TO STUDY EXECUTIVE FUNCTIONS USING VERBAL AND NON-VERBAL TESTS IN PERSONS WITH APHASIA

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CERTIFICATE

This is to certify that this dissertation entitled **"To Study Executive Functions Using Verbal and Non-verbal Tests in Persons with Aphasia"** is a Bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration number P01II21S0012. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru

September 2023

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DECLARATION

This is to certify that this dissertation entitled **"To Study Executive Functions Using Verbal and Non-Verbal Tests in Persons with Aphasia"** is the result of my own study under theguidance of Dr. Hema N, Assistant Professor in Speech Sciences, Department of Speech-Language Science, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Registration number:** P01II21S0012

September, 2023

Acknowledgement

What shall I render to the LORD

For all His benefits toward me?

I will take up the cup of salvation,

And call upon the name of the LORD.

I will pay my vows to the LORD

Now in the presence of all His people.

I will offer to You the sacrifice of thanksgiving,

And will call upon the name of the LORD.

I will pay my vows to the LORD

Now in the presence of all His people,

In the courts of the LORD's house,

In the midst of you, O Jerusalem.

Praise the LORD!

– PSALM:116: 12-19

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CHAPTER I

INTRODUCTION

Aphasia is caused by left hemispheric brain damage that results in an acquired neurogenic linguistic deficit. Damage to the left hemisphere affects four essential language network components, which results in varying severity of deficits in the expression of spoken language, comprehension of spoken language, reading comprehension, and written expression (American Speech Language Hearing Association, 2022). Aphasia is caused by an obstruction that stops the flow of blood to a particular part of the brain, known as ischemic stroke, and the other cause is brought on by a blood vessel rupture that harms the area around the brain tissues, known as hemorrhagic stroke. Apart from cerebrovascular accidents, aphasia is also caused due to traumatic brain injury (TBI), brain tumors, surgeries to the brain, and infections in the brain. However, among these, the primary cause of aphasia is stroke, i.e., cerebrovascular accident (Jenkins & Birkett- Swan, 2010).

According to the estimates from the National Aphasia Association (2019), between 100,000 and 180,000 are thought to develop aphasia annually in the United States. Additional information indicates that 2-4 million Americans are thought to be affected by aphasia. From the data of 43 countries, including high- and middle-income nations, the global rate of post-stroke aphasia is between 7% and 77% (Frederick et al., 2022). However, similar percentages were discovered between high- and middle-income nations. Of individuals below sixty-five years of age with post-ischemic stroke, 15% of those experience aphasia, whereas for eighty-five years or above age individuals, this ratio is increased to 43%. (Engelter et al., 2006).

In India, of stroke survivors, 21%–38% still have aphasia as a disability. Prevalence is about 3000 per million, with a community incidence of around 43 per 100,000 per year. In this nation, there are probably approximately two million people who have aphasia (Pauranik et al., 2019).

Aphasia due to cerebrovascular accidents will damage the insular cortex or frontal area, which includes Broca's area BA 44, 45, and supplementary motor area BA 6, which causes deficits in expressive language. The blood supply for these language areas, as well as the prefrontal cortex, is by the middle cerebral artery (MCA), so damage due to an MCA stroke will cause aphasia as well as executive function deficits because executive functions rely on the prefrontal cortex and its connections to the frontal lobe and other regions of the brain (Baddeley et al., 1997).

The person with aphasia (PWA) has impairment in comprehension and verbal output of the spoken language, which affects effective communication. Additionally, they also have deficits in reading, writing, and the use of gestures. They also have impairment in syntax, memory, word retrieval, linguistic processing, and auditory attention span (Caspari et al., 1998). The two major important classification systems for aphasia are the Boston group classification system and Luria's aphasia interpretation. Boston group classification includes two major fundamental parts. a) Aphasia can be classified into two categories depending on the verbal output: fluent or non-fluent. b) It can be classified depending on the lesion site: cortical, sub-cortical, or transcortical (Goodglass & Kaplan, 1972; Benson, 1979; Albert et al., 1981; Geschwind & Goodglass, 1993;). According to Luria's interpretation, there are seven sub-variants of aphasia, i.e., motor efferent, motor afferent, acoustic-agnostic, acoustic-amnesic, semantic, dynamic, and amnesic. This classification is based on the specific level of language impairment.

In addition to linguistic impairment, PWA mostly has affected cognitive functions, such as executive functions (Murray, 2012). There is growing evidence that the communication barrier faced by PWA is not solely due to linguistic deficits, which may extend beyond comprehension and verbal expression deficits. A confluence of causative elements, on the other hand, will result in a broad spectrum of communicative deficiencies. The preliminary research suggests that aphasic clients' communication success may be contingent on executive function skills integrity (Ramsbergq, 1994).

1.1 Executive functions in neurotypical individuals and persons with aphasia

Executive functions are one of the critical processes of cognition. According to Lezak (1995), executive functions are defined as various skills that help the individual to be socially responsible, independent, self-serving, and perform possible purposive behavior. According to Miyake and colleagues (2000), the executive function may not refer to a single entity but to mental flexibility, task switching, inhibitory control, problem-solving, and attentional control.

Executive functions are broad terms that encompass a variety of behavioral competencies and cognitive processes. These cognitive processes are response inhibition, cognitive flexibility, problem-solving, verbal reasoning, planning, resistance, sequencing multiple tasks, attention skills, feedback utilization, and dealing with novel situations (Chan et al., 2008). It enables an individual to modify and adapt behavior according to contextual changes and is considered a higher-order function (Miyake & Friedman, 2012).

The unique and sophisticated tasks depend heavily on executive function, which helps an individual plan, sequence, organize, and monitor goal-oriented activities according to situational and environmental changes in the most flexible manner (Purdy, 2002). Primarily, there are three major domains of executive functions. They are cognitive flexibility, working memory, and inhibition (interference control and inhibitory control). Cognitive flexibility in an individual helps to shift perspectives spatially and interpersonally. Working memory (WM) enables individuals to work with perceptually unavailable information. Working memory has two types: verbal WM and visual-spatial WM. Inhibitory control inhibits the dominant response, which produces self-control and interference control. It also includes attention control, which is required during conflictual information (Diamond, 2013). Other higher-level skills, i.e., planning, reasoning, and problem-solving are established from the three major domains of executive functions (Diamond, 2013). All executive functions are essential skills for physical health, mental health, and cognitive, psychological, and social development.

To examine the ability of executive functions in PWA, neuropsychological examinations are used to investigate the accuracy, speed, and efficiency in performing certain tasks in the Tower of London(Shallice, 1982), Porteus Maze Test(Porteus, 1959), Tower of Hanoi (Edouard Lucas,1883) and Wisconsin Card Sorting Test (Grant & Berg, 1948) which are intended to assess goal-directed planning and cognitive flexibility domain of executive functions. The findings showed that all speed and efficiency factors had a significant difference, pointing to lower executive functioning abilities in the group. It was determined that it is crucial to consider a client's executive functioning capacity while evaluating their communicative performance (Purdy, 2002).

Design fluency measures were considered to explore the association between language performance and executive functions in PWA. Design fluency particularly assessed executive functions (EF) abilities like cognitive flexibility, planning, and initiation concerning the Ruff figural fluency test (RFFT) (Ruff et al., 1987). This study included left-hemisphere-damaged individuals, right-hemisphere-damaged individuals, and neurotypicals to investigate executive function problems at domain-specific and domain-general levels. Other cognitive tests include the Behavioural Inattention Test BIT (Wilson et al., 1987), the Test of Everyday Attention (Robertson et al., 1996) subtests such as the Map Search (MS), Visual Elevator (VE), and Telephone Search with Counting (TSC) and the Wechsler Memory Scales—Revised (Wechsler, 2009) subtests such as Visual Memory Span—Forward (VMS-F) and visual memory span - backward were administered to all participants as additional tasks to evaluate executive function skills. Results revealed that in PWA and RHD, Ruff figural fluency test scores were significantly lower when compared with neurotypical individuals quantitatively. However, no significant difference between PWA and RHD in other executive function tests. Only RHD individuals showed a significant difference from neurotypical qualitatively. RFFT performance also correlated with other cognitive test scores and language scores using the overall total of unique designs largely associated with an overall total of correct exemplars and semantic clusters and a total number of RFFT unique designs correlated moderately with attention and executive function's other measures. The study concluded by including participants with RHD that difficulties in executive functions and high connection between language skills and executive functions are not present only in PWA but also in RHD individuals. Additionally, it has been discovered that executive function impairment in aphasia is caused by domain-general cognitive problems rather than only language deficits that are particular to that domain (Murray, 2017).

Since there are executive function deficits in PWA, there is a need to explore the executive function aspects. However, a few studies have been carried out in the past. Previous studies mainly focus on a specific domain of executive function. A holistic study tapping details about all the executive functions in PWA would yield details on the status of executive functions in this population.

1.2 Need for the Study

Usually, the nonverbal task was used to evaluate the executive functions in PWA to decrease the impact of impaired linguistic ability, but testing executive functions through a nonverbal task has confounds, in which distinct concepts may be elicited by non-executive motor and visuospatial processes than by assessing executive functions through verbal tests (Keil & Kaszniak, 2002).

The PWA's abilities to profit from communication treatment varies, especially in severe non-fluent types. They mostly rely on their nonverbal executive function skills. In contrast to patients with poor executive function abilities, those with strong executive function skills reacted more effectively to therapy using the other communication strategy. Every aphasia evaluation should incorporate non-verbal measures for assessing executive functions When attempting to identify eligibility for specific kinds of rehabilitation programs (Nicholas et al., 2005).

Regarding aphasia recovery, the nonverbal executive function assessment may provide additional information. Cognitive reverse means an ability to perform ideally, for any given level of lesion, which uses neural pathways that are not involved in the undamaged brain. This cognitive reverse is typically linked with earlier cognitive growth and stimulation, which is usually evaluated by vocabulary and literacy performance. Anyhow assessing vocabulary performance is difficult in persons with aphasia, so a measure of cognitive reverse needs to be found. Non-verbal executive functions, such as matrix reasoning, an effective task, have been found to indirectly measure the cognitive reverse (Fonseca et al., 2018).

Executive functions are linked with an impairment in the language in PWA, which is the major contributing factor to comment on the affected functional communication skills of PWA. The executive function will be crucial to the competence for functional communication, particularly in non-fluent aphasia. Hence, it is necessary to evaluate executive functions at a verbal and non-verbal level in persons with aphasia (Olsson et al., 2019).

For executive task performance, language processing is not essentially required, which is evident from the study, in which individuals with evident language impairment carried evenly on both low and high-verbal demand tasks (Kendrick et al., 2019a). It suggests that limited linguistic ability does not influence assessing executive function through verbal tests.

Various test has been developed to assess the different domains of executive functions, but the most commonly used test has linguistic stimuli that require verbal output. Because of this, it has not been usually assessed in a person with aphasia. When the verbal-based test is not administered for individuals with aphasia, the knowledge of specific issues that aphasic individual confronts in terms of executive skills and language processing is limited (Schumacher et al., 2022).

Only a few attempts have been made to assess the executive function of both verbal and nonverbal performance in patients with aphasia. There are three core domains of executive functions, cognitive inhibition, cognitive flexibility, and working memory, that need to be assessed using verbal as well as non-verbal tasks.

1.3 Aim of the study: The present study aimed to assess and compare executive functions through verbal tasks and non-verbal tasks in persons with aphasia (PWA) and neuro-typical individuals (NTI).

1.4 Objective of the study:

1. To assess executive functions in PWA and NTI through verbal and nonverbal tasks.

2. To evaluate the performance on the verbal and non-verbal tests of executive functions in terms of accuracy score for cognitive inhibition (Stroop test, Go/No-go test), working memory (Digit span backward test, Corsi block tapping test), cognitive flexibility (Alternate verbal fluency test), whereas test completion time would be accounted for cognitive flexibility (Trail making test) in PWA and NTI.

3. To assess and compare the three domains of executive function, cognitive inhibition, cognitive flexibility, and working memory, in PWA and NTI.

4. To study the correlation between language deficits (AQ score of WAB) and executive dysfunction (accuracy score and completion time for three domains of executive function tests) in PWA.

1.5 Hypothesis:

The following null hypothesis was considered for the study:

- There is no statistically significant difference in executive functions between PWA and NTI for verbal and nonverbal tasks.

- There is no statistically significant difference between the performance on the verbal test and non-verbal test of executive functions in terms of accuracy score and completion time in PWA and NTI.

- There is no statistically significant difference between the three domains of executive function such as cognitive inhibition, cognitive flexibility, and working memory, in PWA and NTI.

- There is no statistically significant correlation between language deficits and executive dysfunction deficits in PWA.

CHAPTER II

REVIEW OF LITERATURE

2.1 Executive functions:

The term "executive functions" is also known as executive control or cognitive control, which refers to the group of higher-level cognitive abilities that are essential to explore and accomplish a goal. These capabilities enable us to understand complex or abstract concepts, solve problems that haven't encountered previously, plan our next action, and manage interpersonal relationships. Executive functions are top-down mental processes that require attention or concentration for an automatic task or activity, or relying on some insight or instinct would be inappropriate or inadvisable (Diamond, 2013). According to Miyake and colleagues (2000), executive functions are a complex collection of skills that include, mental flexibility, problem-solving, attentional control, task-switching, and inhibitory control. The tasks used were the ones frequently used to test executive functions, and their research suggested that there are three main domains of executive functions, "inhibiting" undesirable reactions, "shifting" between activities and mental groups (also known as "cognitive flexibility"), and the last one is "updating" and tracking of working memory information. As executive functions are the collection of higher-order cognitive skills, from these three core executive functions, i.e., cognitive inhibition, working memory, and cognitive flexibility, other higher-level functions such as planning, problem-solving, and reasoning are developed (Collins & Koechlin, 2012). These skills are essential for academic and personal success, for physical and mental well-being, as well as for cognitive, social, and psychological development.

