INVESTIGATING THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND NAMING DEFICITS IN PERSONS WITH APHASIA

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CERTIFICATE

This is to certify that this dissertation entitled **"Investigating the Relationship between Executive Functions and Naming Deficits in Persons with Aphasia"** is a Bonafide work submitted in part fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student Registration number P01II21S0036. 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
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DECLARATION

This is to certify that this dissertation entitled **"Investigating the Relationship between Executive Functions and Naming Deficits in Persons with Aphasia"** is the result of my own study under the guidance 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:** P01II21S0036

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कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।

मा कर्मफलहेतुर्भूर्मा ते सङ्गोऽस्त्वकर्मणि ॥ ४७ ॥

Translation

You have a right to perform your prescribed duty, but you are not entitled to the fruits of action. Never consider yourself the cause of the results of your activities, and never be attached to not doing your duty.

-BG 2.47

This verse from the Bhagavad Gita best explains life for me. You have the right to perform your duty, but you are not entitled to the consequences. You are never the reason for your success. It’s Bhagavan Sri Krsna, so focus on the work rather than the result. Stay satisfied and love yourself for doing your duty, working hard, and stay dedicated. Do not look at yourself through the lens of others or through the lens of success.

Jai Sri Krsna!

I am not a person of many words. I find it difficult to express my emotions. So, I am going to keep it short and hope that my actions continue to prove my love and respect for you people mentioned here.

I dedicate this work of mine to my amazing and loving family. My Amma (Shilpa KR), my Thamma (Vaagmi KP), and my Appa (Prasanna BS). They are the most wonderful and supportive family ever. Especially my amma, who stood by me every single time and encouraged me. I love you all and pray for you to have all the happiness, respect, health, and wealth.

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CHAPTER I

INTRODUCTION

Executive control functions encompass a range of cognitive processes that become crucial in situations requiring focused attention and concentration or when relying on automatic, instinctual, or intuitive thinking would be unwise, inadequate, or infeasible. (Burgess & Simons, 2005; Espy, KA., 2004). Utilization of Executive Functions requires exerting effort, as it is more convenient for individuals to operate on autopilot and persist in their established behaviors rather than adapting and succumbing to temptation instead of resisting it.

1.1 Executive Functions

There are three primary executive functions, according to Friedman and Miyake (2000), which influence verbal output. These executive functions consist of 'inhibition control,' encompassing both interference control (managing selective attention and cognitive inhibition) and self-control (regulating behavior). 'Working memory' and 'cognitive flexibility,' also referred to as set-shifting, mental flexibility, or mental set-shifting, which is closely linked to creative capacity.

Inhibitory control stands as a foundational element within Executive Functions, encompassing the capacity to manage attention, actions, thoughts, or emotions with the aim of overriding strong internal inclinations or external temptations. Instead, it allows individuals to engage in actions that are more suitable or necessary. The capability to exercise inhibitory control over attention, specifically in terms of interference control during perception, facilitates the capacity for selective attention, focused attention, and the suppression of attention toward other stimuli. Involuntary attention, driven by external stimuli, operates in an exogenous, bottom-up, and automatic manner. The ability of individuals to consciously disregard or inhibit attention towards specific stimuli and instead focus on others, guided by their goals or intentions, is facilitated by inhibitory control. Other terms used for this function are attentional control or attentional inhibition, and this ability is endogenous, top-down, active, and goal-driven (Theeuwes, 2010). Without inhibitory control, one would respond impulsively, rely solely on ingrained thought patterns, or react passively to stimuli in the surrounding environment. Thus, inhibition makes Humans “thinking” creatures.

Inhibitory control encompasses interference control and self-control, with interference control referring to the suppression of predominant mental representations. This entails the act of actively preventing irrelevant or undesirable thoughts or memories, which may even involve intentionally trying to forget them (Hu et al., 2017), resisting proactive interference (Postle et al., 2004), and retroactive interference. On the flip side, self-control entails managing both behavior and emotions, aiding in the resistance of temptations and impulses. Another aspect of self-control entails the capacity to postpone instant gratification (Mischel et al., 1989), a concept also known as delay gratification, which means being willing to forgo immediate pleasures in favor of receiving larger rewards in the future (Louie & Glimcher, 2010; Rachlin et al., 1991). Inadequate delayed gratification can result in challenges when it comes to accomplishing lengthy, time-intensive tasks such as writing a dissertation. Self-control assists individuals in refraining from impulsively blurting out their initial thoughts and avoiding premature conclusions. The Stroop test is one of the renowned assessment methods utilized to evaluate inhibitory control.

Working memory (WM) refers to the ability to hold and actively manipulate information mentally, even when the stimulus is no longer perceptually present (Baddeley & Hitch, 1994; Smith & Jonides, 1999). Working memory plays a crucial role in processing time-varying information. Consequently, it is essential for storing both past events and forthcoming occurrences within the memory system. As an executive function, working memory aids in the understanding and generation of sentences and coherent discourse. Reversing the order of digits in a backward-digit span test (repeating the items in reverse sequence) aligns closely with a working memory task. Requesting participants to rearrange the heard items is a highly effective way to assess working memory (Diamond, 2013). The aptitude for dynamically and precisely managing and manipulating information within the confines of working memory characterizes working memory updating capability. The updating aspect of working memory involves continuously replacing or updating information in the memory buffer as new information arrives or as the task requires rearranging or modifying the information. Working memory ability is crucial for tasks that involve monitoring changing information, such as mental arithmetic and language comprehension, and tasks that require following complex instructions. N-back tasks (sometimes referred to as AX Continuous Performance Tasks or AX-CPTs) are frequently employed for the evaluation of working memory updating capabilities (Owen et al., 2005; Verhaeghen & Basak, 2005).

Cognitive flexibility represents the third essential executive function, which extends from the foundational skills of inhibition and working memory (Davidson et al., 2006; Garon et al., 2008). It encompasses the capacity to alter viewpoints both spatially, such as visualizing an object from various angles, and interpersonally, which involves grasping others' viewpoints. Achieving a change in perspective necessitates inhibiting the prior viewpoint and replacing it with an alternate one stored in working memory.

Another facet of cognitive flexibility pertains to modifying our thought patterns and fostering innovative thinking. Cognitive flexibility is commonly explored through a diverse range of tasks involving task-switching and set-shifting tasks.

The majority of task-switching scenarios revolve around a pair of tasks, which could encompass tasks like discerning if an alphabet is a vowel or consonant, determining the even or odd status of a number, and similar tasks. These task-switching activities entail responding with a key press to the right or left, where each key corresponds to a specific aspect of each task. Set-shifting is a cognitive process that involves the ability to switch attention between different mental sets. It is a crucial aspect of cognitive flexibility and adaptability, allowing individuals to transition between different modes of thinking or tasks in response to changing environmental demands. One of the tests used for the assessment of set-shifting is the Trail-making test. "The Trail Making Test entails linking a series of numbers and/or letters in alternating sequences, necessitating participants to mentally shift between numbers and letters as they advance through the task."

Switching between different mental sets is extremely challenging when compared to simply maintaining the suppression of a single response. The condition where there's difficulty in shifting between diverse mental sets and an inclination to adhere to the previous one is referred to as attentional inertia. Consequently, mastering the ability to counteract these inertial inclinations and smoothly transitioning between different mental sets renders cognitive flexibility one of the most challenging aspects of executive functions.

These foundational executive processes contribute to the development of advanced executive functions such as reasoning, problem-solving, and planning(Collins & Koechlin, 2012). Fluid intelligence entails the capacity to engage in reasoning and problem-solving and unveil the underlying abstract association between analogies (Ferrer et al., 2010). This encompasses both the application of inductive and deductive reasoning. The evaluations employed to gauge fluid intelligence, like Raven’s Matrices (Raven, 2000), exhibit strong correlations with the fundamental executive functions (Conway et al., 2003; Duncan et al., 2008; Kane & Engle, 2002; Roca et al., 2010)

Working memory plays a vital role in our capacity for reasoning since it allows us to identify links between seemingly disparate concepts and to dissect components from a unified entity. Furthermore, it aids in fostering creativity, as creativity entails the process of deconstructing and reconfiguring elements in novel manners. Working memory also enables us to incorporate conceptual knowledge alongside sensory input when making decisions and to take into account our remembered past experiences and anticipated outcomes when shaping plans and choices. Working memory and inhibitory control frequently complement and occur together. Working memory aids inhibitory control by allowing individuals to maintain a goal in their memory, thereby enhancing the likelihood that information will direct their actions and reducing the chances of committing an inhibitory error (such as incorrectly executing the default or typically dominant response when it should have been suppressed).

Inhibitory control can also assist working memory by preventing our mental workspace from becoming overly crowded. It achieves this by filtering out irrelevant thoughts (excluding irrelevant information from the working memory workspace) and resisting proactive interference through the removal of information that is no longer relevant from that limited-capacity workspace (Hasher & Zacks, 1988; Zacks & Hasher, 2012). These skills play a major role in cognitive, emotional, and social development (Diamond, 2013; Martin & Allen, 2008). These skills, as mentioned above, also have an impact on language functions such as auditory comprehension, naming, verbal fluency, and sentence comprehension and production, as language is one of the cognitive functions.

Among the various deficits significantly influenced by executive functions is the phenomenon of anomia or lexical access deficit, which is the inability to access words' grammatical and phonological forms from one's mental lexicon (Levelt et al., 1999). These deficits of retrieval, causing poor naming or labeling skills and longer latencies for naming, hold particular significance. This impaired access to vocabulary is a prevalent occurrence seen in all forms of aphasia. Anomia in individuals with Aphasia is typically observed in tests that assess naming ability.

1.2 Naming

Naming is the ability to retrieve information regarding the labels or names of various objects and events. One of the most crucial skills in linguistic processing is naming. While naming, it is necessary to retrieve phonological and semantic data, which is stored in a memory system and evaluated by the particulars of a given stimulus (Spezzano & Radanovic, 2010). Naming involves lexical processing to archive and retrieve semantic data and obtain conceptual representations associated with a given word. Naming also involves non-lexical processing, where the recognition and perception of the visual cues will initiate the lexical process (Spezzano & Radanovic, 2010).

Naming disturbances in aphasia comprise errors like paraphasia (phonemic, semantic, or verbal), neologisms, circumlocutions, and perseverations. These signs of word-retrieval difficulties often witnessed in naming tests are the manifestation of executive and lexical deficits (Brown & Cullinan, 1981; Crowther & Martin, 2014). Therefore, in individuals with aphasia, the word retrieval deficits observed also reflect underlying executive deficiencies.

The naming skills can be assessed using general denomination tests, like the Boston Naming Test, or through specific denomination tests, like the Specific Categories Naming Test and the Verb and Objects Naming Battery, which examine various semantic and grammatical categories. The main purpose of these tests is to identify word retrieval deficiencies in aphasia (Basso et al., 1990).

Some of the commonly used naming tasks are confrontation naming tasks, which is the process of choosing a particular label that corresponds to a visual representation of an object or event (Raymer, 2017). The responsive naming task requires the subject to respond to the characteristics or descriptions of objects and events. Generative naming, which is one of the most advanced forms of naming, involves producing or generating words corresponding to a category or sound within a stipulated amount of time. Generative naming mainly involves two variants, semantic fluency tasks (also known as the word fluency task) and phonemic or letter fluency tasks. Semantic fluency tests or word fluency tasks measure a person's ability to produce several words that fall under a specific category. Phonemic fluency tasks or letter fluency tasks assess the ability to generate different words beginning with a particular sound.

Other naming tasks include subordinate naming task which gauges the ability to locate the name of the category to which a particular group of words belong, and coordinate naming, which involves producing words that are in-class coordinates in response to a stimulus provided. Semantic coordinate errors can result from the disruption of various naming-related cognitive processes and, consequently, from various sites of brain injury; they are widespread across all groups of aphasia (Budd et al., 2010). The automated naming task entails creating a list of memorized or over-learned terms associated with one another or belonging under the same category. Sentence completion task that assesses an individual's ability to complete a sentence with a meaningful word giving a complete meaning.

The most frequently used tests to gauge word retrieval deficits are the confrontation naming test, the responsive naming test, and the generative or verbal fluency test (Brown & Cullinan, 1981). These tasks are used quite frequently due to their ephemeral nature of administration and their cognitive and linguistic foundations. These tasks can be measured with no advanced equipment or training. Therefore, these tasks are frequently found across most tests assessing language and cognitive abilities in various cognitive and linguistic deficits of neurological origin (Thiele et al., 2016). But most of these tests do not include all the various types of naming tasks. For instance, the Western Aphasia Battery, includes only the confrontation naming task and word fluency task. In many instances, the normative data for these tests are not available, and if available, the analysis is mostly descriptive and does not include a quantitative means of analysing responses.

Furthermore, the factors that exert a significant impact on an individual's naming skills remain largely unspecified. The method employed to investigate the elements affecting naming proficiency is referred to as the 'critical-variable approach,' a concept pioneered by Shallice, n.d. Characteristics of the word and specific individual attributes like age, gender, and ethnicity, along with elements such as executive functions and educational background, can likewise impact one's capability in naming. Among the prevalent factors related to the property of words that impact naming skill are frequency, familiarity, word length, age of introduction, operability, visualizability, and concreteness."

The “property of words” factor that has been consistently shown to impact both the speed and precision of confrontation naming is the frequency of a specific object's name within the language's vocabulary. Objects with higher frequencies are usually named more quickly and accurately (Oldfield & Wingfield, 1965; Snodgrass & Vanderwart, 1980). Furthermore, the typical age of word acquisition during language development is another factor that affects the speed of object naming. Words acquired at an early age tend to be named more swiftly, as indicated by research by (Morrison et al., 1992). Notably, there exists a strong negative correlation between word frequency and age of acquisition, as demonstrated in the work of (Morrison et al., 1992).

In recent years, numerous research investigations have focused on factors associated with individuals and word characteristics. However, there remains a paucity of studies concerning additional factors like executive functions and education.

1.3 Association between executive function and naming

Many researchers have long associated executive functions and language, especially naming, with each other, mainly because language is considered a part of the higher cognitive functions. Language involves the extensive use of reasoning and other higher cognitive functions, which are heavily dependent on these fundamental executive functions (Goral et al., 2011; Yoon et al., 2015).

Many earlier researchers have attempted to find the relationship between word retrieval and the executive functions. The earlier researchers have found that the integrity of naming performance especially the verbal fluency tasks is dependent on the intactness of the executive function and the lexical process. The naming ability especially capitalizes on one's ability to quickly access the mental lexicon, retrieve the word, systematically monitor the output and inhibit any other irrelevant competing activation. The naming ability heavily relies on integrity of the structure of mental lexicon and semantic stores (Bittner & Crowe, 2006, 2007; Patra et al., 2020a, 2020b; Shao et al., 2014; Troyer, 2000a). Many previous researchers have proven the strong relationship between the naming tests and the executive functions and also highlighted the hybrid nature of the naming tests (Bose et al., 2017, 2022; Patra et al., 2020a, 2020c, 2020b).

Verbal fluency tasks and naming tests have been frequently used in these researches since they are quick to complete and can identify deficits in lexical and executive function skills. Recalling words in a specific language necessitates individuals to access their internal word repository, concentrate on the task, choose words that meet specific criteria, and prevent redundancy. These activities certainly engage executive control processes (Fisk & Warr, 1996). The most used fluency tasks are the word and phonemic fluency tasks. With the ability to gauge both executive and lexical deficits comes the risk of poor discrimination between the executive and lexical deficits in Aphasia.

The naming and verbal fluency tests and their types fail to distinguish what causes a word retrieval error in Aphasia. They are unable to ascertain the root cause of the word retrieval difficulties.

So, the ongoing discussion regarding whether the restricted language output and word-finding challenges observed in individuals with aphasia are attributable to problems with their lexicon or issues with executive control persists. The existing body of literature has not conclusively settled this debate, primarily because most of these studies have relied solely on a single type of naming test and executive function assessment. Many of the studies have used only one level of analysis which is the quantitative analysis or accuracy analysis. The domains of time course and cluster analysis largely remains unexplored by the researchers which may provide extensive information on nature of naming tests and the underlying bases.

1.4 Need of the study

Given that the naming and fluency tests are hybrid, naming and verbal fluency scores may not be a clear indicator of either verbal or executive control abilities as a separate entity.

As revealed by the information above, the naming tests are frequently used in research settings and clinical evaluation, but the underlying process is mostly unclear.

The number of studies dedicated to deciphering the underlying mechanism of word retrieval deficits in Aphasia is relatively less, though the requirement of such research giving more information on the underlying mechanism is high.

There is a poor understanding of how different varieties of naming and verbal fluency tests are affected by underlying executive mechanisms. This leads to a poor understanding of what underlying deficits each of these types of word-retrieval tests represent, and hence, there is poor segregation of tests.

Most of the standardized tests for language use only one or two components of word-retrieval tests ignoring the variety of tests that could provide a better insight into the underlying deficit.

In most naming and verbal fluency reports, results are represented only based on the number of inaccuracies. Although the performances of older adults and disordered populations have been related to higher latencies on various linguistic and cognitive activities, naming latencies or reaction times have rarely been used (Woodard et al., 1996).

1.5 Aims of the study:

The aim of this was to demonstrate the relationship between naming and executive functions in Persons with Aphasia. To find out the extent of association with reference to the executive functions affecting naming performance in persons with Aphasia and Healthy controls.

Objectives of the study:

1. To find out the Executive Functions (updating, shifting, inhibition, working memory) that predict successful and unsuccessful word retrieval using the naming test in persons with Aphasia and healthy control.

2. To outline the executive and linguistic bases of different types of naming tests using quantitative, time course, clustering, and switching parameters in persons with Aphasia and healthy control.

3. To investigate the correlation between the Executive Functions (updating, shifting, inhibition, working memory), and the naming tests (confrontation naming, responsive naming, and generative naming) in persons with Aphasia and healthy control.

4. To segregate the types of naming tests that majorly tap into executive functions versus linguistic abilities in persons with Aphasia and healthy control.

CHAPTER II

REVIEW OF LITERATURE

There have been efforts to comprehend the elements influencing naming ability by researchers earlier. However, the impact of specific factors like executive functions on this ability remains uncertain. Additionally, endeavors have been made to analyze naming performance objectively. Nevertheless, the extent to which these analytical methods enhance our comprehension of the intricacies of naming disorders remains largely unknown.

2. 1 Executive functions in Healthy individuals

A research investigation was carried out involving a group of 61 individuals. Among them, 30 participants (comprising 16 women and 14 men) fell within the age range of 20 to 33 years, while the remaining 31 individuals (including 15 women and 16 men) were between 60 and 80. The authors examined the effects of age-related declines in perceptual speed, working memory, central executive function, and phonological loop function. This assessment was accomplished using tasks such as the letter and pattern comparison speed task, reading and computation span task, random letter generation task, and word and digit span task, respectively. The findings revealed that age-related deficits were evident in working memory, perceptual speed, and central executive function, though not in phonological loop function. Notably, alterations in perceptual speed were identified as the primary factor contributing to changes in working memory span due to aging (Fisk & Warr, 1996).

An examination of set-shifting skills was carried out with a sample of 109 Chinese participants, utilizing the Trail Making and Color Trail tests. The study aimed to understand the performance of individuals on the trail-making tests and examine the effect of age and education on the test. The findings of the study demonstrated that both age and educational background significantly influence individuals' performance on these assessments. Specifically, younger individuals with higher levels of education exhibited superior performance compared to their older counterparts and those with lower educational attainment (Lee & Chan, 2000).

