whether this pattern of deficits is common in IWA. In addition, the order that tasks were presented may have influenced this finding. Although order effects were possible influential factors, order effects may not fully explain performance, as all participants demonstrated difficulty on tasks that were presented either first or second in the assessment battery. For the participants who demonstrated difficulties with tasks presented third and fourth, it is possible that an order effect compounded a CE deficit to lead to reduced performance. It appeared that age and aphasia severity were two participant factors that can further explain CE function in aphasia. Nevertheless, because

the most severe participants were also the oldest (L.W., J.J., R.I), it is difficult to isolate the factors of age and aphasia severity, and the role that each of these factors played in CE performance of the individuals in the current study.

CHAPTER 5

DISCUSSION

The purpose of the current study was to assess the presence of CE deficits in IWA, to determine whether CE function relies on a common network of attention resources in individuals with fluent and nonfluent aphasia, and to determine factors that influence CE abilities in this population. It was hypothesized that: 1) Fluent and nonfluent individuals would experience similar deficits to the CE, indicating that a common network of attention is disrupted in aphasia (Murray et al., 1997a); 2) Individuals would demonstrate decreased performance on all tasks of CE function, as all aspects of CE performance should be affected in the case of CE damage (Baddeley, 1996); 3) CE abilities would be explained by aphasia severity, as it has been argued that executive abilities are related to the language abilities of IWA (Keil & Kaszniak, 2007); and 4) Older participants, and those with a shorter time post-onset of injury would experience greater CE deficits (Fisk & Sharp, 2004; Pohjasvaara et al., 2002).

The current study documented the presence of CE deficits in individuals with different types of aphasia. However, aphasia type did not seem to be a factor in performance on the CTT, CPT, and N-Back tasks. This finding indicates a common attention network may support cognitive processes for these fractions. It has been suggested that CE function relies on a network of prefrontal and posterior cortical areas (Garavan, Ross, Li, & Stein, 2000; Hartley & Speer, 2000). Results from the current study partially support findings that CE functioning relies on an interconnected network

for the CE fractions of inhibition, set switching, and WM updating are assessed, as participants tended to demonstrate executive deficits despite aphasia type on the tasks that assessed these fractions. This finding suggests that regardless of type of aphasia, CE deficits are possible for these three fractions. However, this did not appear to be the case for performance on the dual-task.

Different patterns in the data were evident with regard to the dual-task. In addition to aphasia severity and age, aphasia type was influential when inspecting participant performance on the dual-task, similar to the findings of Marshall and Basilakos (2010). However, given that the nonfluent individuals performed better on the card sorting portion of the task, the extent that they were completing a dual-task is debatable. Performance for card sorting may indicate that the nonfluent participants were allocating a greater amount of attentional resources to this portion of the task. It is possible that R.I. and L.W. could not allocate attentional resources to both tasks and focused their attentional efforts on a portion of the task that was therefore easier for them. Regardless, difficulties with attentional allocation to both portions of a dual-task may indicate a deficit with dual-task performance specific to the nonfluent individuals.

Miyake et al. (2000) found that performance on a dual-task was not related to performance on any other executive function tasks. The researchers suggested that based on their findings, dual-task processing requires a distinct CE ability that is separable from the other fractions and likely recruits different brain regions than the other CE functions. Results from the current study support Miyake et al.'s findings, as dual-task processing was the only fraction assessed where the nonfluent individuals' performance was

relatively poor when compared to that of the fluent individuals. Because those with nonfluent aphasia (typically anterior damage) demonstrated decreased performance when compared to those with fluent aphasia (typically posterior damage), it is possible that some CE fractions may demand more frontal input than others. Because type of aphasia appeared to be influential with the dual-task, and none of the other three fractions assessed (WM updating, set switching, and inhibition), type of aphasia may be an influential factor to CE performance depending on the fraction assessed.

The hypothesis that all four fractions would be affected in the case of a CE deficit (Hypothesis 2) was not supported in the current study. Not all individuals experienced deficits to all four fractions (e.g., R.E., M.W.) indicating that isolated damage to certain fractions is possible. Baddeley (1996) stated that the CE relies on an interconnected network of brain regions, and suggested that the fractions of the CE are unitary in nature. Furthermore, he stated that brain damage, regardless of location, could lead to a CE deficit, and given the unitary nature of the CE, reduced abilities of the four fractions that the CE controls. Because CE fractions were affected differently in each of the participants, it does not appear that all four fractions are necessarily affected in the case of CE damage.