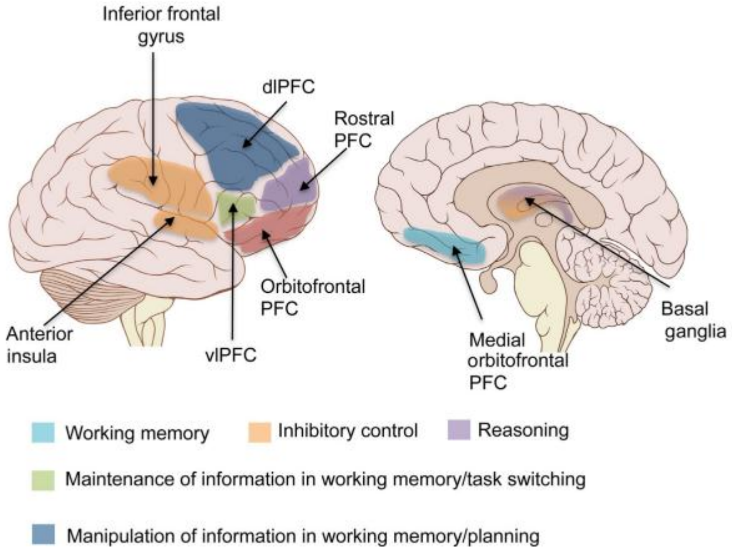
2.1.1 Neural correlates of executive functions:

The coordination of several brain networks produces executive function, which is a crucial condition for various cognitive activities. The prefrontal cortex (PFC) is regarded as a crucial brain area that regulates and oversees several neuronal networks situated in various cortical regions as well as sub-cortical regions of the brain. The PFC is also a very important structure for performing executive functions. While simultaneously sending signals of commands to those regions to regulate their operations, the PFC must constantly track the actions in cortical and sub-cortical regions if it is to perform executive control over various processes of cognition. Therefore, exhibiting executive function involves both observation and regulation of activities in other brain regions. The prefrontal cortex commands signals that control the behavior of other brain areas, which are referred to as "top-down signals." (Funahashi & Andreau, 2013).

The PFC has three major sub-parts, the orbitofrontal region, the medial part, and the dorsolateral part. The parietal and temporal regions of the neocortex provide input projections to the PFC. In addition, the substantia nigra, the hippocampus, the thalamus, the cingulate cortex, and majorly form the medial dorsal nuclei also send information to the PFC. The PFC is closely related to other cortical and subcortical structures because it sends projections back to the medial dorsal nuclei, the basal ganglia, the amygdala, the septal nuclei, and the hypothalamus (Cristofori et al., 2019)

FIGURE 2.1

Brain areas responsible for various domains of executive functions



To evaluate the brain regions connected to the three executive functions (cognitive inhibition, updating, and cognitive shifting) using Positron emission tomography (PET) which used conjunction and interaction paradigms (Collette et al, 2005). The findings suggested that the right intraparietal sulcus and left superior parietal gyrus, below a certain cutoff, the left lateral PFC, showed a common activation center across the tasks, according to a global conjunction analysis. Concerning this analysis, these areas are involved in executive functioning generally. The suppression of extraneous information and selective attention to pertinent stimuli appear to be functions of the right intraparietal sulcus. The switching and integration mechanisms take place in the left superior parietal area. The lateral PFC's functional purpose is to monitor the temporal planning of cognitive processes, which are essential for performing current operations. Interaction studies demonstrated that particular prefrontal cerebral regions are connected to each executive function.

In addition to the PFC, white matter also contributes significantly to executive functions. Specifically, in the verbal fluency task, the least functional recovery was observed in individuals with an impairment in the superior longitudinal fasciculus and anterior corona radiata. The verbal fluency task depends mainly on the fronto-temporo-parietal network. Therefore, white matter impairment can lead to impaired signal transmission between cortical and sub-cortical structures, which are important networks for the performance of executive functions (Cristofori et al., 2015).

Together, these findings show that the PFC's neuronal networks play a key role in executive function. but that other cortical (such as the parietal and temporal cortex) and subcortical (White matter, superior longitudinal fasciculus, anterior corona radiata) brain regions are also interlinked with the PFC and may also have an impact on the proper functioning of executive functions.

2.1.2 Models of Executive Functions:

Models and theories are postulated to understand the process of executive functions in the brain. Luria (1973) accounts that "whose involvement is required for any form of mental activity," the brain comprises three functional components. These functional units, according to Luria, are the arousal and attention unit, which controls tone and awakeness and mental functions; the sensory intake and utilization unit, which receives, processes, and stores information; and the executive planning and organization unit, which directs, controls, and verifies activity. The executive function unit, which is made up of the association cortex and is situated in the frontal and pre-frontal regions of the brain, controls impulses, regulates voluntary actions, and performs language processes like spontaneous speech. Luria's description of the functional organization of the cognitive process is the key component of the theory. In light of this, it has given more importance to the structure which follows that function.

The executive function model which is given by Stuss and Benson (1986) states that executive function processes involve the initiation of the behavior which is followed by planning, sequencing, and organization of those behaviors. The subcomponents of Luria’s model such as planning and execution are resembled by these three subprocesses: planning, sequencing, and organization. Later though, Stuss in 1991 positioned EFs in the center of a hierarchical structure. The executive function in this paradigm gets input from higher-level meta-cognitive operations as well as lower-level operations (such as perception, language, memory, and attention).

Executive function’s clinical model given by Sohlberg and Mateer (2001) has six parts: (1) initiation and motivation (starting or activating a cognitive function); (2) inhibiting the response (avoiding inherent or predetermined response tendencies); (3) task perseverance (sustaining an action up to completing a task); (4) establishment (building and arranging of knowledge) (5) generative thinking (constructing numerous alternatives to a challenge and imaging in an adaptable behavior) and (6) awareness (observing and altering their actions). This model has been used in observation, assessment, and management plans.

The structured event complex concept developed by Grafman (2002) proposed the prefrontal cortex (PFC) has several types of hierarchical information, and when this information is triggered, it manifests as executive functions. A structured event complex is a group of events with a specific objective that is organized in a certain order and serves to express conceptual understanding, ethics, abstract ideas, the standard of behavior, situational characteristics, event borders, and grammar. The traits of these saved concepts provide the basis for the effect of how structures are represented in memory and the relationship between structured event complex concepts.

2.2 Executive functions in persons with aphasia:

There are three major domains of executive functions, cognitive inhibition, working memory, and cognitive flexibility.

2.2.1 Cognitive inhibition:

Cognitive inhibition is the process of ignoring unwanted information and concentrating on the guidelines of interaction or activities. It is the capacity to control one's attention, behavior, ideas, and/or emotions to restrain a strong compulsion inside or an alluring temptation outside and behave in line with what is more appropriate or required. (Diamond, 2013). There are various tasks to assess cognitive inhibition, for example, the Stroop task (Stroop, 1935), in which the participants are asked to say the ink color, while the meaning of the word would be ignored, which usually means a color. The other task most commonly used to measure cognitive inhibition is the Go/No-go test (Gordon & Caramazza, 1982), in which participants are instructed to react to a provided stimulus (Go stimulus) meanwhile inhibiting another similar stimulus (No-Go stimulus).

The relationship between cognitive inhibition and auditory comprehension deficits at the lexical-semantic stage of processing of language was assessed by Wiener et al., (2004) using a modified Stroop test in the numerical form in five PWA (Wernicke’s subtype) and NTI. The Boston diagnostic aphasia examination's complex ideational material subtest and the token test were used to evaluate the comprehension of spoken language association with Stroop interference. The result suggests that the participants with Wernicke's subtype had a much greater interference impact than NTI. This result shows that Wernicke's subtype impairs inhibition. Additionally, there was a strong positive correlation between the Token Test score and the degree of deficit in spoken language comprehension. The study concluded that Wernicke's subtype is associated with an impairment in suppressing at the lexical-semantic level of processing of language, which indicates the inability to effectively suppress the automatically produced stimuli that are interfering. The Stroop interference effect and the degree of comprehension of spoken language impairments are significantly correlated, which implies that inadequate inhibition may be at least partially responsible for the attentional problems producing the dramatic decreases in comprehension of spoken language in Wernicke’s subtype aphasia individuals.

Reactive inhibition and intentional inhibition are the two components of inhibitions studied by Pompon et al, (2015) in nineteen aphasic individuals and twenty age and education-matched neurotypical individuals using the Stroop task. Through the evocation and comparison of interference, facilitation, and negative priming effects in various circumstances, the Stroop task enabled the investigation of intentional and reactive inhibition. The results suggested, that despite deliberate inhibition being present in both groups, PWA showed considerably higher interference effects. PWA did not show any discernible facilitation effects. Significant reverse facilitation effects in neurotypical were found. Although both groups had comparable levels of individual variability, no group demonstrated any discernible signs of reactive inhibition. These findings highlight the difficulty PWA has while producing spoken words because of interruption, which suggests decreased intentional inhibition. PWA had trouble integrating and adjusting to contextual information when performing language tasks.

The neurological and behavioral underpinnings of producing language and controlling cognitive processes were examined using a Go/No-Go picture naming task. By varying the ratio of tasks between naming events (Go trials) and inhibitory events (No-Go trials), it was possible to adjust the degree of difficulty in naming and the demands on cognitive control. The findings showed that individuals' behavioral performance decreased as task demands increased (for example, longer response duration on naming events and more mistakes on inhibition events). While brain activity is specifically elevated for both the language network and domain-general control areas. Additionally, during both producing language and inhibiting response, the right superior and inferior frontal gyri and also left supramarginal gyri were sensitive to an increase in task difficulty. Overall, it implies that cognitive control demands have an impact on language output and that overcoming increases in task difficulty requires the cooperation of cognitive control areas that are both language-specific and domain-general (Zhang et al., 2018).

2.2.2 Working memory:

Working memory is described as the potential to retain and manipulate knowledge in the mind even when it is no longer perceptibly present (Baddeley & Hitch, 1994). Working memory is another important core element in executive functions. There are two types, verbal working memory and non-verbal working memory (visuospatial). Additionally, When making decisions and planning, WM enables a person to take into account their remembered past and future hopes in addition to using conceptual knowledge rather than only perceptual data. There are various tests used to assess working memory. One such test is the digit span backward test (Wechsler D, 2009), in which participants are required to recall numbers from 2 to 9 dependent on the backward sequence in which they are presented. Digit spans are defined as the point at which an individual misses repeating two lists of the same length. Another test used to evaluate working memory is the Corsi backward block tapping test (Stoet, 2010, 2017), which starts with a cross-hatch that is visible in the center of the computer screen, then nine grey blocks on a black background. Individuals are prompted to touch reversely on the blocks that they were highlighted. The moment at which participants incorrectly answer all two trials of a single length will be determined.

The hypothesis states that PWA and right hemisphere damage (RHD) individuals find more difficulty in digit span tasks, i.e., digit span forward and backward tasks (Laures-Gore et al., (2011). The same hypothesis was studied by evaluating seventeen PWA and fourteen RHD to evaluate the disparity of performance. The results suggested that both groups found it more challenging to complete the backward span test than the forward span test and smaller spans for IWA in comparison to the RBD group. The disparities between the RBD group and the IWA might be attributed to the IWA's reduced attentional ability, ineffective resource allocation, or even a weak phonological loop.

Complex interrelationships between working memory, comprehension of spoken language, and temporal processing of information were studied by Choinski et al., (2020). The study considered thirty PWA using a receptive verbal test and Corsi span test (both forward and backward conditions) to evaluate working memory in terms of both types i.e., verbal and spatial. A receptive language test was used to assess the comprehension and perception of the spoken language of temporal order in the time range of milliseconds to assess the temporal information processing ability. The results found that forward WM tasks performed more efficiently than backward ones, and the degree of auditory comprehension impairment related to performance on both the conditions of verbal working memory tests i.e., forward and backward as well as the backward spatial working memory task. These findings show that based on the type of working memory tests, the interaction pattern between working memory and temporal information processing might vary. Level of verbal competency seemed to be crucial in both verbal working tasks, but spatial working memory tasks appeared to be influenced by temporal information processing (which is connected to manipulation processes), but only on the backward test.

The working memory training effects in both language and memory performance in twenty-five PWA of Broca's subtype with varying degrees of severity i.e., mild to moderate were studied by Nikravesh et al., (2021). The clinical group and the control group were formed from these subjects. While the control group had routine speech therapy, the clinical group participated in a working memory training program. Two separate lists of working memory tests were used in this study; one list of working memory tests was used for the before-therapy evaluation and therapy program, and the other list was used for the after-therapy evaluation. The working memory training program was given for one hour per session for 15 sessions, twice a week. The working memory training program included a digit memory span test (DMST) which included both forward and backward tasks. Sequences of three digits were the initial degree of challenges in the forward digit memory span test, which were verbally presented, and the subject was required to recall the sequences. For example, Sequences of 15-digit with the initial level of challenges and Sequences of 15-digit with the next level of challenges were shown in each session of 30-digit sequences. If they accurately completed 60% or more of the first level of challenges, the participants advanced to the next level; or else, they stayed at the same level but with the sequences of new digits.

The results revealed that the clinical group outperformed the control group in both working memory tasks which were given therapy and also for tasks that were not given therapy (near spillover impact) and language tests (far spillover impact). The study found that because working memory training programs have great generalizability on both working memory and language function, it is advised that they be included in rehabilitation programs for PWA.

2.2.3 Cognitive Flexibility

Cognitive flexibility is another core element in executive functions and is the crucial ability that enables someone to transfer their attention from one stimulus to another in a smooth, effective way. It is a crucial component of the more complex working memory (WM) and attention system. In other words, it is the capacity to quickly switch between several response sets (Anderson, 2002). Cognitive flexibility can be evaluated using various measures. One among them is alternate verbal fluency, in which individuals are asked to shift between the two categories within one minute. Another measure is the Trail-making test Part B (Reitan, 1958), which has 25 circles scattered over a paper sheet. These circles feature letters (A – L) and numerals (1-13). The participants would have to draw lines alternatively linking numbers and letters (1-A-2-B-3-C, etc.). Cognitive flexibility is evaluated using the completion time of part B trail-making test.

The degree of cognitive flexibility was assessed by Rajtar-Zembaty et al. (2015) in 43 individuals with speech problems who had an ischemic brain stroke. Depending on the types of speech issues, such as aphasia, dysarthria, and no speech issues, the participants were separated into groups. The overall assessment of the effectiveness of cognitive processes was conducted using the Clock Drawing Test (CDT) and Mini-

Mental State Examination (MMSE) (Folstein et al., 1975). A Trail Making Test (TMT) (Reitan, 1958) was used to assess cognitive flexibility. The results suggested that those with aphasia have the least amount of cognitive flexibility. Executive function disorders may be linked to the prefrontal cortex's dysfunction, which was confirmed using computed tomography (CT), which has been harmed by an ischemic brain stroke. There are probably common functional neural networks that support both linguistic abilities and executive function parts Therefore, if the structures necessary for both tasks are compromised, language and executive dysfunctions may co-occur. The prevalence of executive function deficits in aphasia patients may also impair their performance and have a detrimental impact on the rehabilitation process, which aims to increase communication effectiveness.