In an investigation on Digit Span tests, a secondary assessment was conducted using the standardized sample of the Wechsler Memory Scale–Third Edition (Wechsler, 1997). This analysis aimed to explore the decline in Forward and Backward Digit Span test performance associated with age, as well as to gain insight into the correlation between the Digit Span tests and increasing age. The outcomes revealed a notable decrease in performance on both the Forward and Backward Digit Span tests as age advanced. The decline in performance with age was found to be consistent for both test measures. The suggestion put forward was that both the forward and backward-span tasks engage central executive resources to achieve successful task execution (Hester et al., 2004).

The correlation between executive functions and the decline in episodic memory associated with aging, using the states-of-awareness approach was explored in a study. A word list was presented to both young and elderly participants. Subsequent to the presentation, recognition tests were administered to the two age groups, involving the classification of responses using the Remember-Know-Guess procedure (Gardiner, 2000). Additionally, the study evaluated three specific executive functions: updating, shifting, and inhibition. The outcomes revealed that the older group produced fewer ''R'' responses during the recognition test in comparison to the younger group, while no discrepancy was noted between the groups in the frequency of "K" responses. Furthermore, the correlations demonstrated that remembering was influenced by executive function measures, whereas knowing was not. Hierarchical regression analyses demonstrated that much of the age-related variance in remembering was effectively eliminated by accounting for executive function, particularly the 2-back test. These findings substantiate the concept that executive dysfunction, specifically the decline in updating, plays a central role in the reduction of memory ability related to aging (Clarys et al., 2009).

A sequence of meta-analyses undertaken by Paul Verhaeghen, focusing on the interaction between age and executive control, unveiled that tasks involving selective/focused attention (such as tasks related to inhibiting return, negative priming, flanker challenges, and the Stroop test) or tasks that measured local task-shifting costs did not exhibit distinct age-related deficits (except reading with distractors). On the flip side, the research identified particular deficits associated with age in tasks involving divided attention (such as multi-tasking) and the global costs associated with shifting between tasks. Notably, no age-related variations in complex cognitive functions (including episodic memory, reasoning, and spatial abilities) were identified that went beyond the influences of processing speed and working memory. Consequently, the study's conclusion was that the decline in executive control as age progresses is not a universal phenomenon and might have a limited role in accounting for the age-related declines seen in complex cognitive tasks. (Verhaeghen, 2011).

The widely recognized Trail Making Test (TMT) involved 64 healthy adult volunteers aged 18 to 63 (comprising 33 women and 31 men) was used in a study. Their performance on the Trail Making Test was compared concerning their age, educational background, and gender. The Trail Making Test was executed with speed and was found to be impacted by age, educational level, and gender. The older participants exhibited a lengthier duration in completing the test, with age showing an effect on both TMT-A and TMT-B and the differences between them. Higher educational attainment was linked with a shorter Trail Making Test completion time, particularly for TMT-B. Furthermore, when the B-A difference was analyzed, women displayed superior performance on the Trail Making Test compared to men (Płotek et al., 2014).

An extensive examination was carried out on 176 distinct studies, aiming to confirm the existence of deficiency in inhibition among older individuals and discern if the deficiency is a common occurrence or limited to specific tasks. The selected studies involved participants who were subjected to commonly employed inhibition measurement tasks, including the Stroop test, Eriksen Flanker task, Simon task, stop-signal task, go/no-go paradigm, global and local interference, and compatibility tasks. And also incorporated a framework for evaluating the costs associated with repeating the task from two trials ago in the context of task switching.

For the majority of tasks, such as the Stroop task, Eriksen Flanker task, local interference, and the N-2 Task Repetition Interference Measurement, the outcomes indicate that in older individuals. there is no deficiency in inhibition. However, a limited number of tasks, such as the go/no-go paradigm and stop-signal test, exhibited compromised inhibition among the elderly. As for the remaining four tasks, the evidence from earlier studies recommends that further research is needed to establish a conclusive understanding (Rey-Mermet & Gade, 2018).

A cross-sectional investigation into the impact of age on four executive functions (EFs) – inhibition, shifting, updating, and dual-tasking – was executed. The study encompassed a group of 26 young adults and 25 older adults and employed two tasks for each executive function. Age-associated deterioration was evident across all four executive functions in either one or both of the assigned tasks. When assessing the decline rates comparatively, notable numerical and statistically significant distinctions emerged among the four executive functions. Specifically, inhibition exhibited the most substantial decline, followed by shifting, updating, and dual-tasking (Idowu & Szameitat, 2023).

2.2 Naming abilities in Healthy Individuals

In 1996, Welch and fellow researchers undertook an investigation involving adults aged 60 to 93 years, utilizing the 60-item Boston Naming Test. The findings revealed that although age had a notable impact on the ability to perform confrontational naming, the interplay between the age factor and the education factor seemed to be a more effective indicator of output. Greater variation was observed among older age brackets and individuals with limited educational backgrounds. For individuals who attained education beyond the 12th grade, their naming ability remained stable until the age of 80. Conversely, those with an education level below high school experienced a decrease in naming ability starting at age 70 (Welch et al., 1996).

A study aiming to provide normative values for cluster analysis parameters on specifically the phonemic fluency (/f/,/a/,/s/ or /c/,/f/,/l/) and word fluency (using the categories animals and supermarket) was conducted by Troyer (2000). The data was collected from 411 healthy individuals spanning ages from 18 to 91. The original scores were adjusted for demographic factors (age, educational background, and gender) as well as test-related variables (specifically, fluency form) to assess how these factors influenced performance in fluency. The research indicated that while older individuals tended to generate somewhat larger clusters in phonemic fluency, there was no statistically significant link between growing age and the size of these clusters. As age advanced, there was a notable decrease in the frequency of switching during category fluency tasks for animals. Moreover, those with more extensive educational backgrounds displayed bigger cluster sizes and produced a higher quantity of words. (Troyer, 2000a).

A study was carried out to examine how the ability to speak two languages affects word and phoneme fluency, involving comparisons between individuals who speak two languages versus one language, as well as assessing fluency in both the stronger and weaker languages. In this research, 51 individuals were fluent in both Spanish and English and took part in the study. The study's major findings were that when compared to individuals fluent in one language, individuals fluent in two languages generated a lower number of accurate responses, exhibited longer response times for their initial responses, and had a delayed recall process. In comparison to monolinguals, bilingual individuals generated words with notably lower frequencies and a greater percentage of related responses. Bilinguals also made more errors where words from one language intruded into the other when they were speaking the weaker language, while such intrusions were nearly absent when they were speaking their stronger language (Sandoval et al., 2010).

Another research investigation was conducted on verbal fluency to explore the processes of retrieving semantic information and the errors that occur during word fluency tasks, to identify and detail their components. The research examined the performance of 50 individuals in good health through the utilization of the "supermarket" fluency task. The scores were assessed both before and following a 30-second gap. The findings indicated a reduction in the number of words generated and a growing challenge in switching over time. The act of switching between clusters and the frequency of intrusions stayed consistent while forming clusters, with both the quantity of examples and repetitions on the rise. These results imply a gradual integration of a semantic cognitive retrieval strategy (Raboutet et al., 2010).

2.3 The association between Executive functions and naming abilities in Healthy Individuals

The influence of command over language and executive abilities on the generative performance of bilingual individuals is explored in a study. The research conducted by Lu et al. in 2010 employed a time-course measurement to examine how the capacity of bilinguals to produce words fluently is affected by size mental lexicon and executive abilities. Results showed that bilinguals with a large vocabulary performed better in letter fluency than both monolinguals and bilinguals with a smaller vocabulary. The examination of the temporal patterns in word retrieval during phoneme fluency showed clear and separate effects. The initial resources available at the start of a task, reflecting the size of the mental lexicon, and the capacity to oversee and recall novel words through an innovative phonemic-centered approach, which mirrors executive abilities, had separate influences. Both groups of bilinguals displayed improved executive control compared to monolinguals, while the starting point of word retrieval reflected higher vocabulary levels in bilinguals and monolinguals with large vocabulary compared to bilinguals with small vocabulary. The study's findings suggest that both linguistic abilities and executive abilities play a role in word fluency output, providing insights into the complex relationship between proficiency in language and cognitive skills in bilingual individuals. (Luo et al., 2010).

Another study by Constantinidou et al., 2012 explored the influence of levels of education on fundamental cognitive functions along with the correlation between these executive functions and language using the measure of receptive vocabulary and confrontation naming in two groups of older individuals with ages ranging from 60 to 75 years and > 76 years. The study concluded that a noteworthy connection existed between the composite score of executive function and the language score. Education had a pronounced impact on language test outcomes, as it held significance across all aspects that involve semantic organization, the speed of processing information, cognitive adaptability, cognitive flexibility, receptive vocabulary, and confrontational naming.

A study was conducted to examine how verbal proficiency and executive control influence verbal fluency performance in a group of 82 older adults (Shao et al., 2013, 2014. The research assessed verbal fluency using phoneme and word fluency tasks. The findings indicated that the number of words generated was forecasted by the individual's capacity for updating, and the 1st RT was predicted by vocabulary size and lexical access speed. The study also revealed that images with low name agreement show increased response latency due to increased competition and more substantial demands on lexical selection. Thus, highlighting the hybrid nature of fluency and naming tasks.

To study the role of cognitive skills in semantic interference and regulation of semantic competitors Crowther and Martin, (2014) explored the relationship between variations in cognitive skills among both younger and older adults and the extent of semantic interference in a repetitive naming task with distinct blocks. The study reported that the younger adults and the elderly performed similarly on the cognitive tasks and they showed similar effects of cognitive control abilities on semantic interference. The rise in naming latencies as naming trials progressed within a cycle showed a negative correlation with word span for both related and unrelated conditions. This indicates a strategy of reducing potential responses by relying on memory for the list of item names.

The Stroop interference demonstrated a direct positive correlation with the alteration in naming latencies across cycles, but this correlation was observed exclusively in the related condition. They also obtained a negative correlation between the naming latencies for unrelated cycles and prior exposure, suggesting that greater prior exposure and strengthening of semantic links reduced naming latencies.

A study conducted on 264 older individuals with ages ranging from 55 to 84 years revealed that retrieval success (during a naming task) in older individuals can be predicted with mental shifting tasks, and retrieval speed can be predicted with the help of efficiency in accessing long-term memory (fluency tasks). In the aforementioned study, inhibition did not affect identifying accuracy of responses or reaction times for both tasks (Higby et al., 2019).

A research study conducted by Marsh and others explored the bilingual advantage in phonemic fluency tasks, where bilinguals often outperform monolinguals. The study suggested that this advantage may be due to bilinguals' superior executive processes, which are more involved in phonemic fluency compared to semantic fluency. This study re-analyzed the data obtained from a Betula longitudinal study and found that individuals who speak two languages demonstrated greater switching and clustering, two measures reflecting executive processes, throughout the study period of

15 years. The authors later concluded that bilinguals' better performance on phonemic fluency tasks can be attributed to their superior executive functions (Marsh et al., 2019).

In 2019, Lissett Gonzalez-Burgos and her team conducted research involving a diverse age group spanning 30 to 85 years. Their study identified a significant decline in verbal fluency test performance as individuals transitioned from middle age to early elderly. During this transition, the influence of certain cognitive factors diminished while new cognitive variables began to play a role. Notably, the ability to access the lexicon, speed of processing, and fundamental cognitive functions were crucial contributors to the decline in verbal fluency performance (Gonzalez-Burgos et al., 2019).

Other studies on the healthy population suggest that irrespective of age effects, few individuals perform better on inhibitory control tasks, and they had superior speech discrimination and better performance in tasks involving the recognition of infrequent words. Therefore, the effective management of lexical competition and conflicting input relies heavily on cognitive control (Cahana-Amitay et al., 2016; Sommers & Danielson, 1999).

Additional studies also revealed that the higher executive functions that rely on the core executive functions affect word retrieval abilities and sentence interpretation in older individuals (Goral et al., 2011; Yoon et al., 2015). Hence, performance on the naming and verbal fluency tests in older individuals is optimal when lexical and executive function abilities are intact (Bittner & Crowe, 2007; Patra et al., 2020; Shao et al., 2014; Troyer, 2000b).

2.4 Executive Functions in Individuals with Aphasia

In 2010, Purdy conducted a study that explored the executive function capabilities of individuals with aphasia. The researchers employed four tasks to evaluate executive function: the Porteus Maze Test (PM), the Wisconsin Card Sorting Test (WCS), the Tower of Hanoi (TOH), and the Tower of London (TOL). The study identified notable disparities in task performance accuracy between the aphasia and control groups.

Individuals with aphasia encountered difficulties related to cognitive flexibility, as observed in their performance on the WCS task. Additionally, the TOH task, which demanded an elevated level of cognitive flexibility and the allocation of attentional resources, posed significant challenges for the aphasia group. These findings imply that individuals with aphasia may exhibit deficiencies in cognitive flexibility and working memory (Purdy, 2002).

To evaluate the feasibility, reliability, and internal coherence of an n-back task as a means of assessing impairments in working memory (WM) among individuals with aphasia Mayer and Murray carried out a study in the year 2012. This study involved the participation of 14 adults with aphasia, along with 12 control individuals who were carefully matched for age and educational background, completing n-back tasks involving different types of stimuli and varying levels of WM demand. The study also examined how WM performance was affected by broad factors, including WM load, reaction time, and age, as well as more specialized factors related to language.

The findings suggested that the n-back task had the potential to serve as a clinical tool for quantifying working memory deficits in individuals with aphasia. Both the groups (aphasia and the control group) exhibited similar performance across various types of stimuli, with better WM accuracy when dealing with stimuli that could be named. Significantly, the influence of rising working memory requirements was more pronounced in the aphasia group when contrasted with the control group. The effects on reaction time generally mirrored the accuracy findings, although the impact of age on performance varied across different task conditions (Mayer & Murray, 2012).

A research study conducted by Dutta and Murray in 2023 investigated deficits in executive functioning (EF) in individuals with varying types and degrees of aphasia, which is a language impairment. Its primary objective was to compare these individuals, known as persons with aphasia (PWA), with a control group of healthy individuals (HC) by subjecting them to a range of verbal and nonverbal EF tasks. The results indicated that, overall, PWA performed less effectively than HC on most EF measures, particularly in the realm of verbal tasks. However, there was considerable diversity within the aphasia group, as some individuals did not exhibit EF deficits. Intriguingly, the study did not establish a consistent correlation between the severity of aphasia and performance on EF tasks. This suggests that a significant number of people with aphasia encounter executive function deficits that are not directly associated with the severity of their language impairments. Therefore, the research emphasizes the importance of regularly assessing executive functions during clinical practice to improve the effectiveness of rehabilitation for individuals with aphasia (Dutta et al., 2023).

2.5 Naming Abilities in Individuals with Aphasia

A study conducted by Roberts in 1994 examined semantic verbal fluency in aphasic individuals, explicitly focusing on test-retest conditions and quantitative and qualitative aspects of performance. The study involved two categories of individuals with aphasia: one group comprised individuals who had recently developed aphasia, while the other group consisted of individuals who had been living with aphasia for an extended period. The researcher evaluated the performance by employing both quantitative metrics (total number of correct words) and qualitative criteria (errors and the organization of their responses). The results showed that both groups improved on retesting. Significant correlations were observed between verbal fluency performance and the level of aphasia severity in both groups. The quantity of accurate words exhibited a negative correlation with error count and a positive correlation with the quantity of semantic subgroupings (Roberts & Dorze, 1994).

Sarno and fellow researchers carried out an investigation involving individuals who had experienced post-stroke Aphasia. This research focused on evaluating the capacity of those with Aphasia to create words using a phoneme fluency task. As the treatment advanced, the patients displayed an increased word production, encompassing a diverse range of words, including grammatical indicators. Throughout the intervention period, there was a significant growth in the number of phonemic clusters, more than doubling in number. However, the average length of these phonemic clusters did not increase over time (Sarno et al., 2005).

Kiran researched to explore how bilingual individuals with aphasia access lexical-semantic information and how language proficiency impacts their ability to access lexical information. The research included a group of 12 individuals who were neurologically healthy and bilingual in Spanish and English, as well as another group of 10 individuals who were bilingual in Spanish and English and had aphasia. Three tasks related to the retrieval of words from memory were used: two tasks involving the naming of pictures (BNT and BPNT) and a task involving the generation of words within specific categories (CG). In all tasks, individuals without bilingual aphasia outperformed participants who had bilingual aphasia. Normal control participants and bilinguals with aphasia both committed similar kinds of errors in both English and Spanish, and they also adopted similar clustering approaches. (Kiran et al., 2014).

Thiele and colleagues conducted a systematic review and meta-analysis of studies focusing on supplementary assessments of word generation performance in adult clinical populations who have acquired brain injuries. The systematic review uncovered that the conventional metric employed in word generation tasks is the count of accurate responses; however, this metric failed to encompass all pertinent facets of word generation performance. The research identified that a relatively limited proportion of studies (approximately 15.62%) incorporated supplementary performance metrics alongside the count of correct responses. Additional measures that demonstrated enhanced or comparable diagnostic effectiveness encompassed clustering and switching, types of errors, and temporal attributes. While the study acknowledged that potential novel approaches for analyzing verbal fluency performance were underutilized, there is a lack of agreement on which supplementary metrics are most suitable for describing word generation performance (Thiele et al., 2016).

Shah and Milman conducted a study to explore how post-stroke aphasia, elicitation category, and linguistic factors influence verbal fluency performance. The research revealed that individuals with aphasia (referred to as PWA) exhibited poorer performance compared to neurotypical participants in all verbal fluency tasks, with the animal fluency scores deviating the most from neurotypical performance. Individuals with aphasia (PWAs) generated less complex lexical responses than their neurotypical counterparts, producing fewer clusters and utilizing words with higher frequency across all three verbal fluency tasks. In individuals with aphasia (PWAs), there were connections between animal and action fluency and other language-related assessments, whereas phonemic fluency showed no correlation with language measures (Faroqi-Shah & Milman, 2018).

2.6 The association between Executive functions and naming abilities in a Person with Aphasia

In a study by Hirshorn & Thompson-Schill, 2006 11 participants with frontal lobe lesions were assessed for their semantic fluency abilities and were found to have poor switching abilities as opposed to smaller cluster sizes usually observed in individuals with language deficits. The research suggests that the observed semantic fluency impairments in individuals with frontal lobe injuries primarily result from the impact of frontal lobe damage on interference effects in working memory.

A study analysed clustering and switching abilities in a minute. The study's objective was to examine variations in both the quantity and quality of performance during a 60-second animal fluency task between individuals with aphasia (referred to as PWA) and healthy control speakers (abbreviated as CS). Information was gathered regarding the count of accurate words, the size of clusters, the frequency of switches, the pauses within clusters, and the pauses between clusters at four 15-second intervals. The results indicated that in contrast to healthy control speakers (CS), individuals with aphasia (PWA) generated a reduced number of words, displayed smaller cluster sizes, and had fewer instances of switching. PWA also had longer within- and between-cluster pauses. Both individuals with aphasia (PWA) and healthy control speakers (CS) experienced a decline in the production of accurate words as time progressed, but PWA reached the point of stabilization or plateau earlier. Both groups did not exhibit any alterations in cluster size, and the decrease in the number of switches overtime was only observed in the case of healthy control speakers (CS). The research proposed that individuals with aphasia (PWA) encounter challenges in the process of searching for and retrieving information, as evidenced by smaller cluster sizes, a reduced frequency of switches, longer durations of pauses between clusters, and an overall deceleration in retrieval speed. These difficulties are related to both the task's lexical retrieval processes and executive control components (Bose et al., 2017).