In contrast to Baddeley's belief that the CE fractions were unitary in nature (1996), other researchers (Godefroy, Cabaret, Petit-Chenal, Pruvo, & Rousseaux, 1999; Shallice, 1988) have suggested that the fractions of the CE are nonunitary, and that each fraction can be affected differently. For example, an individual may have difficulties with task shifting, but not inhibition, and vice versa. Miyake et al. (2000) used a latent variable

analysis to show that each executive fraction is separable; however, that there are relations between fractions. In the study, Miyake et al. assessed neurologically intact young adults on nine tasks though to isolate the CE as a whole, in order to determine if some tasks tapped the three domains of CE function (task shifting, inhibition, and WM updating) more than others.³ Results of the study showed that the three CE domains can clearly be distinguished based on task performance. Additionally, because some of the nine tasks were more predictive of performance on some of the CE fractions than the others, Miyake et al. concluded that there is separation between CE fractions. In the current study, the type of deficits, and whether all four fractions were affected, was not consistent among the participants in the study, providing further evidence for the nonunitary nature of the CE.

When considering CE deficits and aphasia severity, and the role of the factors of age and time post-onset of injury (Hypotheses 3 and 4), overall performance indicates that the factors of age and aphasia severity may be predictive of task performance on the CTT (set switching) and N-Back tasks (updating). The extent that each variable, or the combination of these two variables, influenced performance is uncertain due to age and severity confounds. The most severe participants were also the oldest participants (J.J., R.I., L.W.). Therefore, it is indefinite the extent to which age alone, aphasia severity alone, and/or the combination of these two variables influenced performance.

Inspections of individual performance reveal similarities across tasks for the severe individuals, but not for the milder individuals. Those who performed poorly and

³ Miyake et al. did not assess dual-task processing as they found that its correlation with the other domains was relatively low; therefore, it was omitted from analyses.

were the most severe tended to perform poorly across experimental tasks. R.E., the youngest participant, tended to demonstrate the best performance across tasks, while L.W. and R.I., the oldest and most severe participants, tended to perform with the least accuracy across tasks. However, M.W., the mildest participant, demonstrated variable performance across tasks, further supporting research suggesting that different fractions of the CE may be affected differently in IWA (Miyake et al., 2000). Participant performance in the current study suggests that for IWA, severity seems to play a role in the extent that all four fractions are assessed, and the degree of CE deficit. Overall, each participant, regardless of aphasia type, experienced some CE dysfunction, indicating the possibility of CE dysfunction in IWA. In addition, in the case of CE deficits across fractions, it appears that there may be varying degrees of deficit severity. With the limited sample size in the current study, few definitive claims regarding the CE in IWA can be made.

It has been suggested that CE function declines with age, as does the degree that each fraction is related (Fisk & Warr, 1996; Mittenberg, Seidenberg, O'Leary, DeGuillo, 1989; Van der Linden, Beerten, & Pesenti, 1998). Fisk & Warr (1996) and Van der Linden et al. (1998) found age-related changes in a random letter generation task (thought to rely on CE function), and Mittenberg et al. (1989) suggested age-related declines on WCST and Stroop tests (i.e., age-related updating and inhibition deficits). Age was a likely factor in L.W.'s performance, as he was the oldest participant. However, because M.W., who demonstrated difficulties with dual-task processing and inhibition, was the youngest participant, it appears that a factor other than aging affected his CE function of inhibition. Inspection of M.W. and L.W.'s performance on the CPT and dual-task

suggests that the CE function of inhibition may be affected by different variables, in addition to aging.