Tests of verbal fluency are the basic test to assess cognitive flexibility and are frequently used to evaluate executive functioning. However, conventional tests rely on additional cognitive aspects in addition to these elements. The relationships between an altered verbal fluency version test and other executive function measurements were examined (de Paula et al, 2015). The verbal fluency for 60 individuals was examined using both the typical conditions category fluency of fruits and animals and under a modified scenario where they had to switch between the two categories of “fruits” and “animals”. Additionally, semantic skills, mental symptoms, speed of processing, and executive functioning also were examined. The finding indicated that verbal fluency tests and executive function tests had a partial correlation. Cognitive flexibility accounts for nine percent of the verbal fluency test's variance in the animal category, in the fruits category it was around two percent, eight percent in the overall words produced in the alternating condition, and twenty percent in the overall word pairs produced correctly in the alternating condition. The verbal fluency tasks and the other executive function measures each exhibited variances of between one and seven percent. The findings imply that switching verbal fluency, as opposed to other forms of verbal fluency, maybe a more precise metric for assessing cognitive flexibility.

2.3 Executive Functions at linguistic and cognitive aspects in persons with aphasia:

In PWA, their verbal and visuospatial abilities are unrelated to executive function impairment, which is more specific to left frontal and prefrontal injuries (Glosser & Goodglass, 1990). The evidence is from the executive function evaluated using a nonverbal continuous performance test, graphic pattern generation, sequence generation test, and tower of Hanoi in twenty-two PWA, nineteen RHD, along with forty-nine NTI. The result revealed that individuals with left frontal brain damage have a significant impairment than individuals with mixed lesions or retro rolandic lesions in the left hemisphere. Right-sided brain-damaged individuals show more impairment in visuospatial skills.

The study also analyzes the impact of cognitive and linguistic variables on the ability of severe non-fluent aphasia individuals to express using C-speak aphasia (Nicholas et al., 2005). The aim was to determine whether severe non-fluent aphasic individuals could utilize C-speak aphasia, an alternative form of communication that was a picture-based computer application, which would dramatically enhance their functional communication. Ten individuals were included in the study. All individuals took therapy for six months to understand C-speak aphasia, and their expressing ability was routinely evaluated in two conditions - using solely natural ways of communication, such as speaking, writing, drawing, gesturing, and gesturing, in one situation, and C-speak aphasia in addition to natural forms of communication in another. It was evaluated using five untrained functional communications activities (describing pictures, describing short videos, responding to autobiographical queries, making calls, and two writing tasks) to determine treatment impact. Non-verbal executive function, auditory comprehension, and picture-based semantic skills were evaluated as a baseline measure to investigate the connection between response to treatment. The degree of comprehension of spoken language or semantic knowledge did not correlate to the response of the treatment, Executive functioning skills were thought to be more crucial to the response of the treatment. PWA with severe non-fluent subtype responded better who had intact executive functions when compared with the individuals who had impaired executive functions. The study emphasized providing greater importance for the non-verbal executive functions skills over language skills for the treatment which utilized C-Speak aphasia, an AAC system for PWA with severe non-fluent subtype.

In a prospective cross-sectional study, the association between abilities of cognition and aphasia's severity, speech fluency, and comprehension abilities were evaluated for the individuals with severe aphasia and neurotypicals using non-verbal cognitive test batteries. Cognitive performance was assessed in a PWA during the acute stroke and after three months to determine how recovery contributes to cognitive performance. It was evaluated using a non-verbal test of attention, executive functions (Tower of Hanoi, clock drawing, matrix reasoning, and motor initiative), and semantic, episodic, and immediate memory tasks. Results revealed that except for memory tests (immediate memory, semantic memory, and episodic memory), all other tests were within the normal range for baseline cognitive performance. While considering each non-verbal test individually, the Matrix Reasoning test score was the only test result that could be utilized to forecast recovery of the aphasia (Fonseca et al., 2018).

Executive functions and language abilities were evaluated together to determine the major component that contributed to the varying performance in individuals with aphasia. This was evaluated by Schumacher et al. (2019) using three nonverbal executive function tests, which assessed speed, inhibit-generate, and shift update skills, and the three language component tests, which assessed speech quanta, phonology, and semantics, along with MRI. The results revealed that various brain areas are activated during executive function, such as the left temporo-occipital, left frontal, and right fronto-parietal-occipital regions. These non-linguistic areas are crucial for the language skills of individuals with chronic aphasia. These results underline the significance of nonverbal cognitive assessment in the aphasic group.

The influence of the ability of language and executive functions in severe aphasia is studied in functional communication (Olsson et al., 2019). The assessment included the use of the symbol trial test, design generation test, symbol cancellation test, and maze test from Cognitive Linguistic Quick Test (CLQT) for executive function, comprehensive aphasia battery (CAT) for language ability and scenario test and communication effectiveness index test for functional communication. The result revealed that all subtests of executive functions and linguistic ability had a moderately strong correlation, there was a slight correlation between functional communication and executive function, and verbal expression ability being significantly associated with functional communication, executive functions appear to be a key aspect for functional communication in individuals with severe restriction or total absence of expression. Subsequently, according to Mohapatra and Marshall (2020)**,** four domains of executive functions such as inhibition, set-switching, dual-task processing, and updating, are assessed in individuals with aphasia and neurotypicals, which were evaluated using Conners Continuous Performance Test II, Color Trail Task (CTT 1& 2), Divided

Attention Task, and n-back (1- & 2-back), and it revealed that person with aphasia demonstrated significantly reduced performance in all four domains of executive functions when compared with neurotypical individuals and difference were evident on 2-back task and color trail test 2 which demands more sophisticated processing.

The executive function domains of language control are assessed most using verbal executive tests, such as the 'Stroop task,' 'verbal fluency task,' and 'Hayling test,' which assess, initiation, suppression, and generation switching, in patients with aphasia with varying severity (Schumacher et al., 2022). The study aimed to identify the neural correlate that is related to the performance of verbal executive function, MRI was also performed. The findings showed that many PWA could pass verbal-based executive tests, the individual's overall language impairment severity did not explain the variation in the performance, and there was a separate neural correlate for the performance of all executive functions' tests where the Stroop test was associated with angular gyrus, lateral occipital cortex, insula, and medial temporal gyrus. Hayling test was related to the supramarginal gyrus, angular gyrus, superior lateral occipital cortex, and inferior and middle frontal gyrus, anterior cingulate, small cluster in the cerebellum. A verbal fluency test was associated with the right temporal-front-insular structures in the cerebellar region. Typically, person with aphasia due to the middle cerebral infarct, the damage could be in the Sylvian and perisylvian areas of the brain, which is very similar to Schumacher's study of areas associated with executive function control. Therefore, the performance on any executive function task could predict the structural changes of the brain in clinical populations with aphasia.

To investigate whether the non-verbal working memory would be the indicator for successful anomic intervention was studied by Harnish and Lundine, (2015). The study was done on eight chronic aphasia individuals by using the Wechsler memory scale (Wechsler, 2009) spatial span subtest in both conditions i.e., forward and backward conditions for non-verbal working memory tests over four weeks. In Experiment 1, the reproducibility of both the forward and backward condition of the spatial span was evaluated, and it was investigated whether the score of the spatial span was altered once anomia therapy had started. Cued picture naming treatment was used for anomic interventions. The spatial span was examined in Experiment 2 as a potential indicator of anomia treatment efficacy. The results suggested that the spatial span in the forward condition was stable in 7 people in Experiment 1 throughout all sessions, while the backward condition was stable in 5 persons. In either group, they demonstrated that aphasia therapy, i.e., Cued picture naming treatment, did not affect their performance on the span task. Experiment 2 revealed that the spatial span in backward conditions strongly anticipated the effect of anomia treatment magnitude. The study concluded that, hence, non-verbal visuospatial working memory predicted the effect of anomic intervention; it supports the notion that a shared underlying mechanism is related to both visuospatial WM and an improvement in lexical retrieval; more specifically, the positive correlation between a verbal treatment response and visuospatial task suggests that there There could be a similar underpinning mechanism.

The critical significance of executive functions in the recovery of language skills, especially for severe aphasia individuals, has lately been recognized by new aphasia rehabilitation methods. Indeed, EFs include higher-order cognitive skills like problem-solving and planning, which help people adjust to new scenarios and are necessary for daily functional communication. In the study (Pisano et al., 2022), twenty severe PWA of the Italian population had treatment with transcranial direct current stimulation (tDCS) for 20 minutes over two mA on the right dorsolateral prefrontal cortex (DLPFC). Cognitive training was focused on four processes of executive functions: selective attention, planning, visuospatial working memory, and alertness, and these were performed under two circumstances, namely, anodal and sham. Planning skills, selective attention, and visuospatial working memory all improved more following anodal tDCS than they did in the sham group, and even after a month of treatment, this improvement was sustained. In addition, as evaluated by the Communication Activities of Daily Living Scale, considerable improvement was noted in noun and verb expression, comprehension of spoken language and written language, and functional communication. This research highlights how training to executive functions and transcranial direct current stimulation over the right dorsolateral prefrontal cortex enhances functional communication in severe PWA.

2.4 Executive Functions at non-linguistic, and cognitive aspects in persons with aphasia:

The non-verbal deficits in the cognitive process can be hampered in PWA and the effectiveness of the same on therapy for persons with aphasia was studied by Seniow et al. (2009). The non-linguistic cognitive deficits were the visuospatial working memory and abstract thinking deficiencies present in post-stroke aphasia. These skills were assessed and checked for whether they had a deleterious effect on the recovery of language. Pre-therapy visuospatial memory and abstract thinking skills were examined in seventy-eight PWA and thirty-eight NTI. Then, speech and language therapy for three weeks was completed by 47 of the 78 aphasia patients. Boston Diagnostic Aphasia Examination (Goodglass et al., 2001) was used to evaluate the effectiveness of treatment by comparing before therapy and after therapy. Even though the non-linguistic cognitive abilities of the patient generally deteriorated, the patients' deficiencies varied widely. The results suggested that the degree of progress in naming and understanding, two essential aspects of linguistic communication, was related to visuospatial working memory. However, the language treatment outcomes and the capacity for abstract thought were not linked. Hence the visuospatial working memory is crucial for the language recovery process after the stroke.

Language ability in aphasia can vary based on several aspects, including the types of stimuli and the tasks. Martin et al. (2012) analyzed the verbal working memory (WM) burden that was present during the language test which impacts language performance in one aphasia patient and 11 neurotypical individuals using a synonymy judgment task and a rhyming judgment task under varying verbal load conditions (high and low verbal working memory conditions). The authors also evaluated whether synonymy judgment and rhyme judgment tasks would be influenced by varying verbal working memory load, that is the phonological short-term memory, phonological access or semantic access, executive functions in terms of cognitive inhibitions, verbal working memory updating, and set-shifting. The results suggested that increased verbal WM load substantially decreased performance accuracy on synonymy and rhyming evaluations for people with aphasia. Even after accounting for chance, the low verbal WM load circumstances produced better performance. The synonymy challenge had both concrete and abstract word triplets. When these terms were examined separately, the verbal working memory demand effect was substantial for the abstract words, not for the concrete words. independently. The performance of the control individuals followed the same trend. Furthermore, for judgment tasks, the best predictors of the verbal working memory demand effect for PWA were semantic short-term memory and cognitive inhibition of executive function.

Some research findings suggested that the abilities of executive functions would influence the semantic information maintenance in short-term memory, whether such deficits in aphasic individuals were also influenced by executive functions abilities, Allen et al. (2012) studied how aphasia patients' short-term memory, executive functions, and semantic processing skills relate to one another. Short-term memory's semantic and phonological deficits were measured using a two-probe recognition task, i.e. category recognition task and rhyme probe. Additionally, two common memory span tests (word span and digit span) also were carried out so that the results of these tests could be connected to the results of the category probing and rhyming tests. For semantic processing, Picture naming activities, single picture-word matching, the Peabody picture vocabulary exam, pyramids, and palm trees were utilized. Advanced executive functions were measured using Wisconsin card sorting tasks and Tower of Hanoi, whereas basic executive functions were assessed using verbal Stroop tests for inhibition, verbal 1-back for working memory, and cued shifting for shifting tasks. The findings revealed that there was no relationship between semantic short-term memory and either basic or advanced executive function test performance. However, it appears that some executive function tasks need the maintenance or rehearsal of phonological codes, as indicated by the link between phonological STM and the performance of the executive function in activities having a verbal element. Even though executive task demands are shared by activities of executive functions and semantic processing, however, semantic short-term memory was not associated with executive function abilities.

The literature frequently discusses relationships between language and executive function capabilities, although it is still not evident to what extent these skills are interdependent. To understand more about the frequency, severity, and relationship between nonlinguistic cognitive deficits, aphasia, and functional outcomes in the first year following a stroke (El Hachioui et al, 2014) studied PWA at three months and 1 year. Cognition was evaluated using the nonlinguistic cognitive battery, which included executive functioning, visual memory, abstract thinking, and visual perception and construction. The Aphasia Severity Rating Scale, the Screening (a linguistic-level screening exam), and the Token exam were used to evaluate language. With the modified Rankin scale, functional outcomes were assessed. The findings suggested that 107 patients (88%) at three months and 91 patients (80%) at one year exhibited deficits in at least one nonlinguistic cognitive area. Visual memory impairment was the most observed impairment (83% at three months and 78% at one year), whereas perception of visual image and constructing abilities were the least notable reported impairments (19% at three months and 14% at one year). Except for abstract reasoning, all cognitive areas, including language, showed improvement. In comparison to recovered PWA, persistent PWAs performed worse cognitively had worse functional outcomes, and were more likely to be depressed.

To better understand how executive control and language impairments differed in 1) recovery of acute stroke and 2) recovery of longitudinal aphasia. Meier et al. (2022) studied using Western Aphasia Battery-Revised (WAB-R) (Kertesz A, 2006) for individuals who had left hemisphere stroke and also assessed other various language tests such as oral reading, naming, spontaneous speech, and semantics, in addition to it, three non-verbal cognitive tests was assessed using NIH Toolbox (Gershon, 2016). Testing was performed on two patients with aphasia (PWA) who had temporoparietal lesions at subacute and early chronic stages, i.e., three and six months post-stroke, respectively. Two people with aphasia suffered from temporoparietal lesions; one patient with aphasia exhibited more temporal damage but reduced impairment in frontal and superior parietal regions than the other. The findings showed that tasks requiring both language and non-verbal executive control were substantially placed onto different factors. The WAB-R Aphasia Quotient (AQ) indicates that both factors were very significant predictors of the severity of acute aphasia. During the acute post-stroke period, both the patients displayed language and executive control abnormalities. In these individuals' longitudinal recovery, a dissociation was seen. By the initial chronic period, one patient with aphasia had improved (but still noticeable) deficiencies across several language areas and had regained executive function. PWA2, in contrast, showed chronic executive dysfunction despite mostly regained language. The observed behavioral abnormalities may be described by more severe impaired language and attention networks in PWA. These findings show that although language and executive function can be somewhat dissociated, both are crucial in the early post-stroke aphasia presentation and probably have an impact on the course of aphasia recovery.