Wall et al., in 2017 conducted a study on 36 individuals with Aphasia and 32 controls, analyzing the association between 4 cognitive tasks (the Hopkins Verbal Learning Task, the Kettle Test, the fluency test, the Star Cancellation Test) and 2 language tests (the comprehensive Aphasia test, and the Boston Naming test). The study findings indicate that one-third (33%) of individuals with aphasia were unable to finish all of the cognitive tasks, and there were numerous connections between language-related and non-linguistic cognitive functions. Therefore, the majority of the non-verbal as well as verbal cognitive tasks were found to be associated with auditory comprehension, naming, and fluency tests.

A research investigation by Shah and others examined the association between cognitive control and word retrieval in individuals with aphasia. The research revealed that cognitive control was diminished in individuals with aphasia in comparison to individuals without any health-related issues. The study identified a cognitive control advantage in bilingualism among healthy adults and certain bilingual individuals with aphasia. However, there was no significant correlation found between word retrieval abilities in individuals with aphasia and their performance in cognitive control tasks (Faroqi-Shah et al., 2018).

Carpenter and colleagues conducted research that involved 13 individuals with aphasia who were bilingual in Spanish and English (referred to as BPWA) and 22 bilingual individuals who were fluent in Spanish and English. The study's objective was to assess how individuals with aphasia who were bilingual in Spanish and English (BPWA) performed on a semantic category generation task and a conventional letter fluency task within both single and dual-language settings while considering different levels of cognitive control requirements. Bilingual individuals without aphasia outperformed bilingual individuals with aphasia (BPWA) in semantic fluency and phoneme fluency tasks. Individuals with aphasia who were bilingual in Spanish and English (BPWA) exhibited more significant challenges in word retrieval when faced with dual-language situations that required a high level of cognitive control (Carpenter et al., 2020).

A study by Patra et al., 2020 also found adequate fundamental cognitive functions and lexical processing in Aphasics to be a compulsory requirement to perform well on naming and verbal fluency tasks. Patra et al., 2020 studied bilinguals with aphasia who spoke Bengali and English (BWA) and healthy, Bilingual neurotypicals (BHC) for their performance in verbal fluency tests (semantic and phonemic fluency tests) using temporal measures (i.e., reaction times). Bilinguals with Aphasia (BWA) showed significant differences from Bilingual neurotypicals in their generative naming performance in more demanding executive control conditions (such as fluency difference score, count of switches, and intervals between clusters.). However, when it came to variables that required less executive control, individuals with aphasia who were bilingual in Bengali and English (BWA) managed to maintain similar performance levels as bilingual healthy controls (BHC) in terms of cluster size and within-cluster pauses. Although there was a noticeable advantage for bilingual healthy controls (BHC) in Bengali, no distinctions related to language were observed in the case of bilingual individuals with aphasia (BWA). The correlation analyses indicated a notable correlation in individuals with aphasia who were bilingual in Bengali and English (BWA) between inhibitory control and the following variables: the count of accurate responses, the initial retrieval time, and the frequency of switches (Patra et al., 2020).

Carpenter and a group of fellow researchers conducted another study that investigated the performance of bilingual individuals without aphasia and bilingual patients with aphasia (BPWA) on verbal fluency tasks with different levels of cognitive control requirements. The study centered on the concepts of switching and clustering within generative naming tasks in both groups, considering both single-language and dual-language conditions. In summary, the outcomes revealed that bilingual individuals without aphasia performed better than bilingual patients with aphasia (BPWA) across all measurement criteria. The study observed that as control demands increased, switching demonstrated greater sensitivity compared to clustering, and this effect was particularly pronounced in bilingual patients with aphasia (BPWA). Bilingual patients with aphasia (BPWA) generated phonemic clusters with smaller average sizes when compared to healthy bilingual individuals (Carpenter et al., 2021).

In another similar study by Bose et al., 2022, they explored the source of verbal fluency challenges in individuals with aphasia by employing the word and phonemic fluency test on 14 individuals with aphasia and 24 healthy participants. The participants were assessed for the frequency of correct responses, ability to form clusters, frequency of switches, and temporal parameters of word retrieval and their correlation with the Stroop test (for inhibition), the trail-making test (for mental shifting), and the digit span test- backward. According to the study, aphasics score poorly on generative naming tasks due to lexical and executive component deficiencies. The study also highlighted the effects of demanding contexts on executive search strategy and the need to assess the underlying mechanism more extensively to better understand word-retrieval deficits.

CHAPTER III

METHOD

The present study aimed to demonstrate the relationship between naming and executive functions in Persons with Aphasia and find out the extent of association with reference to the executive functions affecting naming performance in persons with aphasia and healthy controls.

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 fourteen neuro-typical individuals/healthy individuals constituting Group I, the control group, and fourteen persons with aphasia constituting Group II, the clinical group were considered for the present study. A total of 28 participants from both groups were in the age range of 18-59 years and all were native Kannada language speakers. Persons with Aphasia (PWA) (all participants were male), were matched for age and education with healthy controls (HC). There were no significant differences between the groups with regard to age (PWA, mean = 37.93 years, SD = 14.024; HC, mean = 36.71 years, SD = 12.493; t = 0.242; $p = 0.720$).

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. 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. All the participants were considered for the study only if they were willing to participate in the study and sign the informed consent of the AIISH ethical committee.

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 (persons with aphasia):

A single episode of stroke involving the left hemisphere determined by neurological and radiological examination.

A formal diagnosis of Aphasia on a standardized test for Aphasia (Western Aphasia Battery in Kannada- WAB-K); with an AQ <93.8. (Chengappa & Kumar, 2008). All participants with persisting Aphasia at least 12 months post-stroke to rule out the effect of spontaneous recovery.

Individuals with Aphasia who could perform with a minimum of 10% accuracy in Boston Naming Test Kannada- BNT-K; (Chengappa & Kumar, 2009), Action Naming Test Kannada- ANT-K; (Girish & Shyamala, 2015) and phonology section of Linguistic Profile Test Kannada (Suchithra & Karanth, 2007).

The persons with aphasia selected for the study included 10 patients with Anomic Aphasia and 4 with Conduction Aphasia. All the participants were able to perform with 10% accuracy on all the above-mentioned naming, semantic processing, and phonological tests. Additionally, all the participants showed no signs of cognitive deficits.

Participants with other neurological illnesses, psychiatric disorders, history of or ongoing substance abuse, visual field or other sensory-perceptual deficits, and cognitive deficits (ruled out using Montreal Cognitive Assessment Nasreddine et al., 2005) 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 1- CONTROL GROUP			**GROUP 2- CLINICAL GROUP**			
Participant number	Age/Gender	Education	Participant number	Age/Gender	Education	Diagnosis
P1	18/F	12	P15	19/M	12	AA
P2	37/M	12	P16	42/M	12	AA
P3	51/M	15	P17	47/M	15	AA
P4	40/M	15	P18	45/M	13	AA
P5	39/M	15	P19	37/M	15	AA
P6	27/F	17	P20	32/M	17	CA
P7	63/M	15	P21	59/M	15	AA
P8	24/M	15	P22	30/M	15	AA
P9	37/F	15	P23	37/M	15	CA
P10	35/M	15	P24	37/M	15	AA
P11	59/M	13	P25	59/M	13	AA
P12	42/M	15	P26	42/M	15	CA
P13	18/M	12	P27	18/M	12	AA
P14	24/F	15	P28	27/M	12	CA

Note: AA- Anomic Aphasia, CA- Conduction Aphasia. Age and Education have been represented in years.

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 and naming ability in persons with aphasia and neurotypical individuals.

3.4.2 Domains of Executive Functions and naming tests:

The domains of the executive functions considered for the present study were cognitive set-shifting, inhibitory control, working memory span, and updating and naming tests were confrontation naming, responsive naming and generative naming (word and phoneme fluency) as shown in Table 3.2. The task for each domain of executive functions and naming ability, along with the instructions and scoring are explained in the following section.

Table 3.2

Domains of Executive functions and Naming task

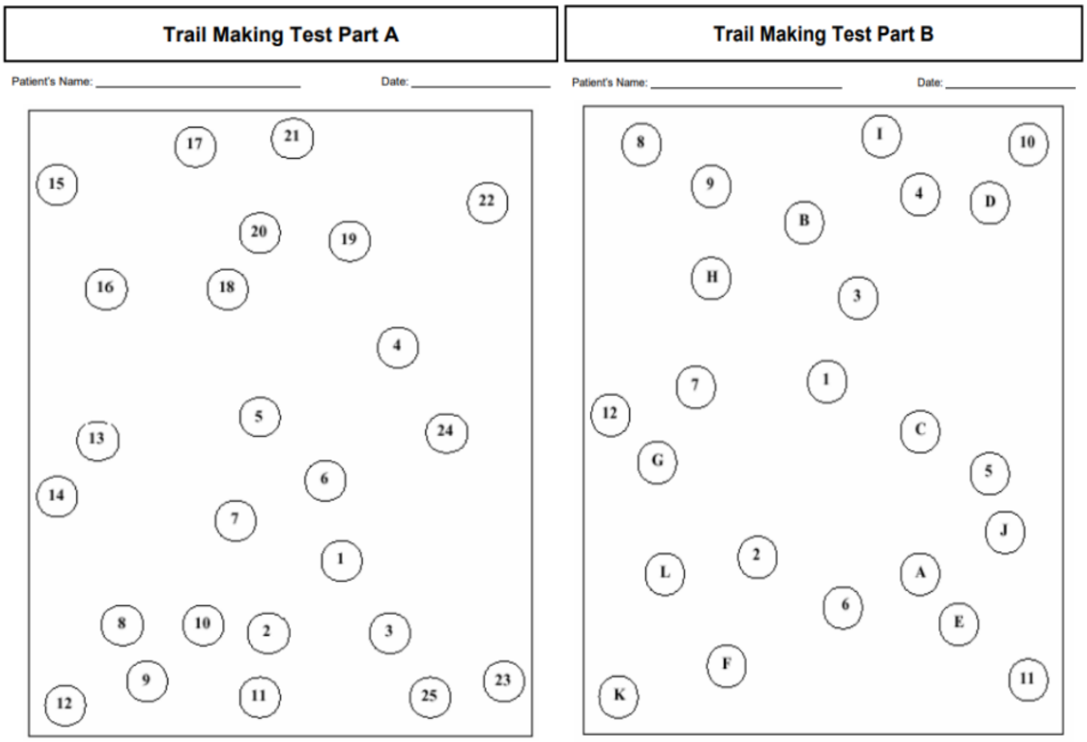
Sl no.	Domains of executive functions and the tests used	Domains of naming tests used
1.	**Set-Shifting** Trail Making Test	**Confrontation naming**
2.	**Inhibitory Control** Stroop Test	**Responsive naming**
3.	**Working Memory Updating** Sem-back test	**Generative naming** • *Word fluency:* Animals Vehicles • *Phoneme fluency:* |s| |a|
4.	**Auditory Working Memory Span** Digit Span Test-Backwards	

3.4.2.1. Set-Shifting

Task Description: Shifting was assessed using the Trail Making Test (Reitan, 1958), a paper-pencil task comprising two parts, namely Part A and Part B as shown in Figure 3.1. In Part A, participants had to link 25 circled numbers (connecting 1, 2, 3…, n) distributed on paper. The total time required for Part A was termed TMT-A (Trail Making Time- A). Part B of the test required participants to link the circles alternatively using a combination of circled numbers and letters (e.g., 1 to A to 2, B to 3 to C…,n). The total time required for Part B is termed TMT-B (Trail Making Time-B).

Figure 3.1

The stimulus for Trail Making Test Part A (left) and Part B (right)



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

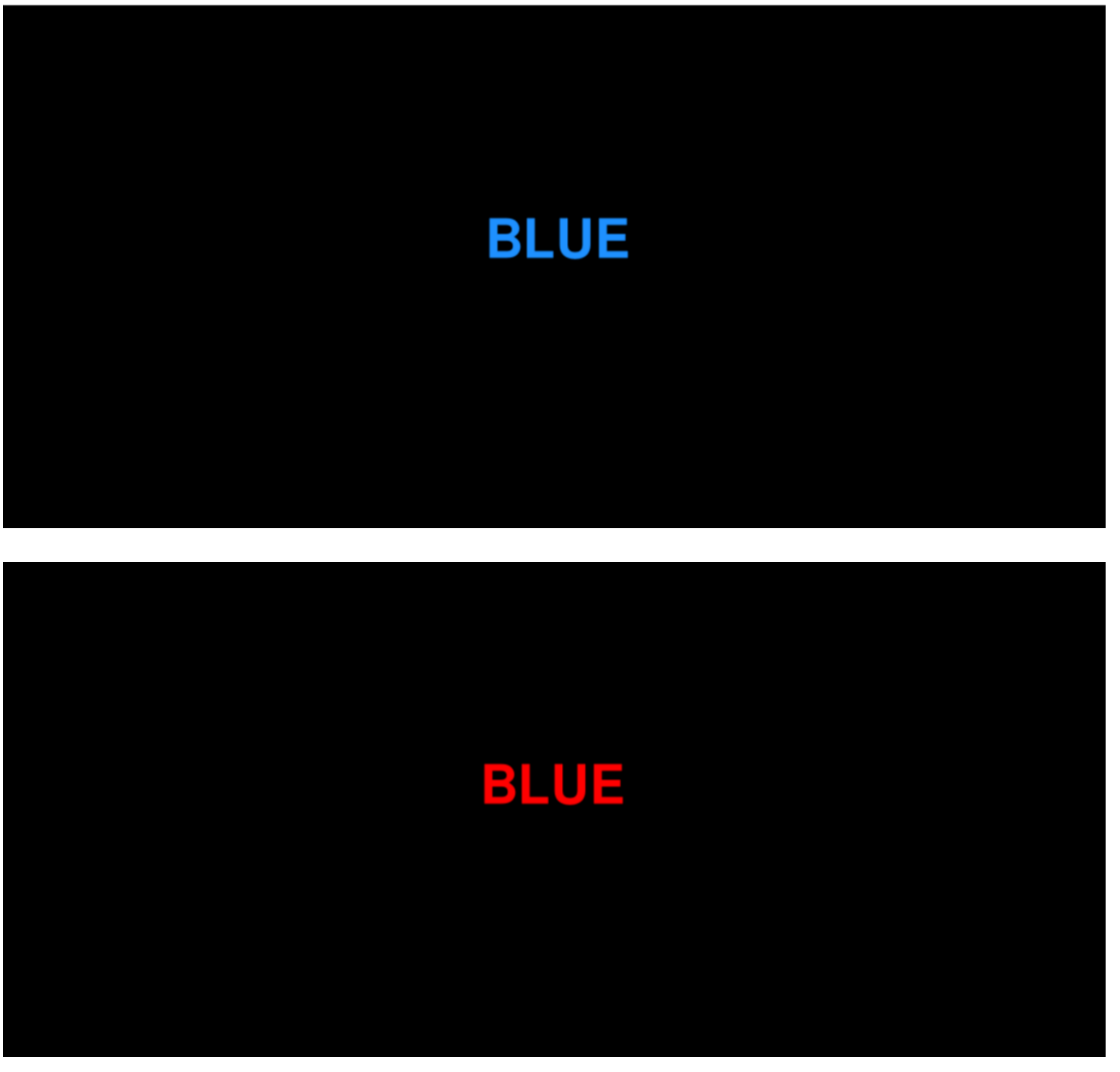
Scoring: The duration to complete each part of the task was noted in milliseconds. The time span was calculated from the beginning of the task to the end. The participants were provided with the Trail Making Test- Part A first, followed by Part B of the test. The participants were given only 1 trial to complete the task. The total duration of time taken by the participants to complete Part A and Part B of the TMT was recorded using a stopwatch from the start (1) to the stop point (25 or L). The time duration was noted in milliseconds (ms), this was the general analysis. For cluster analysis, the difference between the time taken to complete the two tasks (Trail Making Tests Difference or TMT-D=TMT A-TMT B) and the ratio (Trail Making Test Ratio or TMT- R= TMT B/TMT A) of the time taken for both tasks was computed. The difference between and the ratio of the time taken to complete the two tests indicates test-switching ability (Sánchez-Cubillo et al., 2009). The effect of perceptual speech is reduced by the ratio of TMT-A and TMT-B among healthy individuals (Salthouse, 2011).

3.4.2.2. Inhibition control

Task Description: Inhibition control is an umbrella term that describes the voluntary control, or inhibition, of goal-irrelevant stimuli, cognition, and behavioral response (Diamond, 2013). Inhibition is assessed using the Stroop test (Stroop, 1935). The Stroop task was performed from the list of officially available tasks from the *Psytoolskit* website for the study. The task was performed on an HP Pavilion laptop. Four colors and their names made up the test: red, green, blue, and yellow. There were two categories for the test: neutral/congruent and incongruent and a sample of stimuli is shown in Figure 3.2.

Figure 3.2

Images of the stimulus presentation in congruent and incongruent conditions.



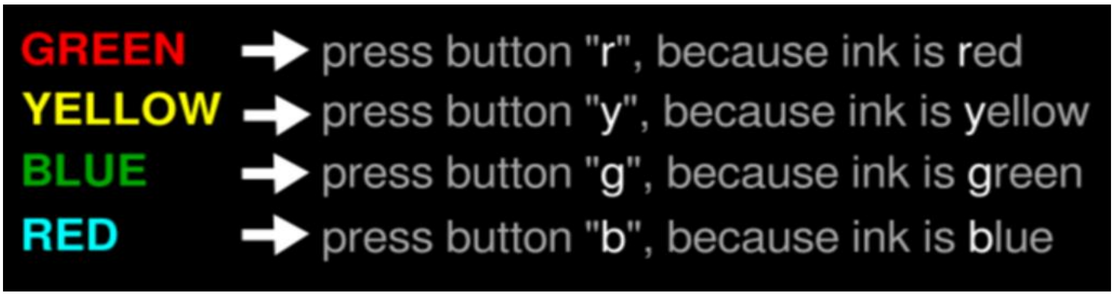
There were three conditions in the Stroop task. In *neutral conditions* (Condition 1- color words printed in black ink), *congruent condition* (Condition 2- ink color and meaning of the word would be in the same color; for example, the word 'Blue' would be written in 'blue ink'), and in *incongruent conditions* (Condition 3- ink color varies with the meaning of the words; for example, the word 'red' would be written in 'green ink').

The stimuli were shown individually in a random sequence. Participants were given a fixed interval of 2000ms to respond to each stimulus before the next one appeared. This same process was used for both test scenarios, where the congruent and incongruent conditions were displayed in random order.

Instruction: The participants were instructed to see color names (red, green, blue, yellow) in different "print" colors, and the participants had to respond to the print color. For example, if one sees "GREEN" ("Green" in Red color) one needs to respond to the print color (red), and press the associated button ("r"). The other buttons used in this study were "g," "b," and "y", for green, blue, and yellow as shown in Figure 3.3.

Figure 3.3

The written instruction provided for the Stroop test



Scoring*:* A response pad with 4 color keys (indicating the colors used for the Stroop test) was used for response recording in the test. The response pad was indigenously prepared for the present study. The reaction times and the accuracy scores were automatically recorded and displayed on the screen. A score of 1 was provided for each correct answer, and a score of 0 was provided for wrong answers. The total number of accurate scores across both the conditions, reaction time (calculated in milliseconds) for the congruent and incongruent condition, the Stroop difference, and the Stroop ratio for reaction times were calculated as part of cluster analysis. The Stroop difference is the difference between incongruent and congruent conditions in terms of reaction time (Scott & Wilshire, 2010). The Stroop ratio was computed by dividing the Stroop difference (mean incongruent-mean congruent) by the mean of the congruent and incongruent trials, then multiplying it by 100 to account for the overall speech difference in response as shown in Figure 3.4.