With respect to a common attention network that is affected in aphasia (Murray et al., 1997a), it appears that there might be a common network when considering attention systems that support WM updating, inhibition, and set switching. However, dual-task processing appears to be supported by differing attention networks (Marshall & Basilakos, 2010) as dual-task difficulties were most pronounced in the nonfluent participants when compared to the fluent participants. . Similar deficits were found in fluent and nonfluent individuals when WM updating, inhibition, and set switching were assessed. Aphasia type appeared to be a factor in distinguishing differences in performance when inspecting the results of the dual-task. Because of participant variability with aphasia severity, age, and time post-onset of injury, results are difficult to compare with other studies that assessed attention among individuals with different types of aphasia. Glosser and Goodglass (1990) found that IWA with more frontally located lesions performed significantly worse on executive tasks than when compared to those with more posterior lesions. Murray et al. (1997a) did not find any significant performance differences when lesion location was compared. Although not discussed as a factor to have influenced the findings of either study, it is possible that additional participant characteristics (age, aphasia severity) affected the results. Results from the current study suggest that performance may be affected by participant characteristics (mostly in terms of aphasia severity and age), and it is possible that these variables affect each fraction differently. Because Murray et al. only tested participants on a dual-task procedure, and because it has been suggested that dual-task procedures are not as closely

related to other CE fractions (Miyake et al., 2000), it is possible that had Murray tested individuals on other tasks of the CE, that group differences may have been evident. Glosser and Goodglass' result of differences based on aphasia type may have occurred because they tested participants on CE tasks that required the CE as a whole, rather than testing each fraction individually.

According to Stuss, the frontal lobes are not synonymous with CE function. Stuss argues that the CE is only one aspect of the frontal lobes, and that it shares connections with most of the entirety of the brain. These connections allow it to integrate information throughout the brain, especially when a task becomes demanding. Therefore, the interconnectivity of brain regions implicates a general network of attention, and that the CE is necessary to direct information through this general network. However, because researchers have shown the nonunitary nature of each CE fraction (Godefroy et al., 1999; Miyake et al., 2000), results of the current study suggest that although CE function may require an interconnected network of brain regions, different types of brain damage may lead to differences in the abilities of each CE fraction, the degree of damage, and the extent that interconnected fronto-parietal networks can support certain cognitive processes.

Given the increasing evidence suggesting post-stroke executive deficits, and the impact of these deficits on linguistic abilities, executive abilities should be routinely screened and/or evaluated during aphasia assessments. Due to the presence of CE deficits in each of the participants, and that other factors (age, aphasia severity) are important with regard to CE abilities, clinicians should consider the role of executive

functioning during the rehabilitation of IWA. Because even the milder participants demonstrated CE deficits, clinicians should be mindful that working memory and CE deficits may be present when patients are challenged, or attention is sufficiently taxed. Because intact executive abilities may facilitate treatment gains (Nicholas et al., 2005) and generalization of treatment objectives outside the therapy setting (Purdy, 1992, 2002), assessing and treating executive deficits may increase the efficacy of traditional aphasia assessment. Future studies could explore the role of CE functioning during aphasia rehabilitation.

Nicholas, Sinotte, and Helm-Estabrooks (2005) suggested that CE abilities may differentiate individuals with severe aphasia who regain linguistic abilities, from those who do not (Nicholas, Sinotte, & Helm-Estabrooks, 2005; Van Mourik, Verschaeve, Boon, Paquier, & Van Harskamp, 1992). Nicholas et al. believe that for an individual with aphasia, reliance on executive abilities (planning, monitoring, updating and adjusting verbal input and outputs) is necessary for successful communicative exchanges. When targeting language objectives, Nicholas and colleagues (2005) found that patients with “more intact” executive function abilities demonstrated superior performance when learning to use methods of alternative communication (C-Speak). According to the researchers, depending on a patient’s therapy objectives, training executive function skills may facilitate progress with improving linguistic abilities. Nicholas et al. suggested that because executive abilities were more predictive of success with treatment gains using augmentative communication devices when compared to aphasia severity or semantic knowledge, that clinicians should routinely assess executive abilities when determining a patient’s candidacy for communication devices. In addition, Purdy (1992, 2002)

suggested that intact executive abilities underlie generalization of treatment gains. Purdy found that those with reduced executive functioning did not implement treatment strategies, even though patients showed mastery of treatment objectives in the clinical setting. Results from both Purdy's and Nicholas et al.'s studies indicate the importance of executive abilities in aphasia rehabilitation.