CHAPTER III

METHOD

The present study aimed to assess and compare executive functions through verbal tasks and non-verbal tasks in persons with aphasia (PWA) and neuro-typical individuals (NTI).

3.1 Research design:

The present study was a standard group comparison consisting of two groups, the clinical group (person with aphasia) and the control group (neuro-typical individual). A cross-sectional study design and purposive sampling were used for the present study.

3.2 Participants:

The participants were ten neuro-typical individuals constituting Group I, the control group, and ten persons with aphasia constituting Group II, the clinical group were considered for the present study. A total of 20 participants from both groups were in the age range of 20-60 years and all were native Kannada language speakers.

3.3 Participants selections:

3.3.1 Ethical Considerations

When choosing study participants, ethical considerations were taken into account. Participants and their family members or caregivers of stroke patients, as well as neurotypicals, were explained the study's goals and methods. The participants or caregivers involved in the study signed an informed consent form (APPENDIX E). All

India Institute of Speech and Hearing, Mysore, ethical committee guidelines for Bio-behavioral Sciences for human subjects (2009) were followed in the present study for collecting data.

3.3.2 Source of the Participants

The participants were sourced from the All India Institute of Speech and Hearing, Mysuru for the clinical population and the control group was selected from the work/residential place in and around Mysuru. All the participants were selected for the present study only after fulfilling the specific selection criteria. The selection criteria of the control group would vary with the clinical group, but there are a few common criteria for both groups.

3.3.3 Inclusion criteria for the control group (neuro-typical individuals):

- Participants with no history or complaint of speech, language, hearing, or other communication disorders were recruited based on a semi-structured interview and self-report by the participant.
- Overall, their general health condition was assessed using a General Health Questionnaire (Goldberg & Williams, 1988).
- Performance on Montreal Cognitive Assessment (MOCA) score was above 26, considered as normal range.
- All participants had at least ten years of formal education in English as the medium of instruction.

3.3.4 Inclusion criteria for the clinical group (person with aphasia)

- Participants of all the groups were diagnosed with aphasia (of various types) by speech-language pathologists on the administration of WAB (Chengappa & Kumar, 2008) and confirmed by the neurologist with reference to the radiological evaluations.
- No associated disorders like dementia and other psychological illnesses were present.
- The aphasia quotient (AQ) of WAB-K had to be less than 93.8, and auditory verbal comprehension had to be greater than 5, where they had been classified as fluent and non-fluent aphasia.
- PWA were able to say at least one correct word for a semantic category of the 'fruit' fluency task.
- There was no history of cognitive deficit or speech and language deficit before aphasia onset.
- All participants should have at least ten years of formal education in English / Kannada as the medium of instruction.

3.2.5 Common Inclusion Criteria Combined for Group I and Group II

- All the participants were native speakers of Kannada and information about the other language (English, Hindi, or any other language) usage was noted on a general history proforma.
- Participants had corrected vision, no visual deficits, and no sensory deficits.
- The age range was between 20-60 years.

- Participants with both right-handedness (pre-morbid duration) and left-handedness (post-morbid duration) were included in the study and were grouped respectively according to the Edinburgh Handedness Inventory(Oldfield, 1971).

3.2.6 Common Exclusion Criteria Combined for Group I and Group II

- Participants with other neurological illnesses and psychiatric disorders were excluded from the study.
- Individuals who were into substance abuse were excluded from the study.
- Participants with visual field or other sensory-perceptual deficits were excluded from the study.
- Cognitive deficits were ruled out using the Montreal Cognitive Assessment MOCA (Nasreddine et al., 2005), and individuals with scores below the cutoff (<26) were excluded from the study.

Table 3.1 below includes details of demographic data of patients with aphasia, including the type of aphasia, age/sex, and education level.

TABLE 3.1

Demographic details of the participants

GROUP I –NEUROTYPICALS			GROUP II – PERSONS WITH APHASIA				
Participant Name	**Age /Gender**	**Education**	**Participant Name**	**Age /Gender**	**Education**	**AQ**	**Aphasia Type**
P1	23/M	UG	P11	23/M	UG	59.1	Anomia
P2	35/M	PG	P12	35/M	PG	75.2	Anomia
P3	30/M	Dip	P13	30/M	Dip	62.4	Anomia
P4	22/F	UG	P14	22/F	UG	62.4	Broca’s
P5	37/M	PUC	P15	37/M	PUC	68.2	Anomia
P6	50/M	UG	P16	50/M	UG	89.9	Anomia
P7	58/M	UG	P17	58/M	UG	69.8	Anomia
P8	35/M	UG	P18	35/M	UG	70.6	Anomia
P9	37/M	UG	P19	37/M	UG	83.2	Anomia
P10	60/M	UG	P20	60/M	UG	82.8	Anomia

Note: ABBREVIATIONS: UG*- undergraduate,* ***PG****- Post graduate* ***Dip****- Diploma,* ***PUC****- Pre-university course,* ***AQ****-Aphasia Quotient*

3.4 Procedure:

3.4.1 Mode of Assessment and Seating

The study was carried out at the Department of Clinical Services. The participants/caregivers were informed about the items needed to administer the test. The participants were asked to sit comfortably in front of the table with the investigator facing them. A computer laptop was used for certain tasks and a few tasks were paper-pencil tasks. As much as possible, all possible distractions were reduced from both ends (participant and clinician). The present study assessed executive functions using the following task of verbal and non-verbal tests, as shown in Table 3.2.

TABLE 3.2

Executive functions at verbal and non-verbal tests

Sl.No	DOMAINS EXECUTIVE FUNCTIONS	COGNITIVE INHIBITION	WORKING MEMORY	COGNITIVE FLEXIBILITY
1.	VERBAL TEST	Stroop test	Digit span backward test	Alternate verbal fluency
2.	NON-VERBAL TEST	Go/No-Go test	Corsi backward block tapping test	Trail-making test

3.4.2 Domains of Executive Functions:

The domains of the executive functions considered for the present study were cognitive inhibition, working memory, and cognitive flexibility. The verbal and non-verbal tests considered under each domain along with the instructions, and scoring are explained in the following section.

3.4.2.1. Cognitive inhibition

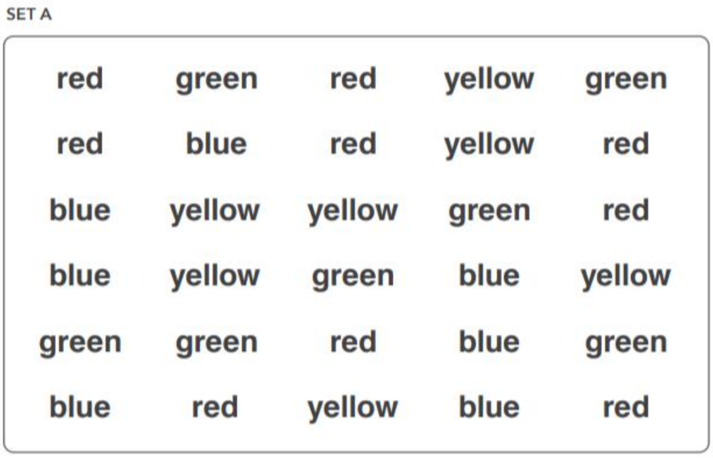
3.4.2.1.1 The Stroop Task

Task description- The Stroop task would assess cognitive inhibition during conflictual situations (Stroop, 1935). In the standard version, the task was to indicate the color of the ink, which was used to write the word, while the meaning of the word would be ignored, which usually means a color. The stimulus for the Stroop test was presented in the PowerPoint presentation, and the stimuli were typed in Times New Roman font at 50 points size. One stimulus was presented in one slide, and different slides were prepared for three conditions of the Stroop task with specific instructions in a few slides. There were three conditions in the Stroop task. In *neutral conditions* (Condition 1- color words printed in black ink), *congruent condition* (Condition 2- ink color and word meaning would be in the same color; for example, the word 'Blue' would be written in 'blue ink'), and in *incongruent conditions* (Condition 3- ink color varies with the word meaning; for example, the word 'red' would be written in 'green ink'). Both the accuracy and reaction times (RTs) difference between incongruent and congruent conditions provide information about cognitive inhibition (Stroop effect). However, for the present study, only the accuracy was taken into consideration.

Instructions- Condition-1 The participants were instructed to read a color words list (for example, red and green) printed in black ink. The sample of a total of 30 stimuli considered for the present study is shown below in Figure 3.1. For the present study, this neutral condition was used as a trial test to screen the participants' reading ability. If the participants had secured more than 5%, it was considered as pass criteria and they were considered for the study.

FIGURE 3.1

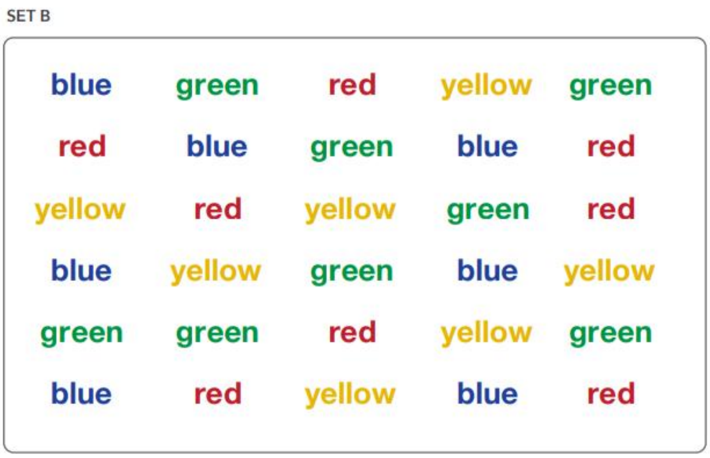
Example of neutral condition (Condition 1)



Instructions: Condition-2 The participants were instructed to read a color words list (for example, red and green) printed in the same ink. The sample of a total of 30 stimuli considered for the present study is shown below in Figure 3.2.

FIGURE 3.2

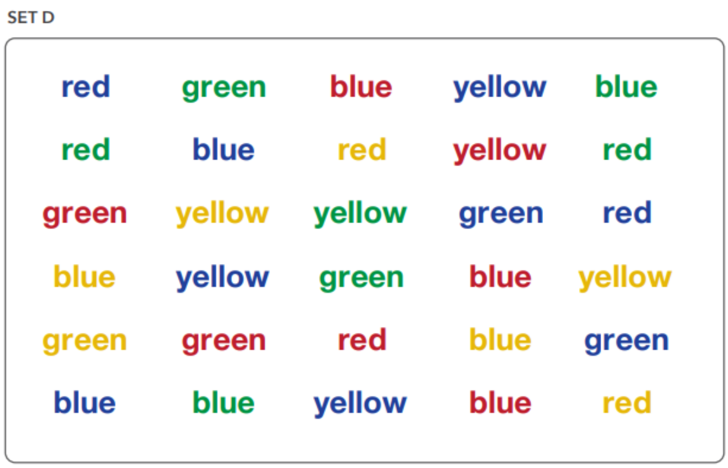
Example of Congruent condition (Condition 2)



Instructions: Condition-3 The participants were instructed to read a color words list printed in different ink (For example: 'red' printed in 'blue' ink). The participants were asked to name the color instead of reading the word. The sample of a total of 30 stimuli considered for the present study is shown below in Figure 3.3.

FIGURE 3.3

Example of Incongruent condition (Condition 3)



Scoring: Participants' responses were collected by noting the accuracy of naming the color (CS) for condition 2 and naming the color word (CWS) for condition 3, and scoring was not done for condition 1. The CS was based on how accurately the participants responded to the word that was written in the same ink, and the CWS was the color-word score, which was based on how accurately participants responded to the word that was written in different ink. For each correct response of naming color and naming the color word a score of 1 was given and for incorrect responses, a score of 0 was given.

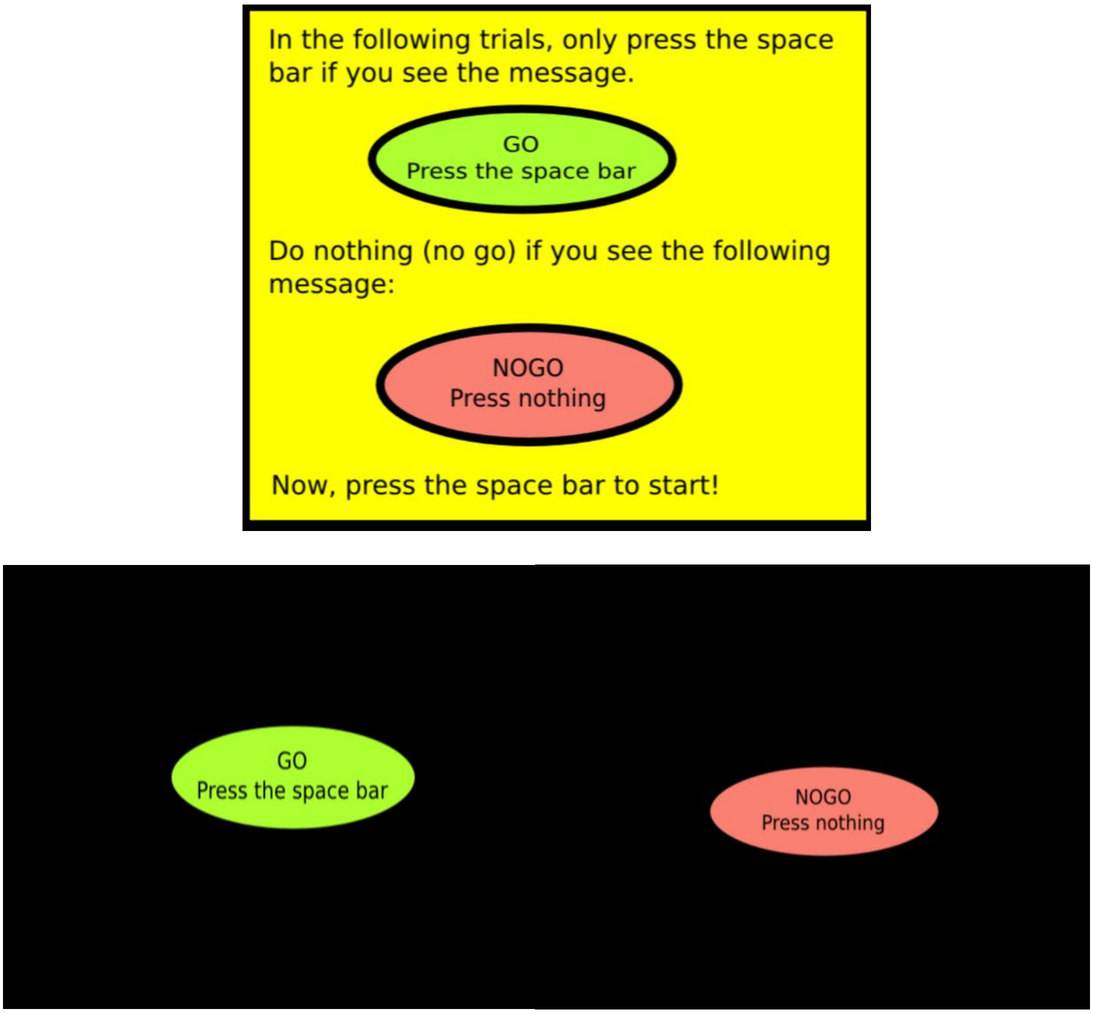
3.4.2.1.2 GO/NO-GO Task

Task description: The GO/NO-GO task was used to assess the inhibitory motor system, which was performed by responding to a given stimulus (Go stimulus) while inhibiting another similar stimulus (NO-GO stimuli) (Gordon & Caramazza, 1982). The critical motor inhibition information is represented by the number of error responses (that is the responses to NO-GO stimuli). The GO/NO-GO task was a computerized test that was run using Psytoolkit software (Stoet, 2010, 2017) on a Dell 5410 desktop laptop. There were 25 trials, of which 20 trials were for the ‘GO’ stimulus and five trials for the ‘NO-GO’ task. Instruction was also displayed on the screen. After pressing the click, the stimuli were presented. Visual stimuli were presented to the individuals via a flat-screen monitor. Participants were seated approximately 50 cm from the computer screen.