Figure 3.4

The formulae used for the calculation of cluster analysis of EF -Stroop difference and Stroop ratio.

$$\text{Stroop Difference} = RT_{INCONGRUENT\,TRIAL} - RT_{NEUTRAL\,TRIAL}$$

$$\text{Percentage Stroop ratio } (\%) = \left[\frac{\frac{RT_{INCONGRUENT\,TRIAL} - RT_{NEUTRAL\,TRIAL}}{RT_{INCONGRUENT\,TRIAL} + RT_{NEUTRAL\,TRIAL}}}{2} \right] \times 100$$

Interpretation: Better inhibitory control is indicated by a reduced Stroop difference and percentage Stroop ratio (Bose et al., 2022).

3.4.2.3. Working Memory Updating

Working memory updating refers to the capacity to retain information in the mind and continuously update it as new information is introduced. The n-back test was used to assess the working memory updating ability. The participants in the n-back test were asked to decide if a current stimulus matched with a prior stimulus sequentially which came in 'n' place. It requires temporal storage, manipulation of the stored information, and continuous revision of the working memory component (Wright & Fergadiotis, 2012). The N-back tests the phonological, semantic, and syntactic levels with respect to language. For the present study, working memory updating was assessed using a semantic version of the N-back test. The SEM-back tests replicated the N-back tests with lexical items (Priences, 2020). The lexical category of fruits was used for the test, and the stimuli under this Sem-back category were considered. The list of stimuli (picture image of the semantic category) considered under the fruits is presented in the table below Table 3.3. The sample of Sem Back from 1-back to 4-back is shown in Table 3.4.

Table 3.3

The stimulus for the Sem-back category-Fruits

THE STIMULUS OF THE SEM-BACK CATEGORY	
S.No.	**FRUITS**
1	Apple
2	Pineapple
3	Banana
4	Mango
5	Pomegranate
6	Watermelon
7	Grapes
8	Pear
9	Orange
10	Papaya

Table 3.4

The stimulus for the Sem-back category of fruits- across conditions

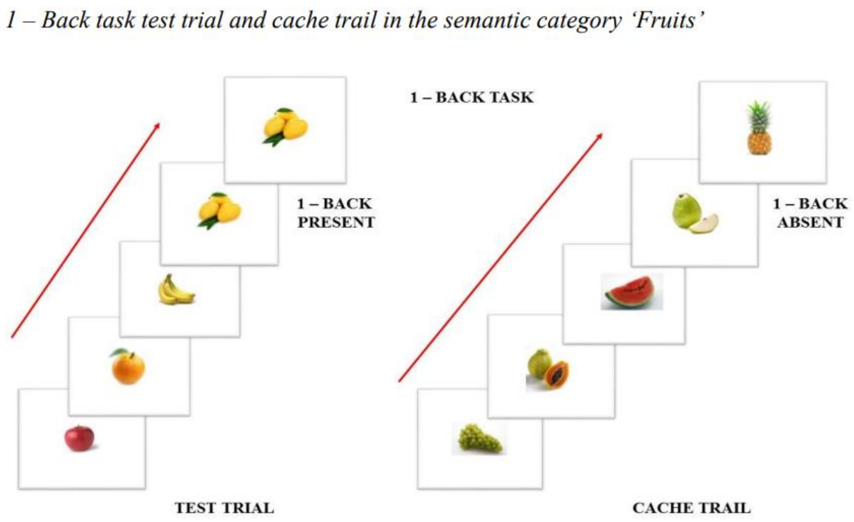
THE STIMULUS OF THE SEM-BACK CATEGORY	
CONDITIONS	**FRUITS**
1-back	1. Apple, Banana, Orange, **Mango- Mango**
2-back	2. Papaya, Apple, **Orange,** Mango-**Orange**
3-back	3. Apple, **Banana,** Pineapple, Orange-**Banana**
4-back	4. **Watermelon,** Papaya, Pomegranate, Banana-**Watermelon**

The Sem-back task was run using the Psychology Software Tool's E-Prime software on a Lenovo G40 series desktop computer. The E-Prime software module, the E-studio by the Psychology Software Tools, was used with fixed stimulus duration, inter-stimulus duration, and response time. The stimulus was 4000ms, and the inter-stimulus duration was 1000ms.

The participants were presented with stimulus one at a time. The participants were seated approximately 50cm from the computer screen. The administration of the test for both groups began with a practice trial followed by 20 experimental trials. The software spanned from 1-back to 4-back, automatically recording the participants' responses across all conditions. The lexical item used consists of 5 trials each for 1-back, 2-back, 3-back, and 4-back. The 5 trials for each condition included test trials and cache trials and one trial is shown in Figure 3.5.

Figure 3.5

Example of stimulus used for Sem-back test



Instruction: The participants were asked to recognize, recall, and match the item that repeated 'n' times later at the end of each trial's sequences. The participants were asked to respond by pressing 1 (in case of a back present/ presence of repetition) or pressing 2 (in case of back absent/ no repetition) after the screen displayed a question mark.

Scoring: A score of 1 was provided for each correct response, and a score of 0 was provided for each wrong answer. The reaction time (calculated in milliseconds) and accuracy data were recorded for each trial. The first practice trial was ignored, and the remaining trials were considered for statistical analysis. All the responses were recorded in the E-prime software and were accessible through the E-data aid.

3.4.2.4 Auditory Working Memory Span

Auditory Working Memory Span (auditory backward digit span)- Memory span is the longest list of items that a person can repeat back in correct order immediately after a presentation on 50% of all trials. The Forward and Backward Digit Span tests are tests that are commonly used to evaluate a person's Working Memory Span. The present study evaluated the Working Memory Span using the Backward Digit Span test.

The ability to recall digit sequences backward was evaluated using Wechsler's Memory Scale—4 (Wechsler, 2009) and the stimuli considered for the present study is shown in Table 3.5. The examination commenced with 2 Digit Span stimuli, which were succeeded by a gradual augmentation in the number of digits as the assessment advanced. The Digit Span series escalated from 2 to 8, with every span comprising 2 trials, except for the 2 Digit Span, which encompassed 4 trials. Once the individuals were unable to correctly recall two trials in a row at any one span size or when the maximum list length had been achieved (8 digits), testing was terminated.

Table 3.5

The stimuli for Backward Digit Span (Wechsler's Memory Scale—4 (Wechsler, 2009)

STIMULUS OF BACKWARD DIGIT SPAN TEST			
S.No.	**Item Span**	**Trial**	**Stimulus**
1	2	Trial 1	2-1
		Trail 2	1-3
2	2	Trial 1	3-5
		Trail 2	6-4
3	3	Trial 1	5-7-4
		Trail 2	2-5-9
4	4	Trial 1	7-2-9-6
		Trail 2	8-4-9-3
5	5	Trial 1	4-1-3-5-7
		Trail 2	9-7-8-5-2
6	6	Trial 1	1-6-5-2-9-8
		Trail 2	3-6-7-1-9-4
7	7	Trial 1	8-5-9-2-3-4-6
		Trail 2	4-5-7-9-2-8-1
8	8	Trail 1	6-9-1-7-3-2-5-8
		Trail 2	3-1-7-9-5-4-8-2

Instructions: The participants were instructed to repeat the series of numbers provided to them in backward or reverse order (Holdnack & Drozdick, 2010). The stimulus was provided to the participants verbally, with the interval between the numbers being approximately 2s.

Scoring: For each trial, a score of 1 was given for every correct response and a score of 0 for every incorrect response. In an item trial, if a participant scores 0 on either of the trials, the test is continued; if the participant scores 0 on both trials, the test is terminated. The item score is the sum of the scores on two trials for that item. The total score was the sum of scores on all the items. Additionally, the maximum longest digit span produced by the participant was also noted.

3.4.3 Naming Tests:

The participants were subjected to a naming test section from Battery for Cognitive-Communication Disorders – Kannada BCC-K (Goswami, 2019). The test included 3 types of naming.

3.4.3.1 Confrontation Naming

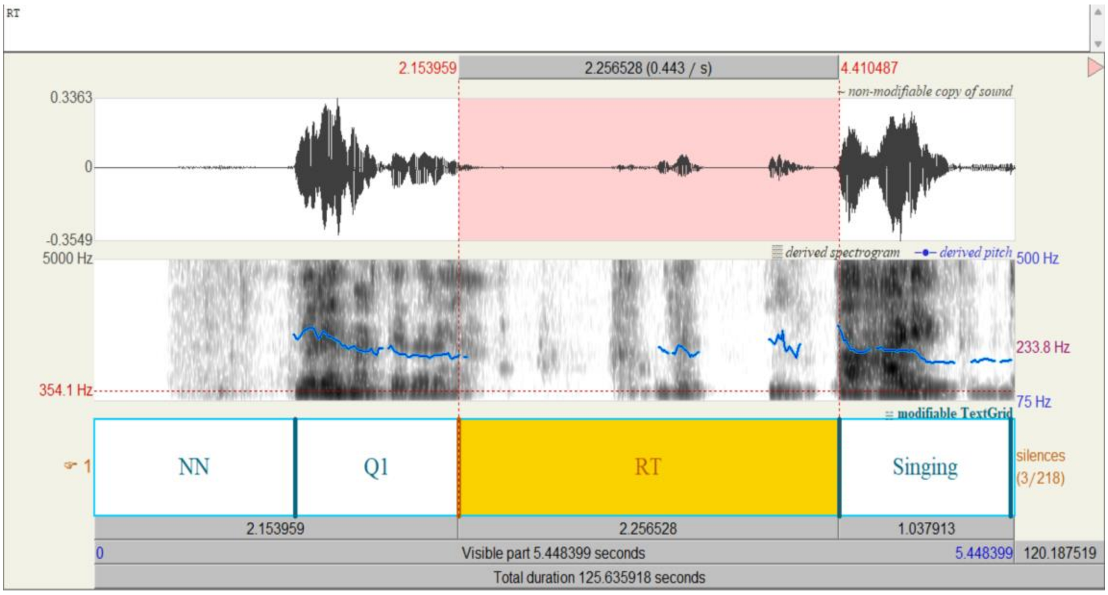
The confrontation naming test includes pictures of verbs, and living, animate and non-living items. Each category consisted of ten stimulus items, all the categories together constituting a total number of 40 picture stimuli that were considered for the present study.

Instructions: Participants were shown images from the confrontation naming segment, beginning with the verbs category. The participants were required to provide a response to the question posed by the clinician immediately after the display of the image and the completion of the question. The participants were specially instructed to respond verbally by loudly mentioning the correct response.

Scoring: The responses were noted using a 3-point scoring (0, 0.5, 1) system. The correct responses were given a score of 1. In the case of only a pointing response, semantic or phonemic paraphasia, a score of 0.5 was provided. In cases of no response, perseverations, circumlocution, and unintelligible response, a score of 0 was provided. Additionally, the reaction times (measured in milliseconds) of responses were calculated as the amount of time that elapsed between the presentation of the question and the beginning of the correct response. The questions provided and the responses of the participants were recorded on PRAAT (Boersma et al., 2015) for easy analysis of reaction time. The responses were interpreted and mentioned in a text grid corresponding to the spectral display of the response as shown in Figure 3.6 and the same was used for cluster analysis.

Figure 3.6

The image representing the estimation of reaction times on PRAAT



3.4.3.2 Responsive Naming

Responsive naming involves the ability to respond to the description of a particular picture. The test of Battery for Cognitive-Communication Disorders – Kannada BCC-K (Goswami, 2019) involves ten questions for responsive naming.

Instructions: The researcher directed the participants to listen attentively to the question and then verbally identify the picture that corresponds correctly to the question. A set of 10 questions was presented to the participants, with the corresponding images given beforehand. To prevent guessing, the questions were randomly presented to the participants.

Scoring: The responses were noted using a 3-point scoring (0, 0.5, 1) system. The correct responses were given a score of 1. In the case of only a pointing response, semantic or phonemic paraphasia, a score of 0.5 was provided. In cases of no response, perseverations, circumlocution, and unintelligible response, a score of 0 was provided. Additionally, the reaction times (measured in milliseconds) of responses were calculated as the amount of time that elapsed between the presentation of the question and the beginning of the correct response. The questions provided and the responses of the participants were recorded on PRAAT (Boersma et al., 2015) for easy analysis of reaction time. The responses were interpreted and mentioned in a text grid corresponding to the spectral display of the response as shown in Figure 3.6 for cluster analysis.

3.4.3.3 Generative Naming

Generative naming involves tests where an individual is asked to generate as many words as possible pertaining to criteria category/sound within a span of 60 seconds.

Instructions: Generative naming involved two major categories,

1. *Verbal fluency test:* In the study, 2 categories (animals and vehicles) were included in the fluency test. The objective for the participants was to say as many words as they could in 60 seconds from the category of ‘animals’ and

‘vehicles’. No guidelines on how a participant should generate and organize words were provided.

2. *Phonemic fluency test:* In the study, 2 sounds, |s| and |a|, were used for the fluency test. Within 60 seconds, the participants were instructed to yield as many words as they could that began with the letters |s| and |a|. The participants were specifically instructed not to produce proper nouns, numbers, and variants of the same word.

Scoring: The total scores for a number of correct responses were calculated by providing a score of 1 for all correct responses and phonemic paraphasia and a score of 0 for all incorrect, unintelligible responses and neologisms. The perseveration scores were not calculated as the participants did not exhibit any perseveration. Additionally, the reaction times of responses were calculated as the amount of time that elapsed between the presentation of the question and the beginning of the correct response. The questions provided and the responses of the participants were recorded on PRAAT (Boersma et al., 2015) for easy analysis of reaction time. The responses were interpreted and mentioned in a text grid corresponding to the spectral display of the response and further used for cluster analysis.

3.4.4 Extended Analysis of Naming Tests:

Traditionally, performance on word and phonemic generation tests is often evaluated in terms of the proportion of correct responses. However, this approach may not provide us enough insight into word generation tasks and may not provide us with as much analytical and explanatory ability. Further measurements such as clustering and switching, error types, and temporal characteristics have been demonstrated to improve the fluency test's analytical efficacy (Thiele et al., 2016). Hence, the current study used measures such as clustering, switching, and temporal characteristics to analyze performance on naming and fluency tests.

3.4.4.1 Quantitative Analysis (Level I):

The responses of individuals were assessed for the following parameters:

In quantitative analysis (QA), two variables were computed, the number of correct responses and the Fluency Difference Score.

1. *The number of correct responses (CR)* is the total number of correct responses produced in a minute (CR), excluding any errors.

2. *The fluency difference score (FDS)* is the number of correct responses in the semantic fluency test subtracted by the number of correct responses in the phonemic fluency conditions as a proportion of correct responses in the semantic fluency condition (Friesen et al., 2015). The formula used to calculate correct responses (CR) and the fluency difference score (FDS) is shown in Figure 3.7.

Figure 3.7

The formula for calculation of Fluency Difference Score.

$$FDS = \left(CR_{semantic\ fluency} - CR_{letter\ fluency}\right) / CR_{semantic\ fluency}$$

3.4.4.2 Time-course analysis (Level II):

In Time-course analysis (TCA), two variables were computed, the 1^{st}-Reaction Time and the Subsequent-Reaction Time as shown in Figure 3.8.

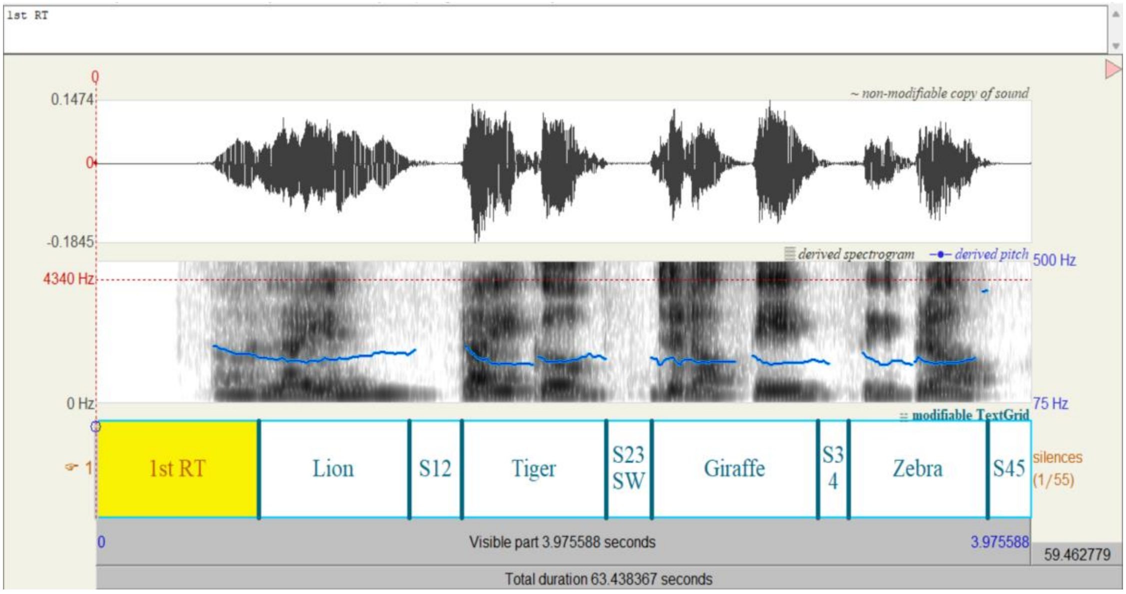
1. *First-Reaction Time (1^{st} RT):* The period elapsed between the beginning of a trial and the initiation of the first response, which is associated with test preparation.

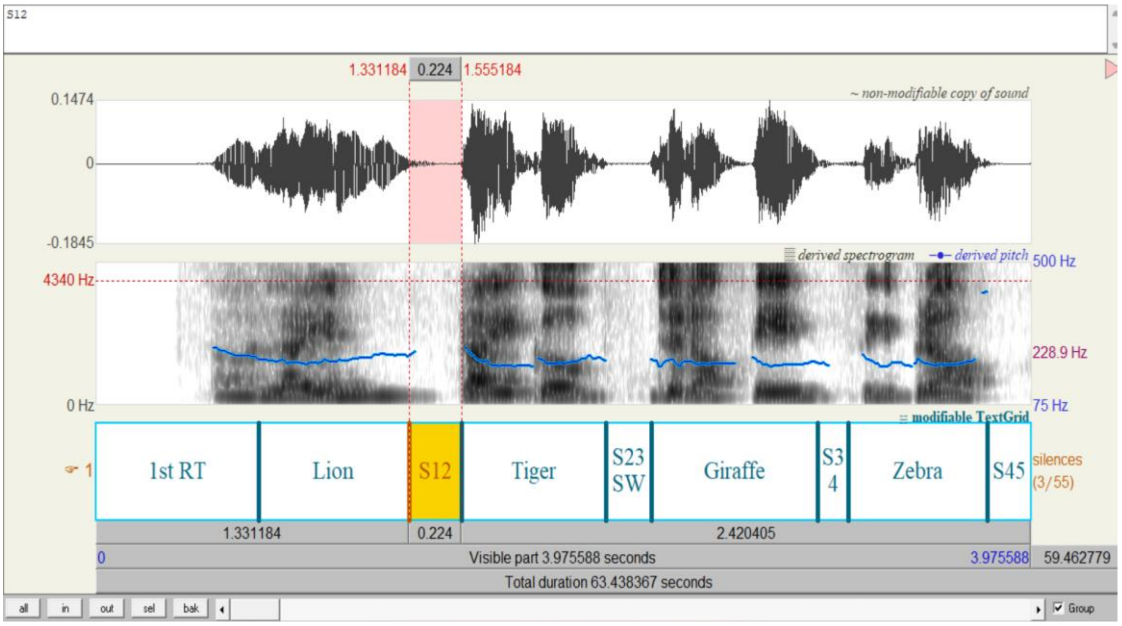
2. *Subsequent Reaction Time (Sub-RT):* The mean value of each recalled item's retrieval latencies in relation to the start of recall is known as subsequent RT (Wixted & Rohrer, 1994).