In view of growing support of attention and WM deficits in IWA, and the small number of participants assessed in the current study, further research regarding the CE and its role in language processing abilities is necessary. It has been suggested that attention, and specifically the WM system (Caspari et al., 1998), play a role in the language deficits of IWA; therefore, it is possible that consideration of these variables may lead to greater gains in aphasia treatment (Murray, 2000; 2002). Although the current study suggests CE deficits in IWA, it is not clear how CE deficits are related to different types of aphasia, severity, or other factors, such as age and time post-onset of injury. More research with a larger sample size and greater control for age and aphasia severity is necessary in order to provide more information regarding CE abilities in this population. Additionally, research regarding CE deficits in post-stroke individuals (without aphasia) will be informative in explaining factors that influence the type of CE deficit, and how CE deficits may manifest in terms of cognitive processes.

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Table 1

Participant Characteristics

<i>Participant</i>	<i>Age</i>	<i>Aphasia Type</i>	<i>WAB AQ</i>	<i>Severity</i>	<i>Time Post-Onset of Injury</i>
M.W.	53	Anomia	91.1	Mild	10 years
J.J.	61	Conduction	59.8	Moderate	3 years
L.W.	65	Broca's	41	Severe	3 years
R.I.	73	Global	42.2	Severe	7 months
R.E.	54	Wernicke's	63.6	Moderate	3 years

Table 2

Color Trails Test (CTT) performance for all participants

Participant	CTT1 Time (seconds)	CTT1 Prompts	CTT1 Errors	CTT1 Standard Score	CTT1 Percentile Rank
M.W.	60.05	0	2	86	18
J.J.	120.08	1	0	61	<1
L.W.	182	1	1	<1	<55
R.I.	111	0	0	61	<1
R.E.	61	0	0	78	7

Participant	CTT2 Time (seconds)	CTT2 Prompts	CTT2 Errors	CTT2 Standard Score	CTT2 Percentile Rank
M.W.	120.51	0	2 number; 2 color	91	27
J.J.	N/A*	3	0	N/A*	N/A*
L.W.	N/A*	5	0	N/A*	N/A*
R.I.	217	3	0	61	<1
R.E.	149	2	0	66	<1

*Data not available because participant was unable to complete the task in the allotted time. Because task was not completed, performance could not be compared to the standardization sample.

Note: Circled data fall outside of normal limits when compared to the CTT Standardization Sample.

Table 3

Individual results by CE deficit

Fluent	Nonfluent
M.W. 1. Inhibition 2. Dual-Task Processing	R.I. 1. WM Updating 2. Dual-Task Processing 3. Inhibition
J.J. 1. WM Updating 2. Inhibition	L.W. 1. WM Updating 2. Dual-Task Processing 3. Inhibition 4. Set Switching
R.E. 1. WM Updating	