Instruction: The participants were instructed to press the space bar for the given ‘GO’ stimulus and do nothing for the given ‘NO-GO’ stimulus.

FIGURE 3.4

Example of GO/NO-GO stimulus



Scoring: Accuracy data were automatically recorded in the Psytoolkit software for correct and wrong responses. Following this, later imported into Microsoft Excel and SPSS spreadsheets for data analysis. For each correct response of Go/No-Go a score of 1 was given and for incorrect responses, a score of 0 was given.

After administering both verbal and non-verbal tests (Stroop test and GO/NO-GO test) of cognitive inhibition, each score would be entered in the score sheet of cognitive inhibition domains of executive functions (APPENDIX A)

3.4.2.2. Working Memory

***3**.4.2.2.1 Digit span backward task*

Task description: Digit span tasks are usually used to access the working memory through auditory sequencing of numbers and auditory digit span. The auditory digit span is categorized into forward and backward conditions. For the present study, only the digit span backward test was used, auditory digits were randomly presented, with an increasing level of difficulty.

Instruction: The participants were instructed to repeat the auditorily presented digit in reverse order. In this, auditory digits were randomly presented, with an increasing level of difficulty. Each time the participant responds correctly, the length of the digits is increased by 1. If the response is incorrect, the digit length is shortened by one digit. The stimulus was taken from the Wechsler's Memory Scale (WMS-IV) (Wechsler D, 2009)as shown in Figure 3.5.

FIGURE 3.5

Stimulus of Digit span backward test

Sl.no	Iems	Trails
1	Trail 1	2-1
	Trail 2	1-3
2	Trail 1	3-5
	Trail 2	6-4
3	Trail 1	5-7-4
	Trail 2	2-5-9
4	Trail 1	7-2-9-6
	Trail 2	8-4-9-3
5	Trail 1	4-1-3-5-7
	Trail 2	9-7-8-5-2
6	Trail 1	1-6-5-2-9-8
	Trail 2	3-6-7-1-9-4
7	Trail 1	8-5-9-2-3-4-6
	Trail 2	4-5-7-9-2-8-1
8	Trail 1	6-9-1-7-3-2-5-8
	Trail 2	3-1-7-9-5-4-8-2

Scoring: In the Digit span backward test, the maximum number of digits that the participant could correctly recall in the reverse order were recorded. For each correct recall, a score of 1 was given and for incorrect responses, a score of 0 was given.

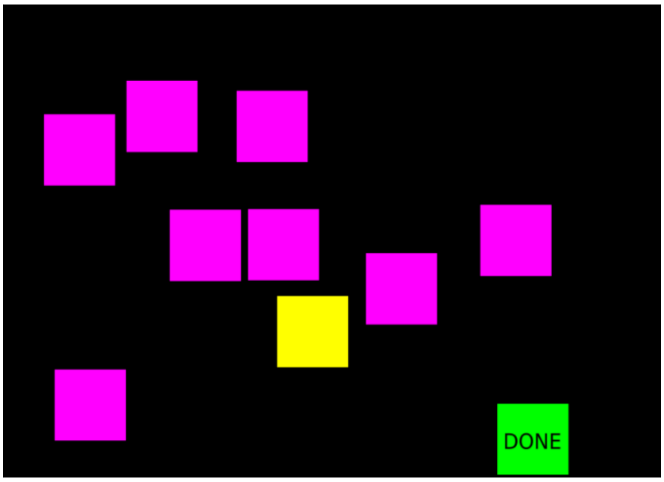
3.4.2.2.2 Corsi backward block tapping test:

Task description: The Corsi block tapping test is widely used to evaluate working memory using nonverbal stimuli, which are analog to the digit span test. This test includes two conditions, in forward conditions, participants were asked to replicate the block sequence in the same serial order. In contrast, the participants were asked to replicate the block sequence in reverse order. Reversing the serial sequence of blocks in a backward state necessitates an additional cognitive process, which increases the demand for working memory. Corsi backward block tapping is a computerized test that was run using Psytoolkit software (Stoet, 2010, 2017) on a Dell 5410 desktop laptop. Initially, the task starts with a sequence of 2 blocks. After touching the block in the reverse order, the participants would get feedback on whether the response was correct or wrong. If participants correctly performed the task, they had to move to the higher number of block sequences. The highest number of block sequences was nine. If participants performed wrongly, they would get one more chance. If they did it wrong again, the test was terminated. Visual stimuli were presented to the individuals via a flat-touch screen monitor. Participants were seated approximately 50 cm from the computer screen.

Instruction: The participants were instructed that there would be nine blocks, where in some blocks, the yellow color light would turn on in sequence. Once the sequence had been shown, the participants would hear 'go' and then they would be asked to touch the block sequence in reverse order, displayed on the screen as shown in Figure 3.5

FIGURE 3.6

Example of Corsi backward span stimulus



Scoring: The highest Corsi backward span data were automatically recorded in the Psytoolkit software for correct and wrong responses with a score of 1 for the correct response and a score of 0 for the wrong response. Following this, later imported into Microsoft Excel and SPSS spreadsheets for data analysis.

After administering both verbal and non-verbal tests (Digit span backward test and Corsi Backward Block Tapping test) of working memory, each score would be entered in the score sheet of working memory domains of executive functions (APPENDIX B).

3.4.2.3. Cognitive Flexibility

3.4.2.3.1 Alternate Verbal Fluency Task

Task description: Diamond (2013) suggests modifications to verbal fluency tests might make them more specialized for the test of cognitive flexibility, such as a switching condition between various information items (For example, fruit and animals). These types of measurement require constant altering between two or more separate pieces of information, which necessitates a stronger use of the cognitive flexibility function. Concerning Diamond (2013), the participants were instructed to mix the two categories, they were asked to say any fruit name followed by any animal name within 60 seconds.

Instruction: The participants were instructed to say any fruit name followed by any animal name within 60 seconds.

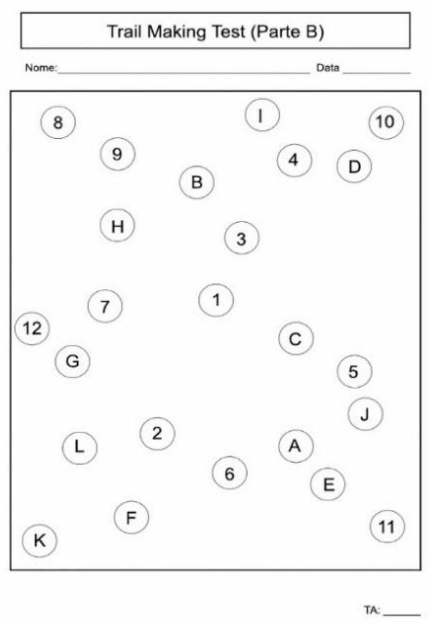
Scoring: Participants’ responses were calculated by scoring the overall correct word- pairs generated within 60 seconds. Each pair consists of a fruit followed by an animal, but the use of an animal followed by a fruit is also scored as correct, The higher the score, performance would be. For each category name a score of 1 was given and for a wrong category name, a score of 0 was given.

3.4.2.3.1 Trail-making test B

Task description: The trail-making test is often used to assess various domains of executive functions. There are two parts to Trail making test- Part A and Part B. In Part A, the participants had to draw a line to connect the consecutive numbers in ascending order from 1 to 25. Part B contains 25 circles scattered over a sheet of paper. The circles feature numbers (1 – 13) and letters (A – L) as shown in Figure 3.6. The participants will have to alternate between numbers and letters (1-A-2-B-3-C, etc.) and draw lines to link the circles in an ascending manner. The completion time for the Part B trail-making test is used to assess cognitive flexibility. The trial-making test is a simple paper-pencil neuropsychological test. Trail-making test Part B was considered for the study since it taps cognitive flexibility. Participants were asked to connect numbers and letters in ascending and alternating sequences.

FIGURE 3.7

Example for trail-making test part B



Instruction: The participants were instructed to connect numbers and letters in ascending order and alternating sequences from 1-A, A-2, and so on.

Scoring: Participants' responses were obtained by calculating the total completion time of Part B tasks (in seconds) of the making test. If an error occurred during the task, the participant was asked to correct the errors, but the stopwatch, which was used to record the time, was not stopped. A few errors were not recorded; only the total completion time taken for the task was considered as the final score.

After administering both verbal and non-verbal tests (Alternate Verbal Fluency test and Trail-Making test) of cognitive flexibility, each score would be entered in the score sheet of cognitive flexibility domains of executive functions (APPENDIX C).

After administering all three domains of executive functions in both verbal and non-verbal tests, the scores would be entered in the overall score sheet of the three domains of executive functions (APPENDIX D).

CHAPTER IV

RESULTS

The present study aimed to assess and compare executive functions through verbal and non-verbal tests in PWA and NTI. The executive function tests were carried out on twenty individuals, comprising ten in each group (neurotypicals were considered as Group 1, and persons with aphasia were considered as Group 2) in the age range of 20-60 years. A qualitative analysis was applied to all the domains of executive functions, such as cognitive inhibition, working memory, and cognitive flexibility in verbal and non-verbal tests. All executive function tests were measured in terms of accuracy score except the trail-making test, which measured the completion time, which comes under the non-verbal cognitive flexibility domain of executive functions. Thus, each domain's total score, as well as individual test scores of the verbal and non-verbal tests, were computed in terms of percentage scores except for the trail-making test and were subjected to statistical analysis using the Statistical Package for Social Science (SPSS) software (version 23.0).

The test of normality was done for the complete data using the Shapiro-Willis test which revealed that the data is not normally distributed for all variables. Since the data did not adhere to the characteristics of a normal distribution $p < 0.05$, non-parametric tests were utilized to answer all the objectives. The complete statistical analysis for executive functions was done in the following sections. **Section I:** Descriptive Statistics of verbal and non-verbal tests of executive functions. **Section II:** Comparison of verbal and non-verbal tests of executive functions between NTI and PWA. **Section III:** Comparison of three domains of executive functions within NTI and PWA. **Section IV:** Correlation between AQ score of WAB and executive function score in PWA.

4.1 Section I: Descriptive Statistics of verbal and non-verbal tests of executive functions.

The findings of descriptive statistics for verbal and non-verbal tests of executive functions for NTI and PWA in terms of the mean, median, and standard deviation in terms of accuracy and completion time for cognitive inhibition, working memory, and cognitive flexibility are shown in Table 4.1.

To discuss further, by comparing the mean, median, and standard deviation of both the groups, NTI performed better in both verbal Stroop test and non-verbal GO/NO-GO tests of cognitive inhibition than PWA concerning the accuracy score. Particularly in the Stroop test, a verbal measure of cognitive inhibition, both groups performed identically when comparing the median under congruent conditions, but as task complexity grew under incongruent conditions, both groups performed poorly. In terms of the overall performance of cognitive inhibitions, NTI outperformed PWA.

In the working memory domain, when the mean, median, and standard deviation of the two groups were compared, NTI outperformed PWA in both verbal and non-verbal tasks in terms of accuracy score, that is, the highest digit that was obtained in digit span backward test and Corsi backward span test. NTI had better performance in overall scores of both verbal and non-verbal tests than PWA.

Both accuracy score and completion time accounted for the cognitive flexibility domain, the accuracy score was considered for the alternate verbal fluency test, and the completion time was considered for the trail-making test, which measured the verbal and non-verbal cognitive flexibility, respectively. NTI was able to say the maximum number of pairs (fruit and animal alternatively) and also took less time to complete trail making test than PWA who were able to say a smaller number of pairs and took a longer time to complete trail making test.

TABLE 4.1

Results of Descriptive Statistics for verbal and non-verbal test of executive functions

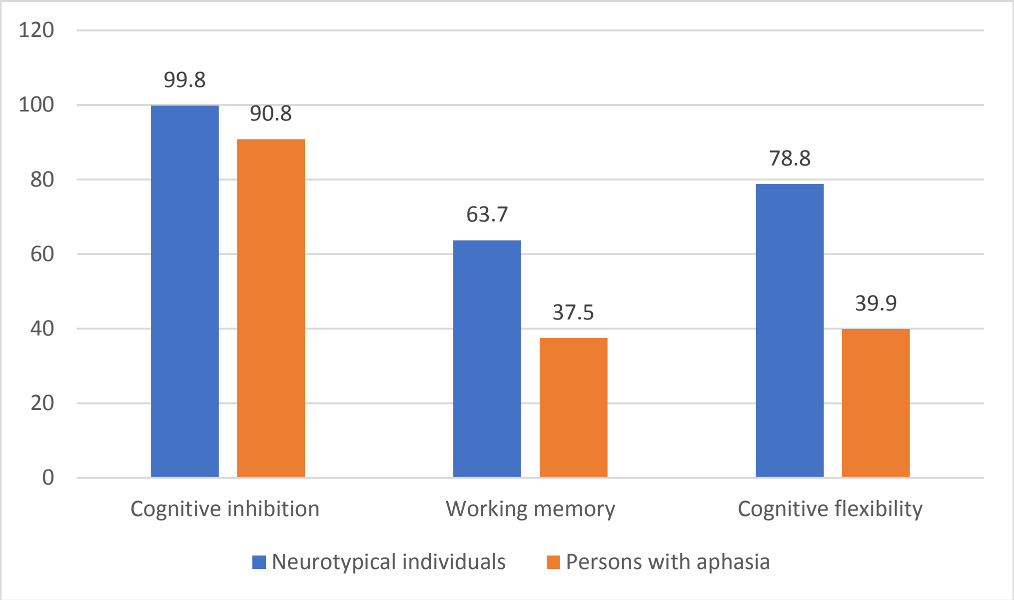
Executive function Tasks	otypical Individuals (NTI) Group I			Persons with aphasia (PWA) Group II		
	Mean	**Median**	**Standard Deviation**	**Mean**	**Median**	**Standard Deviation**
			Cognitive inhibition			
Stroop-CS	100	100	0.000	98.65	100	2.352
Stroop-CWS	99.6	100	1.075	82.96	83.3	12.795
Stroop total (verbal)	99.8	100	0.537	90.8	91.6	7.754
Go/no-go (non-verbal)	99.2	100	1.686	94.8	96	5.977
Total	99.5	100	1.041	92.8	92.98	4.800
			Working memory			
DSBT (verbal)	63.7	62.5	14.965	37.5	37.5	8.333
CBST (non-verbal)	72.5	75	19.364	48.7	50	21.610
Total	68.1	68.7	13.959	43.1	43.7	14.568
			Cognitive flexibility			
AVF (verbal)	78.8	83.2	16.942	39.9	44.4	15.871
TMT (non-verbal)	63.5	66.5	14.706	243.9	265	89.610

Note: Stroop -CS- Stroop color score, Stroop-CWS- Stroop color word score, DSBT- digit span backward test, CBST- Corsi backward span test, AVT- alternate verbal fluency test, TMT- trail making test.