The 1^{st} RT and the Sub-RT were calculated using PRAAT (Boersma et al., 2015) as shown in Figure 3.8. The responses were all marked on the text grid corresponding to the spectral representation of the responses. The Sub RT were marked as 12, 23, 34, and so on to indicate the time elapsing between the 1^{st} and the 2^{nd} response, the 2^{nd} and the 3^{rd} response the 3^{rd} and the 4^{th} response, respectively. The Reaction times mentioned were calculated in milliseconds.

Figure 3.8

Measurement of 1st RT and Sub-RT





3.4.4.3 Clustering and Switching Analysis (Level III):

Clustering and switching analyses involved 4 variables which were the cluster size, the number of switches between clusters, the average within-cluster pauses across the clusters, and the average between-cluster pauses across the response.

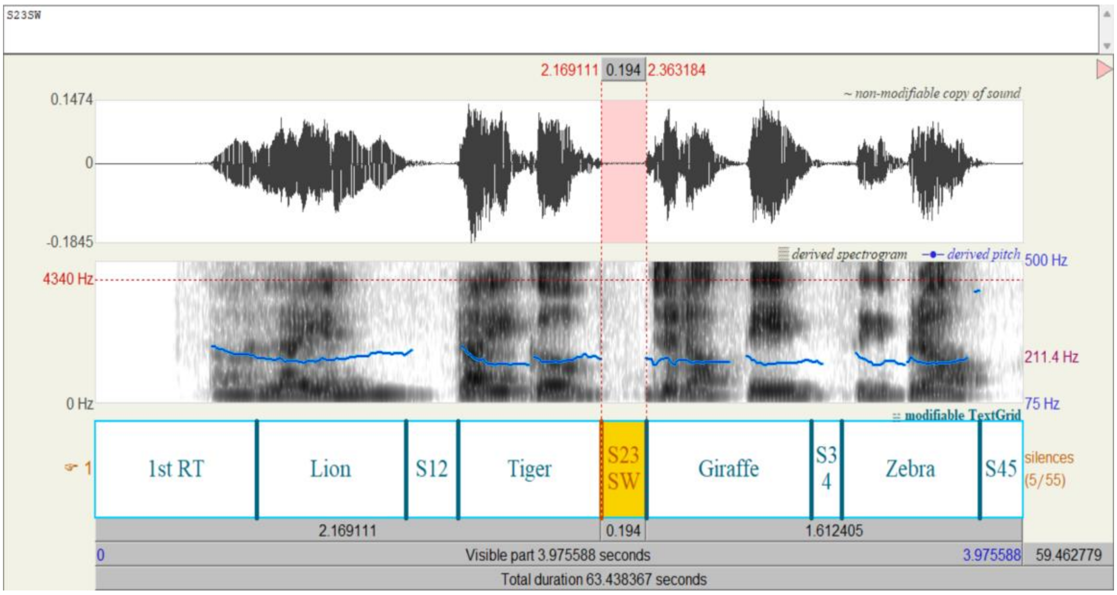
1. *Cluster size (CS)* refers to the total size of a cluster produced by a participant. The cluster size was calculated by scoring the number of words produced in a cluster; for instance, in a cluster of 3 words, Tiger, Lion, and Cheetah, the first word was given a score of 0, the second word a score of 1 and the third word a score of 2. Hence the total size of the cluster was determined to be 2. The total cluster size was determined by summing the sizes of each cluster and dividing this total score by the number of clusters this value was termed as the mean cluster size (Figure 3.9).

   The semantic fluency cluster in verbal fluency consisted of words that belonged to the same semantic subcategory (Troyer, 2000b). Clustering in *letter fluency* is the successive generation of words that meet any one of the requirements mentioned. (Troyer, 2000a): Words having the same 2 letters in the initial position (stop, stone). Words that, regardless of their exact spelling, solely differ by a vowel sound (sheep, ship). Words with rhymes (such as stool and school) or homonyms (son, sun).

2. *The number of switches (NoS):* This parameter refers to the number of switches between clusters. This was manually calculated by noting down the number of switches marked on the text grid as “SW” during PRAAT analysis.

Figure 3.9

The transition from one cluster to another or switch is depicted as SW



3. *Within-cluster pause (WCP):* The mean pause duration between words within a cluster is referred to as the within-cluster pause. For example, in a cluster such as Tiger, Lion, and Cheetah, the pauses between these words are 2000ms and 5000ms, then the average WCP of this cluster is the average of these two pauses. The mean WCP across all clusters was then calculated by averaging the WCP for each cluster. The mean WCP across all clusters was used for statistical analysis.

By summing the within-cluster pause values for each cluster and dividing this total value by the number of clusters, the mean within-cluster pause for a trial was computed.

4. *Between-cluster pauses (BCP)* are defined as the intervals between the final word of one cluster and the commencement of the subsequent cluster. The

average BCP was calculated by summing all the BCPs across the trial and dividing them by the Number of Switches.

All the data pertaining to the above-mentioned parameters for both executive functions tests and the naming tests were imported to Microsoft Excel and SPSS spreadsheet, and each value was checked by hand to ensure the accuracy of the data entry for further data analysis. The mean and individual scores (as per the requirement of the task) of participants were considered for further analysis and discussion.

***Note:** All the formulae in the method section have been provided in the Appendix

CHAPTER IV

RESULTS

The primary objective of the present study was to investigate the correlation between naming abilities and executive functions in both individuals with aphasia and a control group of healthy individuals. The study also aimed to determine the extent of association between executive functions and naming performance in both groups, considering the impact of executive functions on naming skills in individuals with Aphasia and healthy controls.

Four executive function assessments and three distinct naming evaluations were employed to ascertain the executive function and naming abilities in both Persons with Aphasia and the cohort of Healthy Controls and establish the interrelationship between these variables within each group.

The participants underwent a series of executive function assessments, including the Trail Making Test for evaluating cognitive flexibility or the ability to shift between tasks, the Stroop Test for measuring inhibitory control, the Sem-back test for gauging working memory updating skills, and the Backward Digit Span Test for evaluating working memory span. The classification of executive functions examined in this study adhered to the framework introduced by Friedman & Miyake, (2000).

The naming assessments conducted encompassed the Confrontation Naming Test, Responsive Naming Test, and Generative Naming Test, all derived from the naming segment of the Battery for Cognitive-Communication Disorders – Kannada BCC-K (Goswami, 2015). Consistent with the BCC-K guidelines, identical stimuli were utilized across all naming tests, with the exception of the Generative Naming Test, where word fluency was evaluated within the domains of animals and vehicles, while phonemic fluency was assessed using the sounds |s| and |a|.

Within the domain of Executive Functions, an evaluation was conducted on the Trail Making Test, encompassing the total time taken to complete two specific tasks (referred to as TMT-A and TMT-B). Additionally, calculations were made for the TMT Difference (TMT-D) and the TMT Ratio (TMT-R). In the context of the Stroop test, assessments were performed on accuracy (SCR) as well as the response time under both congruent and incongruent conditions (SC and SIC, respectively). Furthermore, calculations were derived for the Stroop Difference (SD) and the Stroop Ratio (SR) based on these metrics. The Sem-back test underwent analysis for both accuracy and the mean Reaction Time. Lastly, the Backward Digit Span Test was utilized to evaluate the complete range or the span of repeated numbers (DSB S) and the corresponding score (DSB SC) achieved by the participants.

All the previously mentioned Naming assessments were subjected to analysis within three primary measurement categories: Quantitative Analysis (QA). This encompasses the measurement of accuracy to quantify the count of accurate responses. Additionally, the Fluency Difference Score (FDS) was computed, furnishing insights into the discrepancy between word and phonemic fluency concerning their respective accuracies; the Time Course Analysis (TCA) involves the examination of reaction time measures. Within the scope of Time Course Analysis, two specific parameters were assessed: the 1st Reaction Time (1st RT) and the Subsequent Reaction Time (Sub-RT); The Cluster Analysis (CA) involved the integration of measurements directed at the evaluation of proficiencies pertaining to both clustering and switching. The comprehensive scope of the Cluster Analysis (CA) involved the evaluation of four specific parameters: the Number of Switches (NoS), the cluster size (CS), the mean Within Cluster Pause (WCP), and the mean Between Cluster Pause (BCP). Only the accuracy and 1st RT of the Confrontation Naming and Responsive Naming tests were evaluated. All eight parameters mentioned earlier were considered during the assessment of the Generative Naming tests.

Table 4.1

Enumeration of parameters evaluated within each test category of executive function and naming

CLASSIFICATION OF PARAMETERS			
Tests Administered	**Quantitative Analysis**	**Time Course Analysis**	**Cluster Analysis**
EXECUTIVE FUNCTION TESTS			
S. **Inhibitory control (Stroop Test)**	• Stroop Correct Response	• Stroop reaction time for the congruent condition • Stroop reaction time for incongruent condition • Stroop difference • Stroop ratio	---
S. **Working memory span- (Digit Span Test- Backwards – DSB)**	• Digit Span Test- Backwards total score	• Digit Span Test- Backwards total span	

S. **Working memory updating (Sem-back test)**	• Working memory updating • Sem-back Accuracy	• Reaction time	
S. **Trail Making Test**	---	• *TMT-A* • *TMT-B* • TMT-Difference • TMT-Ratio	
Tests Administered	**Quantitative Analysis**	**Time Course Analysis**	**Cluster Analysis**
		NAMING TESTS	
1. Confrontation naming	• Confrontation naming accuracy	• 1st Reaction time	---
2. Responsive naming	• Responsive naming accuracy	• 1st Reaction time	
S. **Generative naming**	• Generative naming fluency difference Scores for vehicle and phoneme /s/ • Generative naming fluency difference Scores for animal and phoneme /a/	• 1st Reaction Time • Sub-Reaction Time	• Cluster size • Number of switches • Within Cluster Pause • Between Cluster Pause
(Word fluency test)	• Word Fluency for animals • Word Fluency for vehicles		
(Phoneme fluency test)	• Phoneme Fluency for |s| • Phoneme Fluency for |a|		

These evaluations were performed on a total of 28 participants (Healthy Controls: N=14, Clinical Group: N=14). The Healthy Controls were categorized as Group 1, and the Persons with Aphasia or the Clinical Group were called Group 2. All the participants in the study were in the age range of 18 to 59 years. All the values obtained post the above-mentioned analysis for Executive Function tests and Naming tests were analyzed using the statistical package for *Social Science (SPSS) software (version 26.0).* The data was first subjected to the test of normality.

S.2 **Test for normality**

Upon conducting the Shapiro-Wilk Test of Normality on the acquired dataset, it was observed that the parameters derived from the executive functions and naming assessments exhibited normal and non-normal distribution. This signifies that a portion of the parameters adhered to a normal distribution while others did not. Hence, both parametric and non-parametric tests were applied accordingly for the statistical analyses of the gathered data.

Table 4.2

Compilation of executive function and naming test parameters categorized into normally distributed and non-normally distributed groups.

CLASSIFICATION OF PARAMETERS			
Tests Administered	**Quantitative Analysis**	**Time Course Analysis**	**Cluster Analysis**
EXECUTIVE FUNCTION TESTS			
1. Inhibitory control **(Stroop Test)**	• Stroop Correct Response	• <u>Stroop reaction time for the congruent condition</u> • <u>Stroop reaction time for incongruent condition</u> • Stroop difference • Stroop ratio	---
2. Working memory span- **(Digit Span Test-Backwards – DSB)**	• Digit Span Test-Backwards total score	• Digit Span Test-Backwards total span	
3. Working memory updating **(Sem-back test)**	• Working memory updating • Sem-back Accuracy	• <u>Reaction time</u>	

4. Trail Making Test	---	• *TMT-A* • *TMT-B* • TMT-Difference • TMT-Ratio	
Tests Administered	**Quantitative Analysis**	**Time Course Analysis**	**Cluster Analysis**
	NAMING TESTS		
1. Confrontation naming	• Confrontation naming accuracy	• 1st Reaction time	---
2. Responsive naming	• Responsive naming accuracy	• 1st Reaction time	
3. Generative naming	• Generative naming fluency difference Scores for vehicle and phoneme /s/ • Generative naming fluency difference Scores for animal and phoneme /a/	• 1st Reaction Time • Sub-Reaction Time	• Cluster size • Number of switches • Within Cluster Pause • Between Cluster Pause
(Word fluency test)	• Word Fluency for animals • Word Fluency for vehicles		

(Phoneme fluency test)	• Phoneme Fluency for |s| • Phoneme Fluency for |a|
Note: All the normally distributed parameters have been underlined.	

The data analysis procedure was divided into four distinct sections. The initial section, designated as **Section I: Descriptive statistics,** was carried out with the purpose of computing the **mean, standard deviation, minimum, and maximum.** In the subsequent section, **Section II: Between-group comparison** involving Healthy Controls (HC) and Persons with Aphasia (PWA), employed an Independent Sample t-test for parameters that followed a normal distribution. Conversely, the Mann-Whitney U Test was utilized for parameters that did not adhere to a normal distribution. The intention of this phase was to ascertain which group exhibited superior performance based on the evaluated parameters.

Transitioning to **Section III: Within-group comparison,** a Paired Sample t-test was applied for parameters displaying a normal distribution, while the Wilcoxon Signed Rank test was employed for those without a normal distribution. This comparison aimed to unravel the disparities in performance between Healthy Controls and Persons with Aphasia (PWA) concerning both the executive functions test and the naming tests. **Section IV** encompassed the **correlation analysis,** a process that facilitated the comprehension of the associations between the parameters derived from the executive function tests and naming tests. This analysis specifically examined the relationships in terms of response accuracy, reaction times, and clustering and switching parameters.

4.2 Section I: Descriptive statistics

4.2.1 Descriptive statistics for the Quantitative Analysis/Accuracy scores of the executive functions' tests

The results of descriptive statistical analysis with respect to mean, standard deviation, minimum, and maximum values for accuracy scores on the executive tests for both HC and PWA are shown in Table 4.3.

Table 4.3

Descriptive Statistics of Executive Function Tests-Quantitative Analysis/Accuracy Score

Descriptive Statistics-Quantitative Analysis/Accuracy Score									
	Parameters	**HEALTHY CONTROLS**				**PERSONS WITH APHASIA**			
I	**EXECUTIVE FUNCTION TESTS**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**
1.	Stroop Test Stroop correct responses (SCR)	33.07	9.651	5	40	20.50	13.375	5	40
2.	Digit Span Backward Total Score (DSB-SC)	9.07	3.050	6	14	6.00	1.754	4	10
3.	Sem-back test Accuracy (NCR)	15.00	5.069	6	20	12.57	4.879	3	18

In the context of 'inhibitory control,' as assessed through the Stroop test, a comparison of mean, standard deviation, minimum, and maximum values revealed that the HC group exhibited superior performance. They achieved a notably higher mean accuracy in both congruent and incongruent conditions. In contrast, the PWA group demonstrated a lower mean accuracy and an elevated standard deviation. It is worth noting that the minimum and maximum counts of correct responses were consistent between both groups.

The cumulative score achieved by both the HC and PWA in the ‘working memory span’ domain was assessed in a quantitative manner. Notably, the HC group outperformed the PWA group in terms of the mean total score, particularly excelling in the Backward Digit Span task. Furthermore, the HC group exhibited both a higher minimum and maximum score when compared to the PWA group.

In the realm of ‘working memory updating’, the HC group once again displayed superior performance in comparison to the PWA group. They achieved a higher average accuracy on the Sem-back test and demonstrated both a higher minimum and maximum count of correct responses. In summary, across all the executive function tests, the HC group consistently outperformed the PWA group when subjected to quantitative analysis.

4.2.2 Descriptive statistics for the Time Course Analysis of the executive functions’ tests

Descriptive Statistics for Time Course Analysis (analysis of reaction time and total duration) have been provided in terms of mean, standard deviation, minimum, and maximum in Table 4.4.

In the realm of inhibitory control, the HC group exhibited a slightly faster mean reaction time for congruent stimuli compared to the PWA group. Unpredictably, for incongruent conditions, the PWA group displayed shorter Stroop test reaction times, indicating better performance in this aspect when contrasted with the HC group. This trend was also reflected in the Stroop Difference measure, where the difference was smaller for the PWA group and larger for the HC group. Notably, the PWA group showed a negative Stroop Difference, signifying a reduction in reaction time for incongruent conditions. However, upon closer examination of individual values, it is important to note that the majority of PWA actually had longer reaction times for incongruent conditions, with only patients P15, P16, and P21 exhibiting negative values.

In contrast to the previously discussed results, it was observed that the Stroop Ratio was higher in the PWA group as compared to the HC group. This higher Stroop Ratio suggests diminished inhibitory control in individuals with PWA.

Table 4.4

Descriptive Statistics of Executive Function Tests- Time Course Analysis

	Parameters	Healthy Controls				Persons with Aphasia			
II.	**EXECUTIVE FUNCTION TESTS**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**
	Stroop Test								
1.	Stroop reaction time – congruent (SC)	1059.14	157.23	824	1327	1096.0	341.55	250	1786
2.	Stroop reaction time – incongruent (SIC)	1213.00	160.73	918	1498	1080.35	517.18	.000	1782
3.	Stroop Difference (SD)	153.85	152.28	-26	549	-1.50	576.91	-1786	611
4.	Stroop Ratio (SR)	13.95	12.61	1.47	44.86	30.85	50.73	1.21	200
	Digit Span Backward								
5.	Total span (DSB-S)	4.71	1.590	3	7	3.14	0.949	2	5
	Sem-back test								
6.	Reaction Time (NRT-Avag)	1141.82	356.39	745.5	1744.9	1100.29	348.62	495.8	1663.2
	Trail Making Test								
7.	Duration for Part A (TMT-A)	40329.28	19042.33	20070	94930	79277.85	33459.21	31840	136000
8.	Duration for Part B (TMT-B)	84133.57	44630.022	33940	195640	192459.28	91835.55	61730	408000
9.	TMT Difference (TMT-D)	43804.28	33864.07	590	106150	113181.43	82915.11	6530	338000
10.	TMT Ratio (TMT-R)	2.22	0.970	1.02	3.84	2.62	1.28	1.12	5.83

When it comes to the working memory span domain, the average digit span repetition achieved by the HC group exceeded that of the PWA group, signifying a larger Working Memory Span in the HC group. Additionally, the PWA group displayed diminished minimum and maximum digit span values in the context of the working memory test.

In the realm of working memory updating, the Sem-back test was employed as the evaluation tool. Notably, the PWA group exhibited a slightly lower reaction time in comparison to the HC group, with a marginal difference of 41 milliseconds. These results emerged due to the inclusion of both accurate and inaccurate responses when computing the average reaction time for the Sem-back test.

In the assessment of cognitive flexibility, it was observed that individuals with PWA demonstrated a slower capacity for set-shifting, as evidenced by an extended total completion duration for both parts A and B of the Trail Making Test (TMT). Moreover, the PWA group displayed an expanded range of values, both in terms of minimum and maximum, for parts A and B of the TMT. The calculated TMT difference and TMT ratio also indicated larger values among the PWA group, which further reinforces the conclusion that individuals with PWA experience heightened challenges in the domain of set-shifting abilities when compared to the HC group.

4.2.3 Descriptive statistics for the Quantitative Analysis and Cluster analysis of the Naming tests

Descriptive Statistics for Quantitative Analysis (analysis of accuracy scores) have been provided in terms of mean, standard deviation, minimum, and maximum in *Table 4.5*.