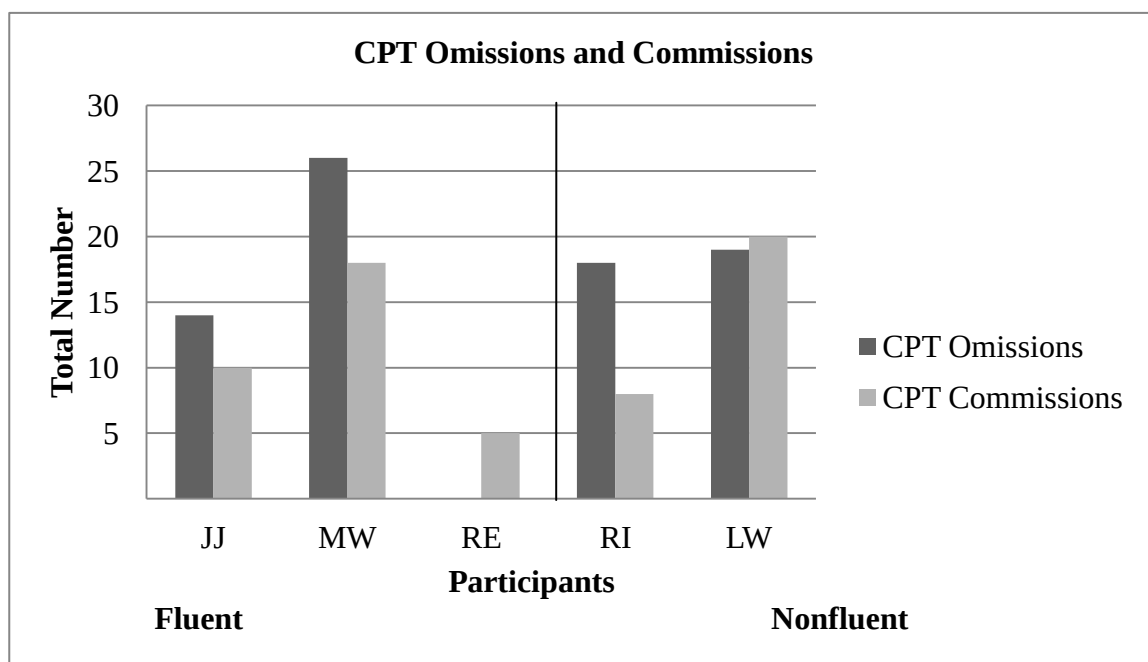


Figure 1. Continuous Performance Test (CPT) performance for all participants.

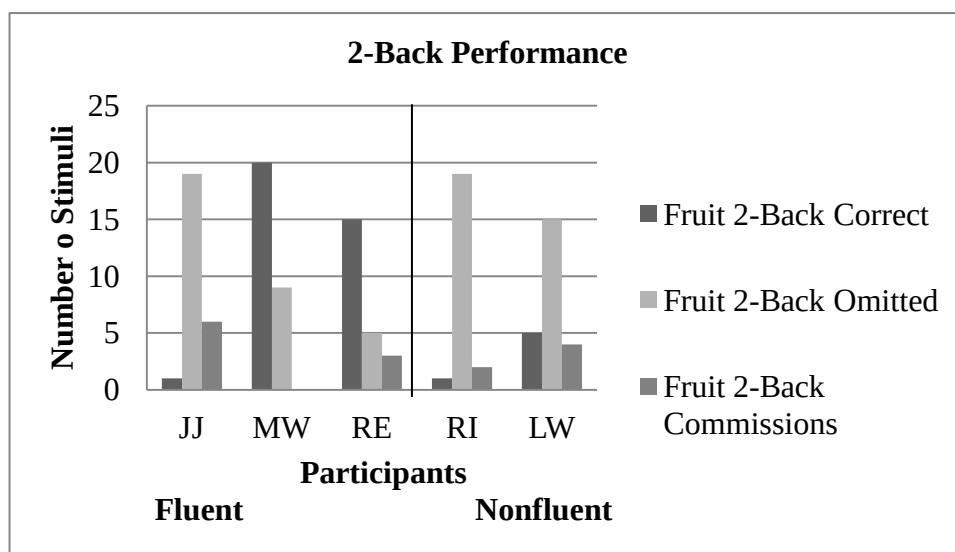


Figure 2. N-Back performance for all participants.

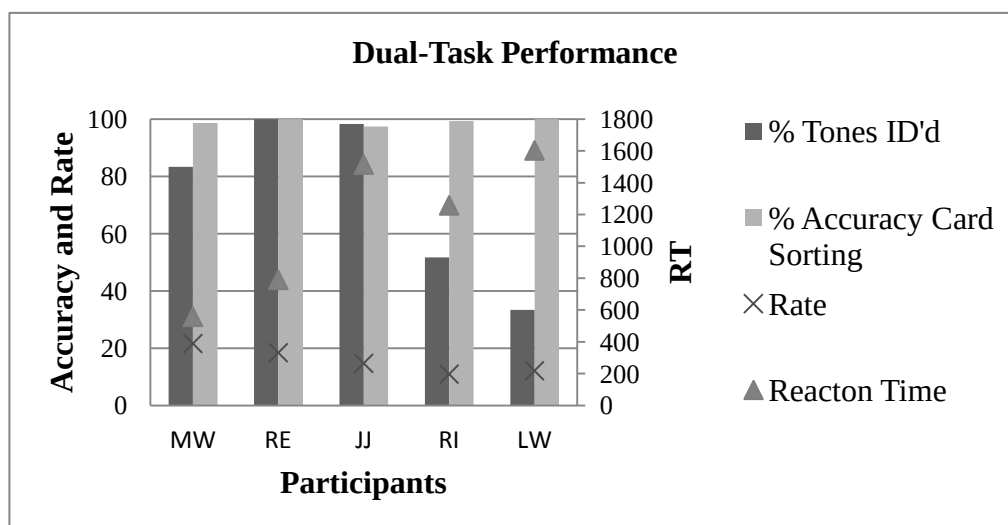


Figure 3. Dual-task performance for all participants.