The mean of verbal tests of cognitive inhibition, working memory, and cognitive flexibility domains of executive functions for NTI and PWA are graphically represented in Figure 4.1.

FIGURE 4.1

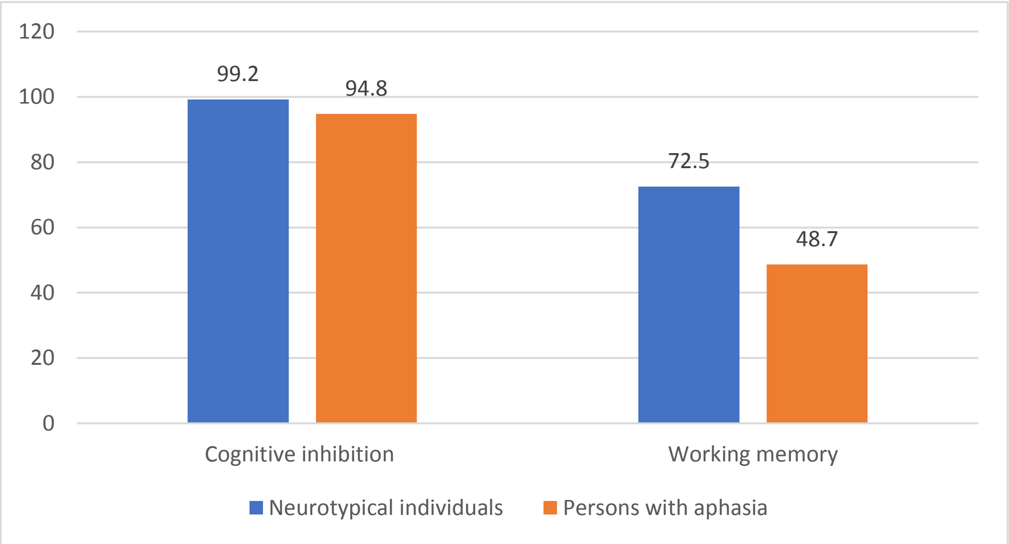
Verbal test of three domains of executive functions in both groups.



The mean of non-verbal tests of cognitive inhibition and working memory domains of executive functions for NTI and PWA are graphically represented in Figure 4.2.

FIGURE 4.2

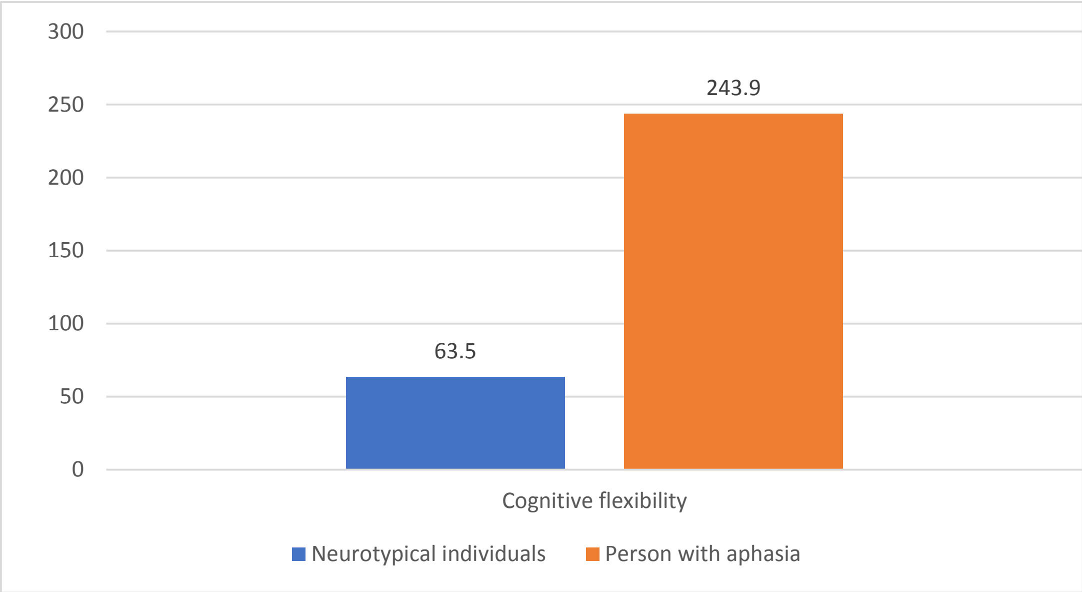
Non-verbal test of cognitive inhibition and working memory domains of executive functions in both groups.



The mean of non-verbal tests of cognitive flexibility domains of executive functions for NTI and PWA are graphically represented in Figure 4.3.

FIGURE 4.3

Non-verbal test of cognitive flexibility domain of executive functions in both groups.



4.2 Section II: Comparison of verbal and non-verbal tests of executive functions between NTI and PWA (Between-group).

The performance of executive functions across all the domains in terms of verbal and non-verbal tests was compared between NTI and PWA. For this between-group comparison, the Mann-Whitney test was administered. The results revealed that the performance of NTI and PWA at verbal tests of cognitive inhibition, working memory, and cognitive flexibility domains of executive functions were statistically significantly different (/Z/ values ranging from -3.34 to -3.55; $p < 0.01$), and there was a statistically significant difference for the non-verbal test of cognitive inhibition, working memory and cognitive flexibility domains of executive functions (/Z/ values ranging from -2.35 to -3.78; $p < 0.01$). The results of the Mann-Whitney test for the cognitive inhibition, working memory, and cognitive flexibility domains of executive functions for both verbal and non-verbal tests between NTI and PWA are tabulated in Table 4.2.

TABLE 4.2

Results of the Mann-Whitney Test between NTI and PWA for the verbal and non-verbal tests of executive functions

Executive functions Task	Cognitive inhibition		Working memory		Cognitive flexibility	
	/Z/	***P* value**	**/Z/**	***P* value**	**/Z/**	***P* value**
Verbal test	-3.55	0.00**	-3.34	0.01	-3.54	0.00**
Non-verbal test	-2.35	0.019**	-2.18	0.029*	-3.78	0.00**

Note ** P<0.01

4.3 Section III: Within-group comparison:

4.3.1 Comparison of three domains of executive functions of verbal tests within NTI and PWA:

The within-group comparison was studied using the Friedman test, a non-parametric test, to find the significant difference between the domains of executive functions concerning verbal tests in NTI and PWA. Friedman's test results revealed that there was a significant difference in cognitive inhibition, working memory, and cognitive flexibility domain of executive functions in both NTI, $\chi 2$ (2, 10) = 14.105, $p < 0.01$ and PWA, $\chi 2$ (2, 10) = 15.200, $p < 0.01$ respectively. The results of Fridman's test for domain differences in NTI and PWA are tabulated in Table 4.3 and Table 4.4, respectively.

Since there was a significant difference in Friedman's test and confirming the significant difference between the three domains of executive functions in both NTI and PWA, a pairwise comparison was made, which revealed that there was a significant difference between cognitive inhibition versus working memory domain of executive functions (Pair 1) in both NTI and PWA (*p* <0.01). Also, there was a significant difference between cognitive flexibility versus cognitive inhibition domain of executive functions (Pair 2) in both NTI and PWA (*p* <0.05). However, there were no statistical differences between working memory and cognitive flexibility domain (Pair 3) in both NTI and PWA. Results of Friedman's test for pairwise comparison between three domains of Neurotypical Individuals and persons with aphasia are tabulated in Table 4.5

TABLE 4.3

Results of Friedman's test for pairwise comparison between three domains of executive functions for Neurotypical Individuals and Persons with Aphasia

Pairwise comparisons of Verbal test	**Neurotypical Individuals**	**Persons with Aphasia**
	***P*-Value**	***P*-Value**
Cognitive inhibition vs. working memory (Pair 1)	0.001**	0.001**
Cognitive flexibility vs. cognitive inhibition (Pair 2)	0.042*	0.05 *
Working memory vs. cognitive flexibility (Pair 3)	0.79	1.000

Note: * P <0.05, ** P<0.01

4.3.2 Comparison of two domains of executive functions of non-verbal test (cognitive inhibition and working memory) within NTI and PWA:

Wilcoxon sign-rank test was done to find the pairwise comparison between two domains of executive functions in terms of non-verbal tests in NTI and PWA. The result revealed that there was a statistically significant difference between the domains in non-verbal tasks, that is, cognitive inhibition versus working memory (/Z/= -2.81, P < 0.01) in NTI and (/Z/= -2.80, P < 0.01) in PWA respectively. Results of the Wilcoxon Signed Rank test for pairwise within-group comparison of non-verbal tests are tabulated in Table 4.6.

TABLE 4.4

Results of Wilcoxon Signed Rank test for pairwise within-group comparison of non-verbal test:

Pairwise comparisons of Verbal test	**Neurotypical individuals (NTI)**		**Persons with aphasia (PWA)**	
	/Z/	***p-value***	**/Z/**	***p-value***
Cognitive Inhibition versus Working Memory	-2.81	0.005**	-2.80	0.005**

Note *p value <0.01

4.3.3 Comparison of verbal and non-verbal tests of two domains of executive functions (cognitive inhibition and working memory) within NTI and PWA:

Wilcoxon sign-rank test was done to find the within-group comparison of verbal and non-verbal tests of two domains of executive functions (cognitive inhibition and working memory) in NTI and PWA. The result revealed that there was no statistically significant difference between verbal and non-verbal tests of cognitive inhibition and working memory domain of executive functions in both NTI and PWA. Results of the Wilcoxon Signed Rank test for pairwise within-group comparison of verbal and non-verbal tests of two domains of executive functions are tabulated in Table 4.7

TABLE 4.5

Results of Wilcoxon Signed Rank test for within-group comparison of verbal and nonverbal test of two executive functions

Verbal vs. non-verbal tests of executive functions	**Neurotypical individuals (NTI)**		**Persons with aphasia (PWA)**	
	/Z/	***p-value***	**/Z/**	***p-value***
Cognitive inhibition	0.00	0.18	33.0	0.21
Working memory	21.5	0.20	37.5	0.06

4.3.4 Correlation of verbal and non-verbal test of cognitive flexibility in NTI and PWA

Since there were no possibilities to compare the results of the verbal test, which measures accuracy score, and the non-verbal test, which measures completion time of cognitive flexibility, the correlation between the alternate verbal fluency test and the trail-making test, which is the verbal and non-verbal tests of cognitive flexibility, was determined using Spearman's rank correlation test. The result revealed that a negative correlation was found between the trail-making test and the alternate verbal fluency test of cognitive flexibility in NTI and PWA. This correlation was found to have no statistical significance in neurotypical individuals, but there was a statistically significant correlation found between the trial-making test and alternate verbal fluency test in persons with aphasia. The results of Spearman’s rank-order correlation between the trail-making test and alternate verbal fluency test are tabulated in Table 4.

TABLE 4.6

Results of Spearman's rank-order correlation between trail making test and alternate verbal fluency tests of cognitive flexibility

Domain of executive functions	Neurotypical individuals (NTI)		Persons with aphasia (PWA)	
	r **value**	***p-value***	***r value***	***p-value***
Cognitive flexibility	-0.096	0.70	-0.701	0.02*

Note: $^{*}p < 0.05$

4.4 Section IV: Correlation between executive function score and AQ score of WAB in PWA.

Spearman's rank correlation test was done to find out the correlation between the aphasia quotient of the WAB score and performance on three domains of executive function tests in PWA. The result revealed a positive correlation found between the aphasia quotient and non-verbal test of cognitive inhibition and verbal test of cognitive flexibility, whereas a negative correlation was found between the aphasia quotient and verbal test of cognitive inhibition, working memory, and non-verbal test of cognitive flexibility. However, this correlation was found to have no statistical significance in persons with aphasia. The result of Spearman's rank order correlation between the aphasia quotient and three domains of executive functions is tabulated in Table 4.9.

TABLE 4.7

Results of Spearman's rank-order correlation between aphasia quotient and three domains of executive functions

Correlation -Aphasia quotient and Cognitive inhibition	**r value**	***p-value***
Verbal	-0.204	-0.57
Non-verbal	0.61	0.80
Correlation -Aphasia quotient and Working memory	**r value**	***p-value***
Verbal	-0.138	0.7
Non-verbal	-0.086	0.80
Correlation-Aphasia quotient and Cognitive flexibility	**r value**	***p-value***
Verbal	0.059	-0.061
Non-verbal	0.8	0.8

CHAPTER V

DISCUSSION

The study aimed to measure executive functions in PWA and NTI to identify whether an executive function deficit exists in PWA. For more than a decade, non-verbal tests have been performed to measure executive functions in PWA to decrease the impact of impairment of linguistic ability, even though testing executive functions through nonverbal task have confounds in which distinct concept may be elicited by non-executive motor and visuospatial processes than by assessing executive functions through verbal tests (Keil & Kaszniak, 2002). However, according to other studies (Fonseca et al., 2018), non-verbal tests are more crucial to identifying cognitive reversal in PWA, which foretells the recovery of aphasia. Also, there is evidence from the study that limited linguistic ability does not influence assessing executive functions through verbal tests (Kendrick et al., 2019).

Hence, in the present study, the executive functions were assessed in terms of three domains, that is, cognitive inhibition, working memory, and cognitive flexibility, using both verbal and non-verbal tests. Both verbal and non-verbal tests were administered to identify the presence of executive function deficits following linguistic impairment due to stroke in PWA, to identify whether non-verbal performance is dominant over the other due to existing linguistic impairment, and to explore the association between linguistic impairment and deficits in executive function. The results of this executive function assessment are discussed in the following sections.