Consistent with the precision of responses observed in the Executive Function test, the HC group demonstrated superior mean accuracy in both confrontation naming and responsive naming tasks, underscoring their superior performance in comparison to individuals with PWA. Additionally, the HC group exhibited higher minimum and maximum values for accurate responses in these tasks.

In the domain of generative naming, the HC group consistently outperformed individuals with PWA across all verbal fluency tasks, encompassing word fluency (both animals and vehicles) as well as phonemic fluency (specifically, |s| and |a|). This superior performance was evident not only in terms of mean scores but also in the broader range of minimum and maximum values achieved in all tasks. Among the HC group, the highest proficiency was observed in the Animal category, followed by the Vehicle category, |s|, and |a|. Remarkably, a parallel pattern was noted in individuals with Aphasia, as they too exhibited greater challenges in phonemic fluency tasks, mirroring the results seen in the HC group.

The Fluency Difference Scores, computed by comparing performance in tasks such as Animal vs. |a| and Vehicles vs. |s|, revealed that individuals with Aphasia (PWA) exhibited higher FDS values compared to the Healthy Control (HC) group. This suggests that individuals with Aphasia faced greater challenges in sustaining their performance, particularly in more demanding tasks like phonemic fluency.

The Descriptive statistics related to Cluster Analysis have been presented in *Table 4.6*

In the context of cluster analysis, this discussion centers on the quantitative parameters involved, namely, Cluster Size and Number of Switches. It was observed that individuals with Aphasia (PWA) exhibited a somewhat smaller cluster size in comparison to the Healthy Control (HC) group, with lower mean, maximum, and minimum values consistently evident. This trend was consistent across all categories of generative naming tasks utilized in the study.

While the Healthy Control (HC) group demonstrated the ability to sustain consistent performance across all generative naming tasks, individuals with Aphasia (PWA) exhibited a decline in performance, particularly in terms of cluster size. This decline was notably pronounced in the context of the phoneme fluency task.

Another parameter subjected to analysis through cluster analysis was the Number of Switches. Across all generative naming tasks, the Healthy Control (HC) group consistently displayed a higher Number of Switches in terms of mean, minimum, and maximum values when compared to individuals with Aphasia (PWA). Furthermore, the HC group demonstrated the capacity to maintain a consistent number of switches throughout the tasks, whereas the PWA group exhibited a decrease in the Number of Switches as the tasks became more challenging. Consequently, this resulted in a lower Number of Switching for the vehicle category and both tasks within the phoneme fluency category for the PWA group.

Table 4.5

Descriptive Statistics of Naming Tests- Quantitative Analysis

Descriptive Statistics-Quantitative Analysis (Accuracy Score)

	Parameters	HEALTHY CONTROLS				PERSONS WITH APHASIA			
III	NAMING TESTS (ACCURACY SCORE)	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**
1.	**Confrontation Naming** Number of Correct Responses (NCQ)	39.71	0.578	38	40	36.86	3.30	30	40
2.	**Responsive Naming** Number of Correct Responses (NRQA)	9.96	0.134	9.5	10.0	8.93	1.371	6.0	10.0
	Generative naming								
3.	**Fluency Difference Scores** (Animals v/s |a|)	0.392	0.242	0.083	0.950	0.446	0.277	0.000	0.834
4.	**Fluency Difference Scores** (Vehicles v/s |s|)	0.227	0.137	0.047	0.461	0.437	0.257	0.000	1
5.	**Word Fluency-Animals** Number of Correct Responses (NGAQ)	17.93	4.63	11	27	11.00	4.77	6	20
6.	**Word Fluency-Vehicles** Number of Correct Responses (NGVQ)	14.36	3.17	8	21	7.36	3.15	4	15
7.	**Phoneme Fluency-|s|** Number of Correct Responses (NGSQ)	14.50	4.85	8	22	5.29	3.79	0	13
8.	**Phoneme Fluency-|a|** Number of Correct Responses (NaQ)	11.21	2.69	6	14	5.86	3.98	2	18

Table 4.6
Descriptive Statistics of Naming Tests- Cluster Analysis (Quantitative parameters)

Descriptive Statistics of Naming Tests- Cluster Analysis (Quantitative parameters)									
Parameters		HEALTHY CONTROLS				PERSONS WITH APHASIA			
III	NAMING TESTS (ACCURACY SCORE)	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation (SD)**	**Minimum**	**Maximum**
Generative naming									
1.	**Word Fluency-Animals** (Cluster Size)	1.51	0.44	1	2.75	1.46	0.66	0	2.5
2.	**Word Fluency-Vehicles** (Cluster Size)	1.57	0.38	1	2	1.55	0.62	1	3
3.	**Phonemic Fluency** -|**s**| (Cluster Size)	1.56	0.70	1	3.5	0.42	0.61	0	1.5
4.	**Phonemic Fluency** -|**a**| (Cluster Size)	1.42	0.98	0	4	0.88	0.81	0	2
5.	**Word Fluency-Animals** (Number of Switches)	9.07	2.73	6	14	6	2.98	1	13
6.	**Word Fluency-Vehicles** (Number of Switches)	7	1.52	5	10	3.64	2.17	1	8
7.	**Phonemic Fluency-|s|** (Number of Switches)	8.71	3.67	1	13	3.64	2.89	0	10
8.	**Phonemic Fluency-|a|** (Number of Switches)	7.21	2.99	3	12	3.36	2.27	1	10

4.2.4 Descriptive statistics for the Time Course Analysis and Cluster analysis of the Naming tests

The first Reaction Time (in milliseconds) (1^{st} RT) in both the confrontation naming and responsive naming tasks was notably shorter for the Healthy Control (HC) group in comparison to individuals with Aphasia (PWA). The HC group consistently displayed quicker reaction times when contrasted with the PWA group, as reflected by lower mean, minimum, and maximum reaction time values.

In the context of Generative Naming, the first Reaction Time (1^{st} RT) for the Animal category appeared consistent between both groups, as they exhibited similar 1^{st} RT values. Nevertheless, it is noteworthy that individuals with Aphasia (PWA) displayed a higher maximum reaction time in comparison to the Healthy Control (HC) group.

In the case of the vehicles category and the phonemes |s| and |a| category, the first Reaction Time (1^{st} RT) was observed to be shorter in the Healthy Control (HC) group, suggesting a slower retrieval speed in individuals with Aphasia (PWA). Moreover, the disparity or discrepancy in the 1^{st} RT values between the two groups expanded notably during the phonemic fluency task. This widening gap signifies an increasing level of challenge faced by individuals with Aphasia as the task conditions become more demanding.

The Healthy Control (HC) group demonstrated consistent 1^{st} Reaction Time (1^{st} RT) values across various tasks. Conversely, individuals with Aphasia (PWA) exhibited a progressive increase in 1^{st} RT as task complexity escalated, with the animal category showing the shortest 1st RT, followed by the vehicles category, and then the phonemes |a| and |s| category.

The mean Subsequent Reaction Times (SubRT) across all tasks consistently exhibited shorter durations in the Healthy Control (HC) group in contrast to individuals with Aphasia (PWA), underscoring a swifter word retrieval ability in the HC group. Notably, within the PWA group, SubRT values increased notably for the phonemic fluency tasks, with the highest SubRT observed for |s|, followed by |a|, and subsequently, the animals and vehicles categories.

The Subsequent Reaction Time (SubRT) serves as an indicator of the pattern of responses over a specific timeframe. A higher SubRT, when accompanied by lower accuracy, signifies heightened cognitive effort and an extended processing duration required for word retrieval.

The Descriptive Statistics for Cluster Analysis (Time Course parameters) have been provided in Table 4.8. In the context of cluster analysis, two parameters, namely Within Cluster Pause (WCP) and Between Cluster Pause (BCP), were taken into account due to their inherent time-related nature. It was observed that the Within Cluster Pause (WCP) was shorter in the Healthy Control (HC) group compared to individuals with Aphasia (PWA), signifying more robust semantic associations and a swifter retrieval of words belonging to the same subcategory.

For both groups, the mean WCP increased in duration as the task complexity increased, with a longer duration for the phoneme fluency task.

The Between Cluster Pause (BCP) was observed to be briefer in the Healthy Control (HC) group, aligning with the findings related to the Number of Switches. The

HC group displayed an elevated frequency of switches and a reduced BCP duration, while individuals with Aphasia (PWA) demonstrated a decreased frequency of switches and an extended BCP duration. Additionally, it is noteworthy that both groups exhibited an extended BCP duration during the phonemic fluency tasks.

Table 4.7

Descriptive Statistics of naming tests-Time Course Analysis

	Descriptive Statistics-Time Course Analysis								
	Parameters	**Healthy Controls**				**Persons with Aphasia**			
IV	NAMING TESTS (TIME COURSE)	Mean	Standard Deviation (SD)	Minimum	Maximum	Mean	Standard Deviation (SD)	Minimum	Maximum
	Confrontation Naming								
1.	1st Reaction Time	786.90	564.77	298	2618.7	2167.25	1316.74	496.25	4473.4
	Responsive Naming								
2.	1st Reaction Time	1297.71	1122.85	291.2	3730.4	2471.24	1466.01	504.7	5876.1
	Generative naming								
	Word Fluency-Animals								
3.	1st Reaction Time	842.36	346.61	354	1674	839.71	540.059	75	2008
	Word Fluency-Animals								
4.	Subsequent-RT	2521.85	1105.73	936.25	4956.1	4429.02	2624.12	1816.4	10015
	Word Fluency-Vehicles								
5.	1st Reaction Time	937	467.86	279	1940	1325.5	2028.25	81	8059
	Word Fluency-Vehicles								
6.	Subsequent-RT	2980.18	913.36	1722.2	4526.6	3501.07	1763.59	1290	6371.25
	Phoneme Fluency-|s|								
7.	1st Reaction Time	902.28	548.99	145	2047	2172.72	3120.81	0.000	11986
	Phoneme Fluency-|s|								
8.	Subsequent-RT	3780.45	1686.29	1856.24	6525.72	9084.28	9047.19	0.000	34496
	Phoneme Fluency-|a|								
9.	1st Reaction Time	1103.78	710.07	433	2860	2022.57	3044.75	0.000	11336
	Phoneme Fluency-|a|								
10.	Subsequent-RT	4840.59	1943.01	2176.23	9564.8	8641.03	6443.35	1452	24384

Table 4.8

Descriptive Statistics of Naming Tests- Cluster Analysis

Descriptive Statistics-Time Course Analysis-Cluster Analysis									
Parameters		**Healthy Controls**				**Persons with Aphasia**			
IV	NAMING TESTS (TIME COURSE)	Mean	Standard Deviation (SD)	Minimum	Maximum	Mean	Standard Deviation (SD)	Minimum	Maximum
	Generative naming								
1.	**Word Fluency-Animals** Within Cluster Pause	834.87	555.57	310.66	1921.36	1617.55	1025.38	0.000	3495.34
2.	**Word Fluency-Animals** Between Cluster Pause	3874.45	1733.08	1437.63	6772	7232.46	9152.42	1385.34	37104
3.	**Word Fluency-Vehicles** Within Cluster Pause	1084.07	684.88	254.167	2931.53	1313.16	859.53	85	2996.5
4.	**Word Fluency-Vehicles** Between Cluster Pause	4875.19	1534.21	2387.2	6838.83	5315.63	3547.29	968	12779
5.	**Phoneme Fluency-|s|** Within Cluster Pause	2568.44	2767.94	0.000	10240	3558.41	9204.64	0.000	34496
6.	**Phoneme Fluency-|s|** Between Cluster Pause	4790.50	2290.28	2257.92	9765	6639.65	5628.48	0.000	15293.5
7.	**Phoneme Fluency-|a|** Within Cluster Pause	2936.72	2736.42	0.000	10039.5	2999.95	4099.38	0.000	12408.5
8.	**Phoneme Fluency-|a|** Between Cluster Pause	5038.59	1979.02	1573.33	8410	7143.95	5386.86	0.000	18177

4.2 Section II: Comparison between the Healthy Control Group and the Persons with Aphasia (Between-Group Comparison).

The between-group comparison with respect to Quantitative Analysis or the Level I of analysis for the Executive Functions and Naming Tests were performed using the Independent sample t-test and the Mann-Whitney U Test based on the normality of the parameters and the results are shown in Table 4.9 and Table 4.10.

Table 4.9

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Quantitative Analysis using Mann Whitney U Test

Between-Group Comparison- Quantitative Analysis (Level I)			
	Parameters	**Mann Whitney U Test**	
I.	**EXECUTIVE FUNCTION TESTS (ACCURACY)**	***z***	***p* value**
1.	**Stroop Test** (Stroop Correct Responses)	-2.029	*0.042
2.	**Digit Span Test-Backward** (Total Score)	-2.605	*0.009
3.	**Sem-back test** (Number of Correct Responses)	-1.764	0.078
II	**NAMING TESTS (ACCURACY)**	***z***	***p* value**
1.	**Confrontation Naming** (Number of accurate answers)	-3.712	*0.000
2.	**Responsive Naming** (Number of accurate answers)	-2.594	*0.009
3.	**Phoneme Fluency-|a|** (Number of accurate responses-|a|)	-3.557	*0.000

Note:*p value< 0.05

From Table 4.9, the Mann-Whitney U test was used to assess the difference between the HC and the PWA group for Quantitative parameters of executive functions and naming tests. For the Executive Functions Test, the parameters were number correct responses on Stroop Test, Digit Span Test- Backwards score, and Sem-back Test. The group showed significant differences in case of the Stroop Test and Digit Span Test- Backward. However no significant difference was noted for the accuracy of responses on the Sem-back Test.

Similar to the Executive Functions Test, a significant difference in performance between the groups was also noted for the Naming Tests. All the naming tests, confrontation naming, responsive naming, and phoneme fluency for the phoneme |a| showed significance across groups.

Table 4.10

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Quantitative Analysis using Independent t-test

	Between-Group Comparison- Quantitative Analysis (Level I)		
	Parameters	Independent t-test	
II.	**NAMING TESTS (ACCURACY SCORES)**	***t***	***p value***
1.	**Fluency Difference Scores** (Animals v/s |a|)	-0.547	0.58
2.	**Fluency Difference Scores** (Vehicles v/s |s|)	-2.682	*0.013
3.	**Word Fluency-animals** (Number of correct responses)	3.898	*0.001
4.	**Word Fluency-vehicles** (Number of correct responses)	5.852	*0.000
.	**Phoneme Fluency-|s|** (Number of correct responses)	5.602	*0.000

Note: *p value < 0.05

From Table 4.10, an Independent Sample t-test was used to evaluate the difference in performance across the two groups for the remaining quantitative parameters of naming tests that were normally distributed. All the parameters, Fluency Difference Score for vehicles v/s |s|, Word Fluency-animals, Word fluency-vehicles, and Phoneme Fluency-|s| showed significant differences except for one parameter, which is Fluency Difference Scores for Animals v/s |a|.

The Between Group Comparison with respect to Time Course Analysis or the Level II of analysis for the Executive Functions and Naming Tests was performed, again using the Independent sample t-test and the Mann-Whitney U Test based on the normality of the parameters and the results are shown in Table 4.11 and Table 4.12.

Table 4.11

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Time Course Analysis using Mann Whitney U Test

Between-Group Comparison- Time Course Analysis (Level-II)			
	Parameters	**Mann Whitney U Test**	
I.	**EXECUTIVE FUNCTION TESTS (TIME COURSE)**	***z***	***p* value**
1.	**Stroop Test** (Stroop Difference-SD)	-0.897	0.370
2.	**Stroop Test** (Stroop Ratio-SR)	-1.103	0.270
3.	**Trail Making Test** (Duration for part A)	-3.308	*0.001
4.	**Digit Span Test-Backward** (Total span)	-2.560	*0.010
II	**NAMING TESTS (TIME COURSE)**	***z***	***p* value**
1.	**Confrontation Naming** (1st Reaction Time)	-3.308	*0.001
2.	**Responsive Naming** (1st Reaction Time)	-2.160	*0.031
3.	**Word Fluency** (Vehicles category-1st Reaction Time)	-0.643	0.520
4.	**Phoneme Fluency** (|s|-1st Reaction Time)	-0.689	0.491
8.	**Phoneme Fluency** (|s|-Subsequent RT)	-1.470	0.141
10.	**Phoneme Fluency** (|a|- 1st Reaction Time)	-0.138	0.890
Note: *p value < 0.05			

Table 4.11 enumerates the results obtained after performing the Mann-Whitney U test for non-normally distributed time course parameters of Executive Function tests and Naming tests. Among the Executive Functions test, the Stroop test parameters did not show any significant difference across the groups, but the Trail Making Test and Digit Span Test- Backward parameters showed significant differences across groups. Among the naming tests, the 1st reaction time of confrontation naming and responsive

naming showed a significant difference, with no statistically significant difference observed for the word and phoneme fluency parameters mentioned above.

Table 4.12

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Time Course Analysis using Independent t-test

Between-Group Comparison- Time Course Analysis (Level II)			
	Parameters	**Independent t-test**	
I.	**EXECUTIVE FUNCTION TESTS (TIME COURSE)**	***t***	**Sign**
1.	**Stroop Test** (Stroop reaction time – congruent)	-0.367	0.717
2.	**Stroop Test** (Stroop reaction time – incongruent)	0.916	0.368
3.	**Sem-back test** (Reaction Time)	0.312	0.758
4.	**Trail Making Test** (Duration for part B)	-3.970	*0.001
5.	**Trail Making Test** (TMT Difference)	-2.898	*0.008
6.	**Trail Making Test** (TMT Ratio)	-0.912	0.370
II.	**NAMING TESTS (TIME COURSE)**	***t***	**Sign**
1.	**Word Fluency** (1st Reaction Time-Animal category)	0.015	0.988
2.	**Word Fluency** (Subsequent-RT-Animal category)	-2.506	*0.019
3.	**Word Fluency** (Subsequent-RT-Vehicles category)	-0.981	0.335
4.	**Phoneme Fluency** (Subsequent-RT-|a|)	-2.113	*0.044

Note: *p value < 0.05

Table 4.12 enumerates the results obtained from performing an Independent Sample t-test on the normally distributed time course parameters of the Executive functions and naming tests. Among the Executive Functions Test, the parameters of the Stroop test and the Sem-back test did not show any significant difference, whereas 2 out of the 3 parameters of the Trail Making Test (i.e., Total duration for completion of part B and the TMT difference) showed statistically significant difference with the 3rd parameters, TMT ratio showing no statistically significant difference. Among the naming test parameters, only the subsequent reaction time parameter of word fluency-animals and phoneme fluency-|a| were found to have statistically significant differences with other word and phoneme fluency parameters mentioned above, showing no statistically significant difference.

The Between-Group Comparison for Cluster Analysis or the Level III analysis of the Generative Naming Test Parameters has been provided in Tables 4.13 below.

Tables 4.13

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Cluster Analysis using Mann Whitney U test

Between-Group Comparison- Cluster Analysis (Level III)

	Parameters	**Mann Whitney U Test**	
II	**NAMING TESTS (ACCURACY)**	***z***	**Sign**
1.	**Word Fluency** (Cluster Size-Animals)	-0.392	0.695
2.	**Word Fluency** (Cluster Size-Vehicles)	-0.213	0.831
3.	**Phonemic Fluency** (Cluster Size-|s|)	-3.535	*0.000
4.	**Phonemic Fluency** (Cluster Size-|a|)	-1.583	0.113
5.	**Phonemic Fluency** (Number of Switches-|a|)	-3.208	*0.001

Note: *p value < 0.05

The cluster analysis parameters were divided into two categories during the statistical analysis as two cluster analysis parameters (i.e., the cluster size and the number of switches) were quantitative in nature, and two other parameters (the within-cluster pause and between-cluster pause) were time course by nature. Mann-Whitney U Test was performed on the non-normally distributed cluster analysis parameters of the word and phoneme fluency tests. The results obtained from the quantitative parameters revealed that only the cluster size obtained for phoneme fluency-|s| and the number of switches obtained for phoneme fluency-|a| showed a significant difference with no other phoneme or word fluency parameter mentioned above, showing a statistically significant difference.

Other quantitative parameters that were normally distributed included the number of switches parameter of the word fluency-animals, word fluency-vehicles, and the phoneme fluency-|s| category. All these parameters showed significant differences across groups on the administration of Independent t-test and the results are shown in Table 4.14.

Table 4.14

Between Group Comparison (HC v/s PWA) of Executive Function Test and Naming Tests- Cluster Analysis using Independent t-test

Between-Group Comparison- Cluster Analysis (Level III)			
	Parameters	**Independent t-test**	
II.	**NAMING TESTS (ACCURACY)**	***t***	**Sign**
1.	**Word Fluency** (Number of Switches-Animals)	2.840	*0.009
2.	**Word Fluency** (Number of Switches-Vehicles)	4.742	*0.000
3.	**Phonemic Fluency** (Number of Switches-|s|)	4.059	*0.000
Note: *p value < 0.05			

The differences in time course parameters of cluster analysis across groups for non-normally distributed parameters were assessed using Mann Whitney U test. Only the within-cluster pause for word fluency-animals and phoneme fluency-|s| showed a statistically significant difference among the time course parameters. The other word and phoneme fluency parameters do not show statistically significant differences across groups as shown in Table 4.15.

Table 4.15

Between Group Comparison (HC v/s PWA) of Naming Test -Time Course Analysis- Cluster Analysis using Mann Whitney U test

Between-Group Comparison- Cluster Analysis (Level III)			
	Parameters	**Mann Whitney U Test**	
II	**NAMING TESTS (TIME COURSE)**	***z***	**Sign**
1.	**Word Fluency** (Within Cluster Pause-Animals)	-2.251	*0.024
2.	**Word Fluency** (Between Cluster Pause-Animals)	-0.781	0.435
3.	**Word Fluency** (Within Cluster Pause- Vehicles)	-0.643	0.520
4.	**Phoneme Fluency** (Within Cluster Pause-s)	-2.045	*0.041
5.	**Phoneme Fluency** (Within Cluster Pause-a)	-0.787	0.431

Note: *p value < 0.05

The differences in normally distributed time course parameters of cluster analysis was assessed using Independent t-test, which include between cluster pause for word fluency-vehicles, phoneme fluency- |a| and |s|. All three parameters did not show any statistically significant difference across groups and the results are shown in Table 4.16.

Table 4.16

Between Group Comparison (HC v/s PWA) of Naming Test -Time Course Analysis-Cluster Analysis using Independent t-test

Between-Group Comparison- Cluster Analysis (Level III)			
Parameters		**Independent t-test**	
II.	**NAMING TESTS (TIME COURSE)**	***t***	**Sign**
1.	**Word Fluency** (Between Cluster Pause-Vehicles category)	-0.426	0.673
2.	**Phoneme Fluency** (Between Cluster Pause-|s|)	-1.139	0.265
3.	**Phoneme Fluency** (Between Cluster Pause-|a|)	-1.373	0.182

Note: *p value < 0.05

4.3 Section III: Comparison within the Healthy Control Group and the Persons with Aphasia group across two conditions: Naming Test and Executive Functions Test (Within Group Comparison)

Within-group comparison was performed using the Wilcoxon Sign Ranked Test (non-normally distributed parameters) and the Paired Sample t-test (normally distributed parameters). Performance difference was checked across two conditions, the executive function tests and the naming tests within the same group. The statistical analysis, like in between-group comparison, was done in 3 major levels of analysis. The quantitative or, the Level I analysis, followed by the Time Course or the Level II analysis, followed by the Cluster or the Level III analysis.

The statistical significance of performance disparities within individual groups (Healthy Controls and Persons with Aphasia) and across two distinct test conditions, namely the Executive Function tests and the Naming tests, within the framework of Quantitative Analysis (Level I) is shown in Table 4.17, 4.18, 4.19.

Table 4.17

Within Group Comparison across Naming test and Executive Function test-Quantitative Analysis (Naming tests v/s Stroop test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Quantitative Analysis (Level I)					
Wilcoxon Sign Ranked Test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		z	**Sign**	***z***	**Sign**
1.	**Confrontation Naming** (Number of accurate answers) – **Stroop Test** (Stroop Correct Responses)	-2.937	*0.003	-3.045	*0.001
2.	**Responsive Naming** (Number of accurate answers) – **Stroop Test** (Stroop Correct Responses)	-3.245	*0.001	-2.695	0.179
3.	**Word Fluency** (Animals-Number of accurate answers)- **Stroop Test** (Stroop Correct Responses)	-3.113	*0.002	-2.762	*0.001
4.	**Word Fluency** (Vehicles-Number of accurate answers)-**Stroop Test** (Stroop Correct Responses)	-3.208	*0.001	-3.114	*0.001
5.	**Phoneme Fluency** (|s|- Number of accurate answers)-**Stroop Test** (Stroop Correct Responses)	-3.236	*0.001	-3.184	*0.007
6.	**Phoneme Fluency** (|a|- Number of accurate answers) – **Stroop Test** (Stroop Correct Responses)	-3.239	*0.001	-3.182	0.122

Note: *p value < 0.05

Table 4.17 specifically delineates the within-group comparison between the quantitative parameters of the naming tests and the Stroop test. As noted in the table above, in most instances, a statistically significant difference is observed across the conditions within each group. There is a significant difference across all the test conditions mentioned above, especially for the HC group. However, there was no statistically significant difference between Responsive Naming, Phoneme Fluency-|a|, and the Stroop Test among the Persons with Aphasia (the clinical group), which indicates that the performance on responsive naming and phoneme fluency-|a| was similar to the performance on the Stroop test.

Table 4.18

Within Group Comparison across Naming test and Executive Function test-Quantitative Analysis (Naming tests v/s Digit Span Test-Backward) for Healthy Control and Persons with Aphasia

Within Group Comparison- Quantitative Analysis (Level I)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	***p*-value**	***z***	***p*-value**
1.	**Confrontation Naming** (Number of correct responses) – **Digit Span Test-Backward** (Total Score)	-3.301	*0.001	-3.297	*0.001
2.	**Responsive Naming** (Number of accurate answers) – **Digit Span Test-Backward** (Total Score)	-1.344	0.179	-3.194	*0.001
3.	**Word Fluency** (Animals-Number of accurate answers)- **Digit Span Test-Backward** (Total Score)	-3.306	*0.001	-3.306	*0.001
4.	**Word Fluency** (Vehicles-Number of accurate answers) – **Digit Span Test-Backward** (Total Score)	-3.176	*0.001	-1.482	0.138
5.	**Phoneme Fluency** (|s|- Number of accurate answers) – **Digit Span Test-Backward** (Total Score)	-2.716	*0.007	-1.027	0.304
6.	**Phoneme Fluency** (|a|- Number of accurate answers) – **Digit Span Test-Backward** (Total Score)	-1.545	0.122	-.948	0.343

Note: *p value < 0.05

Table 4.18 specifically delineates the within-group comparison between the quantitative parameters of the naming tests and Digit Span Test-Backward (Total Score). In most instances, a statistically significant difference was observed across conditions with each group. In the HC group, all the parameters showed significant differences except for responsive naming and phoneme fluency-|a|, where there was no statistically significant difference, indicating that the performance on these tests was similar to the performance on the Digit Span Test.

In PWA (clinical group), a statistically significant difference in performance was found in 3 tests: responsive naming, confrontation naming, and the word fluency-animals, which indicates that the performance in these tests was significantly different from the performance on the Digit Span Test-Backward. Whereas the other 3 tests, word fluency-vehicle, phoneme fluency-|s| and phoneme fluency-|a|, show no statistically significant difference, and the result indicates that the performance on these tasks was similar to performance in the Digit Span Test-Backward.

Table 4.19

Within Group Comparison across Naming test and Executive Function test- Quantitative Analysis (Naming tests v/s Sem-back Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Quantitative Analysis (Level I)					
Wilcoxon Sign Ranked Test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Confrontation Naming** (Number of correct responses) – **Sem-back test** (Number of correct responses)	-3.314	*0.001	-3.298	*0.001
2.	**Responsive Naming** (Number of accurate answers) – **Sem-back test** (Number of correct responses)	-2.709	*0.007	-2.207	*0.027
3.	**Word Fluency** (Animals-Number of accurate answers)- **Sem-back test** (Number of correct responses)	-1.576	0.115	-1.084	0.278
4.	**Word Fluency** (Vehicles-Number of accurate answers) – **Sem-back test** (Number of correct responses)	-.504	0.614	-2.240	*0.025
5.	**Phoneme Fluency** (|s|- Number of accurate answers)-**Sem-back test** (Number of correct responses)	-.491	0.623	-2.735	*0.006
6.	**Phoneme Fluency** (|a|- Number of accurate answers) – **Sem-back test** (Number of correct responses)	-1.994	*0.046	-2.419	*0.016

Note: *p value < 0.05

Table 4.19 specifically delineates the within-group comparison between the quantitative parameters of the naming tests and Sem-back Test. The performance on naming tests is similar to the performance on the Sem-back test in many instances, especially in the HC group.

Among the HC, the confrontation naming and responsive naming test show a statistically very significant difference in performance compared to the Sem-back test, whereas the Phoneme Fluency-|a| shows a statistically significant difference compared to the Sem-back test. The other tests are word fluency-animals, word fluency-vehicles, and phoneme fluency-|a|, which do not show any statistically significant difference, indicating similar performance to the Sem-back test.

In the PWA group, a statistically significant difference was observed in most conditions, indicating a disparity in performance between most of the naming tests and the Sem-back tests except for word fluency-animals, which showed no statistically significant difference when compared to the Sem-back test.

The Table 4.20 mentioned below delineate the statistical significance of performance disparities within individual groups and across two distinct test conditions, namely the Executive Function tests and the Naming tests, within the framework of Time Course Analysis (Level II).

Tables 4.20

Within Group Comparison across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Stroop Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Time Course Analysis (Level II)					
Wilcoxon Sign Ranked Test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Confrontation Naming** (1st Reaction Time) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
2.	**Responsive Naming** (1st Reaction Time) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Animals-1st Reaction Time) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
4.	**Word Fluency** (Animals-Subsequent RT) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
5.	**Word Fluency** (Vehicles-1st Reaction Time)- **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
6.	**Word Fluency** (Vehicles- Subsequent RT) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
7.	**Phoneme Fluency** (|s|-1st Reaction Time) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.233	*0.001
8.	**Phoneme Fluency** (|s|-Subsequent RT) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.233	*0.001
9.	**Phoneme Fluency** (|a|-1st Reaction Time) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.233	*0.001
10.	**Phoneme Fluency** (|a|-Subsequent RT) – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001

Note: *p value < 0.05

Table 4.20 specifically delineates the within-group comparison between the time course parameters of the naming tests and Stroop Test. Time Course Analysis or Level II analysis included two major parameters: 1st Reaction and Subsequent Reaction Time.

The 1st Reaction time for the confrontation and responsive naming test and the 1st Reaction time and Subsequent reaction time of the generative naming tests (word fluency and phoneme fluency) were compared with a Stroop test parameter. The Stroop test parameter selected for the comparison was the Stroop Ratio. There was a significant difference between performance on all the naming tests mentioned in the table above and the Stroop ratio in both the groups.

Tables 4.21

Within Group Comparison across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Digit Span Test-Backward) for Healthy Control and Persons with Aphasia

Within Group Comparison- Time Course Analysis (Level II)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Confrontation Naming** (1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
2.	**Responsive Naming** (1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001

3.	**Word Fluency** (Animals-1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
4.	**Word Fluency** (Animals-Subsequent RT) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
5.	**Word Fluency** (Vehicles-1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
6.	**Word Fluency** (Vehicles- Subsequent RT) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
7.	**Phoneme Fluency** (|s|-1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.233	*0.001
8.	**Phoneme Fluency** (|s|-Subsequent RT) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.233	*0.001
9.	**Phoneme Fluency** (|a|-1st Reaction Time) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.233	*0.001
10.	**Phoneme Fluency** (|a|-Subsequent RT) – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001

Note: *p value < 0.05

Table 4.21 specifically delineates the within-group comparison between the time course parameters of the naming tests and Digit Span Test-Backwards (Total Span). The same findings as the previous comparison were encountered here. The performance of both groups on the different types of naming tests was significantly different from their performance on the Digit Span Test. In both groups, no similar performance was observed in any condition.

Tables 4.22

Within Group Comparison across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Trail Making Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Time Course Analysis (Level II)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	**z**	**p-value**
1.	**Confrontation Naming** (1st Reaction Time) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.296	*0.001
2.	**Responsive Naming** (1st Reaction Time) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Vehicles-1st Reaction Time) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.296	*0.001
4.	**Phoneme Fluency** (|s|-1st Reaction Time) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.233	*0.001
5.	**Phoneme Fluency** (|s|-Subsequent RT) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.233	*0.001
6.	**Phoneme Fluency** (|a|-Subsequent RT) – **Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.233	*0.001

Note: *p value < 0.05

Table 4.22 specifically delineates the within-group comparison between the time course parameters of the naming tests and Trail Making Test (TMT Ratio).

The Trail Making Test included 4-time course parameters, and the TMT Ratio was selected for within-group comparison. The results delineated in the table above are comparable to the results obtained in the previous analysis. A statistically significant difference was obtained for both the groups on comparison of their performance on all the naming tests and the TMT ratio. There was no similarity between the parameters obtained from the naming tests and the TMT ratio.

Table 4.23

Within Group Comparison across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Sem-back Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Time Course Analysis (Level II)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Confrontation Naming** (1st Reaction Time) – **Sem-back Test** (Reaction Time)	-2.417	*0.016	-2.354	*0.019
2.	**Responsive Naming** (1st Reaction Time) – **Sem-back Test** (Reaction Time)	-.408	0.683	-2.794	*0.005
3.	**Word Fluency** (Vehicles-1st Reaction Time) – **Sem-back Test** (Reaction Time)	-1.224	0.221	-1.161	0.245
4.	**Phoneme Fluency** (|s|-1st Reaction Time) – **Sem-back Test** (Reaction Time)	-1.350	0.177	-.785	0.433
5.	**Phoneme Fluency** (|s|-Subsequent RT) – **Sem-back Test** (Reaction Time)	-3.296	*0.001	-3.045	*0.002
6.	**Phoneme Fluency** (|a|-Subsequent RT) – **Sem-back Test** (Reaction Time)	-.282	0.778	-.220	0.826

Note: *p value < 0.05

Table 4.23 specifically delineates the within-group comparison between the time course parameters of the naming tests and the average reaction time of the Sem-back Test. Unlike other previously mentioned within-group analyses, a significant difference between performance on naming tests and the average reaction time on the Sem-back test was not obtained in all instances. Within the HC group, a statistically notable variance was solely observed in confrontation naming (1^{st} Reaction time) and phoneme fluency-|s| (Subsequent RT) when contrasted with the Sem-back test.

The different types of naming assessments, IIing Responsive naming (1st RT), the word fluency test for vehicles (1^{st} RT), and phoneme fluency tests encompassing the 1^{st} RT for the phoneme |s| and the subsequent RT for the phoneme |a|, exhibited comparable performance to the Sem-back test in individuals with HC, and no noteworthy statistical distinctions were observed between them.

Within the group of PWA, there was no statistically significant difference obtained between the word Fluency- vehicles (1^{st} Reaction Time), phoneme fluency-|s| (1^{st} Reaction Time), phoneme fluency-|a| (Subsequent RT), and the Sem-back Test (Reaction Time) indicating similar performance across all these naming test parameters and the Sem-back test reaction time.

A paired sample t-test was performed on all the normally distributed parameters. The results obtained through paired sample t-tests have been enumerated in the tables below from Table 4.24 and Table 4.25.

Table 4.24

Within Group Comparison (paired sample t-test) across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Trail Making Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Time Course Analysis (Level II)					
Paired Sample t-test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		t	**p-value**	***t***	**p-value**
1.	**Word Fluency** (Animals-1st Reaction Time)- **Trail Making Test** (TMT Ratio)	-9.080	*0.000	-5.804	*0.000
2.	**Word Fluency** (Animals-Subsequent RT)- **Trail Making Test** (TMT Ratio)	-8.528	*0.000	-6.311	*0.000
3.	**Word Fluency** (Vehicles-Subsequent RT)- **Trail Making Test** (TMT Ratio)	-12.204	*0.000	-7.421	*0.000
4.	**Phoneme Fluency** (|a|-Subsequent RT)- **Trail Making Test** (TMT Ratio)	-9.315	*0.000	-5.017	*0.000

Note: *p value < 0.05

Table 4.24 delineates the within-group comparison between the time course parameters of the naming tests and the TMT Ratio of the Trail Making Test showed a statistically significant difference from the performance on the Naming tests. This finding holds good for both the groups as the statistically significant differences were observed within both groups.

Table 4.25

Within Group Comparison (paired sample t-test) across Naming test and Executive Function test- Time Course Analysis (Naming tests v/s Sem-back Test)

Within Group Comparison- Time Course Analysis (Level II)					
Paired Sample t-test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		t	**p-value**	***t***	**p-value**
1.	**Word Fluency** (Animals-1st Reaction Time)- **Sem-back Test** (Reaction Time)	2.047	0.061	1.680	0.117
2.	**Word Fluency** (Animals-Subsequent RT)- **Sem-back Test** (Reaction Time)	-4.451	*0.001	-5.221	*0.000
3.	**Word Fluency** (Vehicles- Subsequent RT)- **Sem-back Test** (Reaction Time)	-7.105	*0.000	-5.336	*0.000
4.	**Phoneme Fluency** (|a|-Subsequent RT)- **Sem-back Test** (Reaction Time)	-6.701	*0.000	-4.549	*0.001

Note: *p value < 0.05

Table 4.25 delineates the within-group comparison between the time course parameters of the naming tests and the average reaction time of the Sem-back Test. The table above indicates statistically significant differences among all the comparisons except for word fluency-Animals (1st Reaction Time) compared with Sem-back Test (Reaction Time). There is no statistically significant difference between the performance on word fluency-animal (1st RT) and Sem-back Test (reaction time).

The final step of within-group comparison was the Cluster Analysis (Level III analysis). The tables mentioned below delineate the statistical significance of performance disparities within individual groups and across two distinct test conditions, namely the Executive Function tests and the Naming tests, within the framework of Cluster Analysis (Level III).

The cluster analysis has been divided into two major categories: quantitative analysis and time course analysis, as 2 parameters of cluster analysis (the cluster size and the number of switches) are quantitative in nature, and the 2 other parameters (the within-cluster pause and between- cluster pause) are time-related in nature.