5.1 Difference in NTI and PWA for the verbal and non-verbal tests of executive functions:

The results of the present study made it abundantly clear that PWA fared much worse than NTI in all the domains of executive functions like cognitive inhibition, working memory, and cognitive flexibility in terms of both verbal and non-verbal tests. There was a significant difference in the accuracy score of the Stroop test and Go/no-go test for the cognitive inhibition domain, digit span backward test and corsi block tapping test for the working memory domain, and alternate verbal fluency test for the cognitive flexibility domain, and completion time of trail making test B for cognitive flexibility domains in PWA and NTI.

These executive function deficits in PWA, especially for the Stroop test, which is the verbal test of the cognitive inhibition domain, PWA performed poorly in incongruent conditions compared to the congruent condition. There could be two possible explanations, One could be the higher sensitivity to the interference effect that PWA demonstrates and this suggests that there are not enough attentional resources available to deal with interfering stimuli. To put it another way, these enhanced interference effects for PWA may point to a worse ability to suppress irrelevant knowledge relative to NTI due to improperly managed attention allocation. This is in support of various studies (Wiener et al., 2004; McNeil et al., 2010; Pompon et al., 2015).

Another explanation could be concerning the PET neuroimaging investigation (Jonides et al., 1998), and was discovered that the incongruent condition activated Broadmann's area 45 more than the congruent condition did in the left inferior frontal gyrus. The findings indicate that inhibiting the irrelevant information, which was most frequently impacted in PWA, may take place in this left inferior frontal region. Because PWA involves an analogous neuroanatomical region, it may likewise have an impact on the executive functions' cognitive inhibition process.

Even in non-verbal tests of the cognitive inhibition domain, the Go/no-go test, PWA fared worse than NTI. The possible reason would be that there was a greater need for internal verbalization to stabilize perceptual discrimination when visual stimuli were identical on a higher level. According to the "verbal-loop hypothesis," people with aphasia have even more trouble understanding these verbal codes since they are more complicated when dealing with novel abstract visual content. The visual stimuli of the Go-No-Go task may require linguistic processing to recognize the stimuli; this skill is reduced in PWA which lowers the speech of response (Spaccavento et al., 2019).

Concerning the working memory domain of executive functions, both verbal and non-verbal tests showed that PWA performed worse than NTI. In comparison to the digit span forward test, which emphasizes only the storage and maintenance of WM, the digit span backward test is thought to be a more complex task because it needs both storing of knowledge and simultaneous processing which is necessary for cognitively rearranging the knowledge. Overall, the Digit span test stimulates the central executive, for visual stimulus visuospatial sketchpad, and the phonological loop, depending on how much manipulation is required. On average, PWA scored 3 and 4 in the digit span backward test and corsi backward block tapping test, respectively, whereas the NTI scored 5 and 6 in the digit span backward test and corsi backward block tapping test, respectively. The poor performance of PWA in working memory tests could be due to impaired phonological loop deficits, limited capacity of the central executive, and insufficient resource allocation (Waters & Caplan, 1996). These phonological loop deficits may also contribute to comprehension deficits and impaired language learning and performance (Murray, 2004). These findings are also supported by other studies (Mayer & Murray, 2012; Wright & Shishler, 2005), which illustrate that there are disparities in the ability of the working memory between PWA and NTI using the following tests, word span, forward, and backward digit span, judgment task and the n-back task.

The neural correlates for working memory tasks have been investigated in several studies considering NTI using PET and fMRI scan procedures. More precisely, investigations included tasks intended to assess the frontal and parietal areas of the brain, which are the correlates of the phonological loop. The prefrontal cortex, or dorsolateral prefrontal cortex (DLPFC), and Broca's area are involved in frontal areas. According to several studies (Barch et al., 1997; Smith & Jonides, 1997; Smith et al., 1998; Newman et al., 2002), the DLPFC is linked to the active preservation of information. A rise in DLPFC activation indicates that this region holds onto maintaining the knowledge as other knowledge is being processed. According to several studies (Jonides et al., 1998; Newman et al., 2002; Smith et al., 1998), Broca's region has also been activated and the function is to facilitate verbal rehearsal. Additionally essential to verbal working memory is the parietal cortex, which has been repeatedly activated in investigations. Others have confirmed the findings of Jonides et al. (1997), who hypothesized that the posterior parietal cortex regulates the maintenance of linguistic information (Newman et al., 2002; Smith & Jonides, 1997; Smith et al., 1998). Hence, PWA usually has damage to the left frontal or left parietal cortices in their brains, and they may show signs of working memory impairment. These findings are supported by (Burgio and Basso,1997; Caspari et al., 1998), where patients with left hemisphere injuries performed noticeably worse on verbal memory and spatial memory tests as compared to neuro-typical individuals.

The numerous factors relating to the individual participants would have contributed to the results. Participants in the NTI and PWA used divergent approaches. Some participants seemed to rehearse verbally the order of the visual picture and keep track of how many were there in the correct order. As a result, some participants were able to organize responses in reverse order or not at all. The NTI group participants were able to identify an effective approach quickly, giving them an edge over the PWA group participants, who took longer to do so.

In the present study, all PWA with left hemisphere damage performed poorly in non-verbal working memory tasks Corsi backward block tapping test. According to Baddeley's model (Baddeley, 1992), spatial working memory involves a visuospatial sketchpad that is triggered to maintain places and order in the brain for a short period. In addition, it also needs central executive as well as attentional control, which is engaged to manipulate information needed for backward spatial span (Baddeley, 1992.; Hester et al., 2004; Wilde et al., 2004). Even though earlier investigation explains the right hemisphere is predominantly responsible for visuospatial abilities, this is also true for visuospatial working memory (Kessels et al., 2002; Smith et al, 1996). In contrast to the above findings, in the present study, it was found that PWA with left hemisphere damage performed poorly. The possible reason for the above findings would be because of the fact, that these spatial working memory tests rely on verbally mediated strategies. Neuroimaging studies have evidence that lesions in front and posterior areas of the brain may disrupt spatial span working memory-supporting domain-general dorsal attention network made up of the superior frontal cortex and the intraparietal sulcus as well as a left frontoparietal network consisting of left somatosensory cortex, lateral prefrontal cortex, frontal eye fields, and the supramarginal gyrus (Majerus et al., 2016; Paulraj et al., 2018).

In the cognitive flexibility domain, in both verbal and non-verbal tests, the Alternate verbal fluency test and Trail making test B, PWA performed worse than NTI. The possible reason could be that the cognitive flexibility domain involves various other cognitive processes, such as creating a variety of ideas, considering alternate responses, and altering decisions to handle changing scenarios. PWA made errors, demonstrating their inability to establish and formulate a new set of rules and the attachment to the existing set of rules. NTI effectively limited earlier response sets by formulating flexible rules that they could adjust to. This discovery of reduced innate control mechanisms (reorganization and interference) by PWA confirms and extends the results of the Mecklinger et al., (1999) study, which found that altering between two visuo-graphical tasks costs much effort for language impairment and left-hemisphere damage individuals. They explained these deficiencies as being caused by ineffective interference suppression and challenges with cognitive process reconfiguration. Similar findings were also supported by Chiou and Kennedy (2009). In addition, there would be another possible reason that, even though PWA had diminished cognitive flexibility process because of ineffective interference suppression and reorganization process, the extended completion time for the trail-making test would also be influenced by existing motor difficulties. This should also be kept in mind while deciding about executive function deficits, especially when using trail-making tests to assess the cognitive flexibility domain. These findings are also supported by Gaudino et al. (1995), who stated that trail making test Part B is more challenging than Part A due to complex cognitive reliance as well as a greater need for motoric coordination and speed, and visual attention.

5.2 Difference in three domains of executive functions of NTI group and PWA group

5.2.1 Comparison of verbal tests of three domains of executive functions and non-verbal tests of cognitive inhibition and working memory domain of executive functions:

All three domains of executive functions, cognitive inhibition, working memory, and cognitive flexibility, were compared within PWA and NTI to identify the difference between the performance of three different cognitive processes. The study findings revealed that there was a significant difference between cognitive inhibition and the other two domains of executive functions, working memory and cognitive flexibility, in both PWA and NTI. The participants performed better in the cognitive inhibition domain compared to working memory and cognitive flexibility domains in verbal tests, and the participants performed better in the cognitive inhibition domain compared to working memory in non-verbal tests. The possible reason could be that the cognitive inhibition process relies on inhibiting irrelevant information and selecting relevant information and additional attentional resources. But the working memory process requires attentional resources, resources availability for processing and storage, a resource for the maintenance of memory and attention for perception, and a resource for attentional control, also it requires cognitive inhibition to block the irrelevant information from the working memory workspace, which holds and manipulates the temporary information. Hence, working memory is a complex process that does not only rely on single cognitive domains but also requires two or more processes to perform the working memory tasks. These findings are also supported by other studies as well (Diamond, 2013; Husher & Zucks, 1988; Zacks & Hasher, 2006).

Another possible explanation could be that since both cognitive inhibition and working memory share a limited-capacity system, raising the demand for one process will reduce the other's ability to accomplish its tasks. As we previously discussed, working memory needs two or more cognitive processes to perform the activity which makes it even more complex for the working memory process to perform the tasks in both PWA and NTI. Concerning the above findings, “Engle and Kane define WM as the ability to (a) maintain selected information in an active, easily retrievable state while (b) inhibiting (blocking) distractors and interference (short-term memory + interference control) at the attentional and cognitive levels” (Kane & Engle, 2000).

As we discussed above, even the cognitive flexibility domain also requires a cognitive inhibition process because cognitive inflexibility depends on the concept of prepotency or the capacity to suppress the previous response set to shift to a new response set or a concept. Hence, cognitive flexibility requires two or more cognitive processes to shift an activity. Both PWA and NTI found it quite difficult to perform the task when compared to performing the individual task for cognitive inhibition, which only requires inhibiting irrelevant information and selecting relevant information.

These findings are supported by a study (Kendrick et al., 2019), which investigated all three domains of executive using high and low-verbal tasks and suggested that in cognitive flexibility tasks, participants must process the task they are supposed to do, process task inputs, and choose the proper response while keeping in mind the task instructions. It was reported from the participant's feedback that switching was more difficult and time-consuming than the other activities.

To conclude, cognitive inhibition is a single process that works independently, but working memory and cognitive flexibility are complex cognitive processes that rely on the cognitive inhibition domain as well. Hence, PWA and NTI find it easier to perform cognitive inhibition tests compared to working memory and cognitive flexibility in both verbal and non-verbal tests. These findings are also supported by Kendrick et al. (2019), which stated that Aphasia makes individuals more susceptible to errors when performing tasks that require keeping track of various sources of information, including switching or updating.

5.2.2 Comparison between verbal and non-verbal tests within NTI and PWA:

The other aim of the present study is to compare verbal and non-verbal tests in each domain within PWA and NTI to identify whether there is any performance difference between verbal and non-verbal tests. In the present study, results showed that there is no significant difference between verbal and non-verbal tests in cognitive inhibition and working memory domains of executive functions in both PWA and NTI.

PWA fared worse than NTI on both verbal and non-verbal assessments in the cognitive inhibition domain. The possible reason could be that when visual stimuli are identical on a higher level, even a nonverbal cognitive inhibition task needs internal verbalization to stabilize perceptual discrimination. From the results of the present study, it could be understood that executive control deficits in aphasia appear to be domain-general rather than language-specific because of their obvious insensitivity to verbal task demands.

Although PWA scored worse than NTI in working memory domains, they did so in both verbal and non-verbal tests, namely the digit span backward test and the Corsi backward test. A possible explanation could be that even though the right hemisphere controls spatial memory tasks, it has been argued that the left hemisphere oversees processing or storing subsequent inputs regardless of the modality (Chein et al., 2003; Potagas et al., 2011).

Another possible explanation could be the use of masked verbal methods for recalling spatial stimuli. A similar finding was observed in various studies (Kendrick et al., 2019; Murray, 2004) where high verbal and low verbal executive functions tests were carried out, which stated that verbal load did not consistently affect PWA and NTI's performance in terms of response time or accuracy. Response times in PWA generally slow down the response time across all categories, when compared to NTI, and they perform less accurately on updating and switching tasks. Given that verbal load is irrelevant, the results do indicate that the processing of language is not necessary for the successful completion of executive control tasks. The above findings are also supported by

To conclude, even though the participants with language impairment, when given a verbal executive control task, may depend on language-independent inhibiting, switching, and updating skills. Thus, it paved the way for us to use verbal tests for executive functions, which were pre-assumed that performing verbal tests in PWA would be influenced by linguistic impairment. Hence, administering the verbal tests for executive functions can either support findings based on nonverbal testing, or they might even be more sensitive and identify issues that would not have been noticed otherwise. Having a thorough comprehension of someone's problems and resources could influence the amount of participation and engagement.

5.2.3 Correlation between Alternate verbal fluency and trail-making test of cognitive flexibility in NTI and PWA:

Correlation between alternate verbal fluency and trail-making test have revealed that there is a significant negative correlation between the verbal and non-verbal test of cognitive flexibility domains in PWA. Since the PWA had fewer correct words on alternate verbal fluency tests and increased completion time for the Trail-making test. The following studies (Schumacher et al., 2019; 2022) investigated verbal and non-verbal cognition tests in 38 PWA with left hemisphere stroke, where they found a significant correlation with verbal fluency tests and other non-verbal cognition tests, which also supports the above findings. However, there is no significant correlation between verbal and non-verbal tests of cognitive flexibility domains in NTI.

5.3 Correlation between executive functions deficits and language deficits in PWA:

The present study aimed to identify the relationship between language impairment and executive function deficits. The present study revealed that there is no significant correlation between executive function deficits and language deficits in both verbal and non-verbal tests. These results demonstrate that linguistic severity does not predict executive function difficulties. The supporting studies (Helm-Estabrooks, 1995; Helm-Estabrooks, 2002) investigated the cognitive status with varying levels of severity in PWA through the Cognitive-Linguistic Quick Test (CLQT)(Helm-Estabrooks, 2001), which comprises four linguistic tasks as well as non-linguistic tasks. It suggested that it was unable to anticipate the accuracy of non-verbal skills, including memory, executive function, visuospatial ability, and attention, depending on the aphasia severity. Thus, this study offers further support that language deficiencies cannot be used to predict the apparent integrity of other cognitive areas.

In contrast, studies done by Fucetola et al, (2009) and Mohapatra and Marshall, (2020), suggested that there was a moderate correlation between the language impairment severity obtained using the WAB-R aphasia quotient score and executive functions. Even though there was a moderate correlation, they support the notion that significant and distinct contributions from the right hemisphere are made to nonverbal cognition. The possible reason could be that they have considered only non-verbal cognitive measures irrespective of three domains of executive functions. However, other findings from the study (Lee & Pyun, 2014) assessed nine cognitive functions that included both verbal and non-verbal tests, which revealed that there was only a correlation between the digit span test and the trail-making test and supported the notion that PWA's nonverbal cognitive abilities are not entirely explained by the severity of their aphasia, pointing to other potential causes that right hemisphere is predominately involved in this area of cognition. Hence, there is a mixed finding; future research must be carried out in a larger population with homogenous groups with varying levels of severity.

CHAPTER VI

SUMMARY AND CONCLUSION

The present study aimed to assess and compare executive functions through verbal tasks and non-verbal tasks in persons with aphasia (PWA) and neuro-typical individuals (NTI). The objectives of the study were,

1. To assess executive functions in PWA and NTI through verbal and nonverbal tasks.
2. To evaluate the performance on the verbal and non-verbal tests of executive functions in terms of accuracy score for cognitive inhibition (Stroop test, Go/No-go test), working memory (Digit span backward test, Corsi block tapping test), cognitive flexibility (Alternate verbal fluency test), whereas test completion time would be accounted for cognitive flexibility (Trail making test) in PWA and NTI.
3. To assess and compare the three domains of executive function, cognitive inhibition, working memory, and cognitive flexibility in PWA and NTI.
4. To study the correlation between language deficits (AQ score of WAB) and executive function deficits in PWA.

Standard group comparison was utilized in the present study consisting of two groups, the clinical group (PWA) and the control group (NTI), with ten participants in each group. All the participants were native Kannada language speakers; additionally, their vision and hearing acuity were within normal ranges. Based on inclusion criteria and exclusion criteria, all the participants were allotted to the groups. Every participant gave consent to take part in the study and gave their general history and demographic information. Montreal Cognitive Assessment MOCA was used to identify any cognitive issues.

6.1 Executive functions at verbal and non-verbal tasks:

The data collection involved assessing all three domains of executive functions in both verbal and non-verbal tests, using the Stroop test and Go/No-go test for the cognitive inhibition domain, Digit span backward test, and Corsi backward block tapping test for the working memory domain and alternate verbal fluency and Trail-Making test for cognitive flexibility domain in PWA and NTI. The participants were instructed to sit comfortably in front of the table with the investigator facing them. A computer laptop was used for certain tasks, and a few tasks were paper-pencil tasks. As much as possible, all possible distractions were reduced from both ends (participant and clinician). The accuracy scores were considered for all tests of three domains of executive functions except the Trail-making test, which considered completion time. Both accuracy score and completion time were tabulated and accounted for further statistical analysis.

The major findings of the present study for three domains of executive functions are discussed under three sections, the between-group comparison, within-group comparison, and correlation between language deficits using the AQ score of Western Aphasia Battery (WAB) and executive functions deficits. Descriptive statistics mean, median, and standard deviation for accuracy score for all three domains of executive functions and completion time for the trail-making test of cognitive flexibility domain of executive functions were obtained for PWA and NTI. It was observed that accuracy score and completion time were better for NTI and PWA in all three domains of executive functions in both verbal and non-verbal tests.

For between-group comparison, to identify the significant difference between PWA and NTI in all three domains of executive functions in both verbal and non-verbal tests, the Mann-Whitney U test was done. The result revealed that there were significant differences between PWA and NTI in all cognitive inhibition, working memory, and cognitive flexibility domains of executive functions in both verbal and non-verbal tests in which PWA performed poorly than NTI. The possible reasons could be enhanced interference effects and improperly managed attention allocation for cognitive inhibition, impaired phonological loop deficits, limited capacity of the central executive, insufficient resource allocation for working memory, and ineffective interference suppression and difficulties with the reconfiguration process for cognitive flexibility domain.

For within-group comparison, the Friedman test was utilized to identify the significant difference between the domains of executive functions concerning verbal tests in NTI and PWA. The results revealed that there was a significant difference within the three domains of executive functions, and by comparing the median score, the cognitive inhibition domain performed well by both PWA and NTI, then the cognitive flexibility domain and working memory domains were poorly performed. However, there was a significant difference between cognitive inhibition versus working memory domain of executive functions (Pair 1) in both NTI and PWA. Also, there was a significant difference between cognitive flexibility versus cognitive inhibition domain of executive functions (Pair 2) in both NTI and PWA. However, there were no statistical differences between working memory and cognitive flexibility domain (Pair 3) in both NTI and PWA.

To identify a significant difference between two domains (cognitive inhibition and working memory) of executive functions concerning the non-verbal test in NTI and PWA, the Wilcoxon signed-rank test was used. The result revealed that there was a significant difference between the two domains of executive functions in non-verbal tests, in which the cognitive inhibition domain performed better than the working memory domain of executive functions in both PWA and NTI. The possible reason could be that cognitive inhibition is a single process that works independently, but working memory and cognitive flexibility are complex cognitive processes that rely on the cognitive inhibition domain as well. Hence, PWA and NTI find it easier to perform cognitive inhibition tests compared to working memory and cognitive flexibility in both verbal and non-verbal tests.

To find significant differences between verbal and non-verbal tests of two domains of executive functions (cognitive inhibition and working memory) within NTI and PWA, the Wilcoxon signed-rank test was used. The result revealed that there was no significant difference between the verbal and non-verbal tests of executive functions in both NTI and PWA. The finding indicates that, even though the participants with language impairments, they could rely on their language-independent inhibiting, switching, and updating abilities for a verbal executive control task. Thus, it paved the way for us to use verbal tests for executive functions, which were pre-assumed that performing verbal tests in PWA would be influenced by linguistic impairment.

To identify the correlation between verbal and non-verbal tests of cognitive flexibility domains in PWA and NTI, Spearman's rank-order correlation test was used. It revealed that there was a significant correlation between verbal and non-verbal tests of cognitive flexibility only in PWA and not in NTI.

To identify the correlation between language deficits and executive function deficits in PWA, Spearman's rank-order correlation tests were used, which revealed that there was no significant difference between language deficits and executive function deficits in PWA. These findings show that the integrity of executive functions is not used to predict language impairment in PWA. However, it has to be addressed in larger populations with homogenous groups with varying levels of severity.

6.2 Clinical implication:

This study provides very good insight into the importance of using verbal tests in addition to the non-verbal test for assessing executive functions in PWA. The present study would advocate for a clinically oriented strategy for administrating and interpreting the tests instead of supporting or hindering the specific test administration in particular individuals. Importantly, as the present study findings highlight, it is frequently more instructive to do a task than to assume that a patient would not be able to complete it. The present study wants to emphasize that, just as with any other patient population, the entire profile is essential when evaluating the results in PWA. Hence, administering the verbal tests for executive functions can either support findings based on nonverbal testing, or they might even be more sensitive and identify issues that would not have been noticed otherwise. Having a thorough comprehension of someone's problems and resources could influence the amount of participation and engagement as well as in rehabilitation.

6.3 Limitations and Future Directions:

The present study has certain limitations, including a very small sample size. It was not possible to discover the well-documented earlier variations in the kind and degree of cognitive impairment in PWA because the cognitive deficits pattern was not explored at an individual level. Future research with a bigger sample size is required to examine the obvious correlation between executive function and aphasia. Future research should focus on establishing norms for these tests and replicating the study in the same population with increased participants. Grouping PWA in terms of severity may give more information in assessment and rehabilitation process for executive function. Additionally, follow-up measurements may shed more light on the part that executive function plays an important role in aphasia rehabilitation.

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APPENDIX-A

SCORE SHEET –1

Cognitive Inhibition Domain of Executive Functions

1. **Verbel test: Stroop test**

Set-1 Neutral condition				
Sl.no	**Stimulus**	**Response**	**Correct/ Incorrect**	**Remarks**
1.	Red			
2.	Green			
3.	Red			
4.	Yellow			
5.	Green			
6.	Red			
7.	Blue			
8.	Red			
9.	Yellow			
10.	Red			
11.	Blue			
12.	Yellow			
13.	Yellow			
14.	Green			
15.	Red			
16.	Blue			
17.	Yellow			
18.	Green			
19.	Blue			
20.	Yellow			
21.	Green			
22.	Green			
23.	Red			
24.	Blue			
25.	Green			
26.	Blue			
27.	Red			
28.	Yellow			
29.	Blue			
30.	Red			
Total score				

Note: Delayed response/ Expected visual cues/ Expected verbal cues/ Requested for repeated instruction/ others (if any mention)

Set-2 Congruent condition				
Sl.no	**Stimulus**	**Response**	**Correct/ Incorrect**	**Remarks**
1.	Blue			
2.	Green			
3.	Red			
4.	Yellow			
5.	Green			
6.	Red			
7.	Blue			
8.	Green			
9.	Blue			
10.	Red			
11.	Yellow			
12.	Red			
13.	Yellow			
14.	Green			
15.	Red			
16.	Blue			
17.	Yellow			
18.	Green			
19.	Blue			
20.	Yellow			
21.	Green			
22.	Green			
23.	Red			
24.	Yellow			
25.	Green			
26.	Blue			
27.	Red			
28.	Yellow			
29.	Blue			
30.	Red			
Total score				

Note: Delayed response/ Expected visual cues/ Expected for verbal cues/ Requested for repeated instruction/ others (if any mention)

Set-3 Incongruent condition				
Sl.no	**Stimulus**	**Response**	**Correct/ Incorrect**	**Remarks**
1.	Blue			
2.	Green			
3.	Red			
4.	Blue			
5.	Green			
6.	Green			
7.	Blue			
8.	Yellow			
9.	Red			
10.	Green			
11.	Red			
12.	Yellow			
13.	Green			
14.	Blue			
15.	Blue			
16.	Yellow			
17.	Blue			
18.	Green			
19.	Red			
20.	Yellow			
21.	Yellow			
22.	Red			
23.	Red			
24.	Yellow			
25.	Blue			
26.	Blue			
27.	Green			
28.	Blue			
29.	Red			
30.	yellow			
Total score				

Note: Delayed response/ Expected visual cues/ Expected verbal cues/ Requested for repeated instruction/ Too much confusion/ others (if any mention)

2. Non-verbal test - Go/No-Go test:

Sl.no	Stimulus	Correct/Incorrect
1.	Go	
2.	Go	
3.	Go	
4.	Go	
5.	Go	
6.	Go	
7.	Go	
8.	Go	
9.	Go	
10.	Go	
11.	Go	
12.	Go	
13.	Go	
14.	Go	
15.	Go	
16.	Go	
17.	Go	
18.	Go	
19.	Go	
20.	Go	
Total number of correct Go response		/20
Sl.no	**Stimulus**	**Correct/Incorrect**
1.	No-Go	
2.	No-Go	
3.	No-Go	
4.	No-Go	
5.	No-Go	
Total number of correct No-Go response		/5
Total number of correct Go/No-Go response		/25

APPENDIX-B

SCORE SHEET- 2

Working Memory Domain of Executive Functions

1. **Verbal Test- Digit Span Backward Test**

Sl.no	Stimulus	Response	Correct/incorrect
1.	2-Back		
2.	2-Back		
3.	3-Back		
4.	3-Back		
5.	4-Back		
6.	4-Back		
7.	5-Back		
8.	5-Back		
9.	6-Back		
10.	6-Back		
11.	7-Back		
12.	7-Back		
13.	8-Back		
14.	8-Back		

Total backward digit span is _____________

2. **Non-Verbal Test - Corsi Backward Block Tapping Test**

Sl.no	Stimulus	Response	Correct/Incorrect
1.	2-Back		
2.	2-Back		
3.	3-Back		
4.	3-Back		
5.	4-Back		
6.	4-Back		
7.	5-Back		
8.	5-Back		
9.	6-Back		
10.	6-Back		
11.	7-Back		
12.	7-Back		
13.	8-Back		
14.	8-Back		

Total Corsi backward span is __________

APPENDIX-C

SCORE SHEET- 3

Cognitive Flexibility Domain of Executive Function

1. **Verbal Test- Alternate Verbal Fluency Test:**

SL.No	Word-Pair Response	Correct/Incorrect	Remarks
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Total number of correct word-pair: _________

2. **Non-Verbal Test- Trail Making Test (Part B):**

Stimulus			Extended Analysis		
Numbers	**Alphabets**	**Correct/incorrect**	**Alphabets**	**Numbers**	**Correct/incorrect**
1	A		A	2	
2	B		B	3	
3	C		C	4	
4	D		D	5	
5	E		E	6	
6	F		F	7	
7	G		G	8	
8	H		H	9	
9	I		I	10	
10	J		J	11	
11	K		K	12	
12	L		L	13	
13					

Total duration taken to complete the test: ______ (seconds)

APPENDIX-D

OVERALL SCORE SHEET

Three Domains of Executive Functions

Sl.No	Domains	Scoring
1.	**Cognitive Inhibition**	
	Verbal test: Stroop test	
	Color score	
	Word-color score	
	Non-verbal test: Go/No-Go test	
2.	**Working Memory**	
	Verbal test: Digit span backward test	
	Non-verbal test: Corsi backward span test	
3.	**Cognitive Flexibility**	
	Verbal test: Alternate verbal fluency	
	Non-verbal test: Trail-making test	

APPENDIX- E

All India Institute of Speech and Hearing, Naimisham Campus, Manasagangothri, Mysore-570006

CONSENT FORM

Dissertation on

"To study executive functions using verbal and non-verbal tests in persons with aphasia"

General Information

You are invited to participate in the study titled "To study executive functions using verbal and non-verbal tests in persons with aphasia." This study is conducted by Ms.Getcy Bebayal F, a postgraduate student of the All India Institute of Speech and Hearing, under the guidance of Dr. Hema N. Assistant Professor, Department of Speech-Language Sciences, All India Institute of Speech and Hearing. The study aims to assess and compare executive functions through verbal tasks and non-verbal tasks in persons with aphasia (PWA) and neuro-typical individuals (NTI). Participants and caregivers will be interviewed to obtain demographic details and necessary medical information prior to confirming eligibility for the study. Once eligible, verbal, and non-verbal tests will be administered and will be recorded for further reference. The identity of the participant will not be revealed at any time, the information and recordings will be maintained confidential. The data obtained from the recording will not be disclosed, and access will be limited to individuals who are working on the project. Participation in this study is voluntary. You can refuse to participate or withdraw at any point in the study without penalty or loss of benefits to which you are otherwise entitled. The procedures of the study are non-invasive, and no risks are associated.

Informed Consent

I have read the foregoing information, or it has been read to me in the language I understand. I have had the opportunity to ask questions about it, and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate in this study.

I, ____, consent to be a participant in this investigation/study/program.

Signature of participants/Guardian — Signature of the investigator

(Name and Address) — Date _______

____________________ ____________________