The within-group comparison between the quantitative parameters of the cluster analysis of word and phoneme fluency tests and the quantitative parameters of the Executive Functions test (Stroop test, Sem-back test, and the Digit Span test) was assessed using Wilcoxson signed rank test. The results of the same is shown in Tables 4.25, 4.26, and 4.27 enumerate

Table 4.26

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (Cluster size and number of Switches v/s Stroop Test)

Within Group Comparison- Cluster Analysis (Quantitative Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Word Fluency** (Animals- Cluster Size) – **Stroop Test** (Stroop Correct Response)	-3.297	*0.001	-3.296	*0.001
2.	**Word Fluency** (Animals-Number of Switches) – **Stroop Test** (Stroop Correct Response)	-3.238	*0.001	-3.185	*0.001
3.	**Word Fluency** (Vehicles-Cluster Size) – **Stroop Test** (Stroop Correct Response)	-3.297	*0.001	-3.297	*0.001
4.	**Word Fluency** (Vehicles- Number of Switches) – **Stroop Test** (Stroop Correct Response)	-3.236	*0.001	-3.297	*0.001
5.	**Phoneme Fluency** (|s|-Cluster Size) – **Stroop Test** (Stroop Correct Response)	-3.296	*0.001	-3.297	*0.001
6.	**Phoneme Fluency** (|s|-Number of Switches) – **Stroop Test** (Stroop Correct Response)	-3.236	*0.001	-3.299	*0.001
7.	**Phoneme Fluency** (|a|- Cluster Size)- **Stroop Test** (Stroop Correct Response)	-3.297	*0.001	-3.300	*0.001
8.	**Phoneme Fluency** (|a|- Number of Switches) – **Stroop Test** (Stroop Correct Response)	-3.297	*0.001	-3.298	*0.001

Note: *p value < 0.05

As the table above mentions, a statistically significant difference exists between the participants' (HC and the PWA) cluster size and number of switches for word and phoneme fluency tests versus the Stroop Test-correct responses. This indicates that there is no similarity between the performance of participants across these two conditions.

Similar findings were encountered for the analysis performed over cluster size and number of switches for word and phoneme fluency versus the Sem-back accuracy score. There was a statistically significant difference between cluster size and number of switches for word and phoneme fluency tasks compared to the Sem-back accuracy score. The within-group comparison of cluster size and number switches versus the Sem-back accuracy has been provided in Table 4.27 below.

Table 4.27

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (Cluster size and number of Switches v/s Sem-back Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Quantitative Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Word Fluency** (Animals- Cluster Size) – **Sem-back Test** (Number of correct responses)	-3.296	*0.001	-3.296	*0.001
2.	**Word Fluency** (Animals-Number of Switches) – **Sem-back Test** (Number of correct responses)	-2.801	*0.005	-2.521	*0.012
3.	**Word Fluency** (Vehicles-Cluster Size) – **Sem-back Test** (Number of correct responses)	-3.296	*0.001	-3.297	*0.001
4.	**Word Fluency** (Vehicles- Number of Switches) – **Sem-back Test** (Number of correct responses)	-3.112	*0.002	-3.050	*0.002
5.	**Phoneme Fluency** (|s|-Cluster Size) – **Sem-back Test** (Number of correct responses)	-3.297	*0.001	-3.304	*0.001
6.	**Phoneme Fluency** (|s|-Number of Switches) – **Sem-back Test** (Number of correct responses)	-2.634	*0.008	-3.120	*0.002
7.	**Phoneme Fluency** (|a|- Cluster Size)- **Sem-back Test** (Number of correct responses)	-3.297	*0.001	-3.305	*0.001
8.	**Phoneme Fluency** (|a|- Number of Switches) – **Sem-back Test** (Number of correct responses)	-2.798	*0.005	-3.024	*0.002

Note: *p value < 0.05

Table 4.28

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (Cluster size and number of Switches v/s Digit Span Test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Quantitative Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	**z**	**p-value**
1.	**Word Fluency** (Animals- Cluster Size) – **Digit Span Test- Backwards** (Total Score)	-3.299	*0.001	-3.305	*0.001
2.	**Word Fluency** (Animals-Number of Switches) – **Digit Span Test- Backwards** (Total Score)	0.000	1.000	-.103	0.918
3.	**Word Fluency** (Vehicles-Cluster Size) – **Digit Span Test- Backwards** (Total Score)	-3.298	*0.001	-3.306	*0.001
4.	**Word Fluency** (Vehicles- Number of Switches) – **Digit Span Test- Backwards** (Total Score)	-2.097	*0.036	-2.769	*0.006
5.	**Phoneme Fluency** (|s|-Cluster Size) – **Digit Span Test- Backwards** (Total Score)	-3.297	*0.001	-3.316	*0.001
6.	**Phoneme Fluency** (|s|-Number of Switches) – **Digit Span Test- Backwards** (Total Score)	-0.060	0.953	-2.706	*0.007
7.	**Phoneme Fluency** (|a|- Cluster Size)- **Digit Span Test- Backwards** (Total Score)	-3.300	*0.001	-3.311	*0.001
8.	**Phoneme Fluency** (|a|- Number of Switches) – **Digit Span Test- Backwards** (Total Score)	-1.232	0.218	-2.799	*0.005

Note: *p value < 0.05

Unlike the findings obtained earlier, the performance of participants on cluster size and number of switches parameters for the word and phoneme fluency did not show a statistically significant difference from the performance on Digit Span Test-Backwards (Total score) in all instances. No statistically significant difference was obtained between word fluency-Animals (Number of Switches) and Digit Span Test-Backwards (Total Score) for both HC and PWA. No statistically significant difference was obtained between phoneme fluency-|s| (Number of Switches) and Digit Span Test-Backwards (Total Score), phoneme fluency-|a| (Number of Switches) and Digit Span Test- Backwards (Total Score) only for the HC group.

Table 4.29

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (within-cluster pause and between-cluster pause v/s Stroop Test-Stroop Ratio) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)

	Wilcoxon Sign Ranked Test				
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**Sign**	***z***	**Sign**
1.	**Word Fluency** (Animals- Within Cluster Pause)- **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.233	*0.001
2.	**Word Fluency** (Animals – Between Cluster Pause)- **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Vehicles- Within Cluster Pause)- **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
4.	**Word Fluency** (Vehicles – Between Cluster Pause)- **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.296	*0.001
5.	**Phoneme Fluency** (|s|-Within Cluster Pause – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-.471	0.638
6.	**Phoneme Fluency** (|s|-Between Cluster Pause – **Stroop Test** (Stroop Ratio)	-3.233	*0.001	-3.107	*0.002
7.	**Phoneme Fluency** (|a|-Within Cluster Pause – **Stroop Test** (Stroop Ratio)	-3.107	*0.002	-2.354	*0.019
8.	**Phoneme Fluency** (|a|-Between Cluster Pause – **Stroop Test** (Stroop Ratio)	-3.296	*0.001	-3.107	*0.002

Note: *p value < 0.05

A statistically significant distinction was detected in both groups, signifying variances in the participants' abilities concerning word and phoneme fluency within clusters and between clusters when contrasted with the Stroop Test's Stroop ratio. No statistically significant distinction in performance was observed between phoneme fluency-|s| (Within Cluster Pause) and Stroop Test (Stroop Ratio) only for PWA.

Table 4.30

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (within-cluster pause and between-cluster pause v/s Digit Span Test-Total Span) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Word Fluency** (Animals- Within Cluster Pause)**- Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.233	*0.001
2.	**Word Fluency** (Animals – Between Cluster Pause)**- Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Vehicles- Within Cluster Pause)**- Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
4.	**Word Fluency** (Vehicles – Between Cluster Pause)**- Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.296	*0.001
5.	**Phoneme Fluency** (|s|-Within Cluster Pause – **Digit Span Test-Backward** (Total Span)	-3.233	*0.001	-.474	0.636

6.	**Phoneme Fluency** (|s|-Between Cluster Pause – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.107	*0.002
7.	**Phoneme Fluency** (|a|-Within Cluster Pause – **Digit Span Test-Backward** (Total Span)	-3.107	*0.002	-2.355	*0.019
8.	**Phoneme Fluency** (|a|-Between Cluster Pause – **Digit Span Test-Backward** (Total Span)	-3.296	*0.001	-3.108	*0.002

Note: *p value < 0.05

A statistically significant difference was observed for both groups, indicating differences in the participants' performances on the within and between cluster parameters of word and phoneme fluency when compared to the total span of digits repeated by participants on the Backward Digit Span Test.

Table 4.31

Within Group Comparison (Wilcoxon Sign Ranked Test) across Executive Function test and Naming test- Cluster Analysis (within-cluster pause and between-cluster pause v/s Trail Making Test-TMT Ratio) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
Parameters		**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Word Fluency** (Animals- Within Cluster Pause)**- Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.233	*0.001
2.	**Word Fluency** (Animals – Between Cluster Pause)**- Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Vehicles- Within Cluster Pause)**- Trail Making Test** (TMT Ratio)	-3.296	*0.001	-3.296	*0.001
4.	**Phoneme Fluency** (|s|-Within Cluster Pause – **Trail Making Test** (TMT Ratio)	-3.233	*0.001	-.471	0.638
5.	**Phoneme Fluency** (|a|-Within Cluster Pause – **Trail Making Test** (TMT Ratio)	-3.107	*0.002	-2.354	*0.019

Note: *p value < 0.05

Similar to the results obtained for previously mentioned parameters, a statistically significant difference was observed for both groups, indicating differences in the participants' performances on the within and between cluster parameters of word and phoneme fluency when compared to the TMT Ratio of the Trail Making Test.

Table 4.32

Within Group Comparison (Wilcoxon Sign Ranked Test) across Naming test and Executive Function test- Cluster Analysis (within-cluster pause and between-cluster pause v/s Sem-back tests-Reaction time) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)					
Wilcoxon Sign Ranked Test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		z	**p-value**	***z***	**p-value**
1.	**Word Fluency** (Animals- Within Cluster Pause)**- Sem-back Test** (Reaction Time)	-1.538	0.124	-1.224	0.221
2.	**Word Fluency** (Animals – Between Cluster Pause)**- Sem-back Test** (Reaction Time)	-3.296	*0.001	-3.296	*0.001
3.	**Word Fluency** (Vehicles- Within Cluster Pause)**- Sem-back Test** (Reaction Time)	-0.847	0.397	-0.471	0.638
4.	**Phoneme Fluency** (|s|-Within Cluster Pause – **Sem-back Test** (Reaction Time)	-1.852	0.064	-0.408	0.683
5.	**Phoneme Fluency** (|a|-Within Cluster Pause – **Sem-back Test** (Reaction Time)	-2.291	*0.022	-0.910	0.363

Note: *p value < 0.05

Unlike the comparison of within and between-cluster pauses with other tests, the comparison of within and between-cluster pauses with the Sem-back test (reaction time) revealed no significant difference in performance across the two tests within each group in many instances. Only these two combinations of word fluency-animals (Between Cluster Pause) and Sem-back Test (Reaction Time) showed significant difference but for phoneme fluency-|a| (Within Cluster Pause) and Sem-back Test (Reaction Time) there was no significant difference observed in any other combination.

A paired Samples t-test was performed on the parameters that were normally distributed to understand the difference exhibited within each group between the time course parameters of the cluster analysis (word and phoneme fluency tests) and the time course parameters of executive functions tests. The results of the same is shown in Table 4.33 and Table 4.34.

Tables 4.33

Within Group Comparison (Paired Samples t-test) across Naming tests and Executive Function test- Cluster Analysis (between-cluster pause v/s TMT Ratio) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)					
Paired Sample t-test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		t	**p-value**	***t***	**p-value**
1.	**Word Fluency** (Vehicles- Between Cluster Pause)- **Trail Making Test** (TMT Ratio)	-11.886	*0.000	-5.603	*0.000
2.	**Phoneme Fluency** (|s|-Between Cluster Pause – **Trail Making Test** (TMT Ratio)	-7.822	*0.000	-4.412	*0.001
3.	**Phoneme Fluency** (|a|-Between Cluster Pause – **Trail Making Test** (TMT Ratio)	-9.520	*0.000	-4.961	*0.000

Note: *p value < 0.05

Tables 4.34

Within Group Comparison (Paired Samples t-test) across Naming tests and Executive Function test- Cluster Analysis (between cluster pause v/s Reaction time – and the Sem-back test) for Healthy Control and Persons with Aphasia

Within Group Comparison- Cluster Analysis (Time Course Analysis) (Level III)					
Paired Sample t-test					
	Parameters	**Healthy Controls**		**Persons With Aphasia**	
		t	**p-value**	***t***	**p-value**
1.	**Word Fluency** (Vehicles- Between Cluster Pause)- **Sem-back Test** (Reaction Time)	-8.821	*0.000	-4.542	*0.001
2.	**Phoneme Fluency** (|s|-Between Cluster Pause – **Sem-back Test** (Reaction Time)	-6.012	*0.000	-3.666	*0.003
3.	**Phoneme Fluency** (|a|-Between Cluster Pause – **Sem-back Test** (Reaction Time)	-7.320	*0.000	-4.399	*0.001

Note: *p value < 0.05

Tables 4.33 and 4.34 indicate that the comparison of the between-cluster pause for the word and phoneme fluency tests with the Trail Making Test (TMT Ratio) and Sem-back test (reaction time) using the paired samples t-test revealed a statistically significant difference between the compared parameters.

To summarize, in most of the instances the performance of participants on the naming tests was significantly different from their performance on the executive functions tests (especially the Stroop test and the Trail Making Test). Only the Digit

Span test and the Sem-back tests results exhibited similarity with the results obtained from the naming tests, with the Sem-back tests exhibiting the most similarity across many parameters, followed by the Digit Span Test, the Trail Making Test and the Stroop Test.

4.4 Section IV: The correlation between the Naming test parameters and the Executive Function parameters at the level of Quantitative, Time Course, and Cluster Analysis

The results of the correlation analysis between the Naming tests and the Executive functions tests at the level of quantitative analysis is shown in Table 4.35. A strong correlation was found between the accuracy score of the word fluency test-animals and the Digit Span Test-Total score and the word fluency test-vehicles and the Stroop correct responses within the group of healthy controls.

A strong correlation was observed between the responsive naming test and the Digit Span test score for PWA. A strong correlation was also noted between the Word Fluency Test-Animals and the Stroop correct response and Digit Span Test scores for this group.

Table 4.35

Correlation between the Naming test parameters and the Executive Function Parameters-Quantitative Analysis (Level I) for healthy control and persons with aphasia

Correlation Analysis-Quantitative parameters				
HEALTHY CONTROLS				
Naming Test		**Executive Functions Test**		
Parameters	**Correlation coefficient**	**Stroop Test-** Stroop correct responses	**Digit Span Backward-** Total Score	**Sem-back test-** Accuracy
1. **Confrontation Naming** Number of Correct Responses (NCQ)	*rs*	0.571	0.276	0.429
2. **Responsive Naming** Number of Correct Responses (NRQA)	*rs*	0.385	-0.282	0.212
3. **Word Fluency-Animals** Number of Correct Responses (NGAQ)	*rs*	0.479	*0.665	-0.136
4. **Word Fluency-Vehicles** Number of Correct Responses (NGVQ)	*rs*	*0.661	0.250	-0.130
5. **Phoneme Fluency-|s|** Number of Correct Responses (NGSQ)	*rs*	0.532	0.106	-0.202

6.	**Phoneme Fluency-|a|** Number of Correct Responses (NaQ)	*rs*	0.396	-0.076	-0.402
	PERSONS WITH APHASIA				
1.	**Confrontation Naming** Number of Correct Responses (NCQ)	*rs*	0.321	0.345	-0.157
2.	**Responsive Naming** Number of Correct Responses (NRQA)	*rs*	0.534	*0.675	-0.073
3.	**Word Fluency-Animals** Number of Correct Responses (NGAQ)	*rs*	*0.627	*0.764	-0.249
4.	**Word Fluency-Vehicles** Number of Correct Responses (NGVQ)	*rs*	0.561	0.344	-0.196
5.	**Phoneme Fluency-|s|** Number of Correct Responses (NGSQ)	*rs*	0.384	0.461	0.411
6.	**Phoneme Fluency-|a|** Number of Correct Responses (NaQ)	*rs*	0.532	0.497	0.154

Note: Spearman's correlation

Both Parametric and non-parametric tests were used to find the correlation between the time course parameters of the naming and the executive functions tests.

The Table 4.36 depicts the results obtained for correlation analysis (for Spearman's and Pearsons rank correlation) between the time course parameters of the naming tests and executive function tests, the results mentioned above showed no significant correlation between any of the naming parameters and the executive function parameters at the level of time course analysis for both the groups.

Table 4.36

Correlation (Spearman's correlation) between the Naming test parameters and the Executive Function parameters-Time Course Analysis (Level II) for healthy control and persons with aphasia

Correlational Analysis- Time Course Analysis						
HEALTHY CONTROLS						
Naming Tests			**Executive Functions Test**			
	Parameters	**Correlation coefficient**	**Stroop Ratio**	**Digit Span Backward-** Total span	**Trail Making Test-** Ratio	**Sem-back test-** Reaction Time
1.	**Confrontation Naming** 1st Reaction Time	*rs*	0.156	-0.098	-0.389	0.481
2.	**Responsive Naming** 1st Reaction Time	*rs*	0.112	-0.365	0.319	0.218
Generative naming						
3.	**Word Fluency-Animals** 1st Reaction Time	*rs*	0.015	-0.315	---	---

4.	**Word Fluency-Animals** Subsequent-RT	*rs*	0.020	-0.433	---	---
5.	**Word Fluency-Vehicles** 1st Reaction Time	*rs*	-0.314	0.289	-0.380	-0.059
6.	**Word Fluency-Vehicles** Subsequent-RT	*rs*	-0.046	-0.278	---	---
7.	**Phoneme Fluency-|s|** 1st Reaction Time	*rs*	0.574	-0.021	-0.266	-0.292
8.	**Phoneme Fluency-|s|** Subsequent-RT	*rs*	0.134	0.002	0.024	-0.222
9.	**Phoneme Fluency-|a|** 1st Reaction Time	*rs*	-0.393	0.476	-0.354	0.314
10.	**Phoneme Fluency-|a|** Subsequent-RT	*rs*	0.112	0.292	---	---
	PERSONS WITH APHASIA					
1.	**Confrontation Naming** 1st Reaction Time	*rs*	0.218	-0.414	-0.103	0.235
2.	**Responsive Naming** 1st Reaction Time	*rs*	0.380	-0.023	0.301	0.073

	Generative Naming					
3.	**Word Fluency-Animals** 1st Reaction Time	*rs*	0.169	-0.550	---	---
4.	**Word Fluency-Animals** Subsequent-RT	*rs*	0.095	-0.200	---	---
5.	**Word Fluency-Vehicles** 1st Reaction Time	*rs*	-0.121	-0.343	-0.037	-0.138
6.	**Word Fluency-Vehicles** Subsequent-RT	*rs*	0.169	-0.235	---	---
7.	**Phoneme Fluency-|s|** 1st Reaction Time	*rs*	0.596	-0.550	-0.138	0.090
8.	**Phoneme Fluency-|s|** Subsequent-RT	*rs*	0.538	-0.566	-0.116	0.108
9.	**Phoneme Fluency-|a|** 1st Reaction Time	*rs*	-0.433	0.216	-0.090	-0.323
10.	**Phoneme Fluency-|a|** Subsequent-RT	*rs*	0.196	-0.173	---	---

Note: Spearman’s correlation; the sign (---) indicates a normally distributed parameter, and hence, Pearson’s correlation has been provided in another table.

Unlike the results in the previous table, Pearson’s correlation analysis as indicated in Table 4.37 a strong correlation between the Sem-back test- reaction time and the word fluency test-animal. It also indicated a strong correlation between the

Sem-back test reaction time and the phoneme fluency test for |a|. These correlations were observed only for PWA or the clinical group as shown in able 4.37.

Table 4.37

Correlation (Pearson's correlation) between the Naming test parameters and the Executive Function parameters-Time Course Analysis (Level II) for healthy control and persons with aphasia

Correlational Analysis- Time Course Analysis				
HEALTHY CONTROLS				
Naming Tests			**Executive Functions Test**	
	Parameters	**Correlation coefficient**	**Trail Making Test-** Ratio	**Sem-back test-**Reaction Time
1.	**Word Fluency-Animals** 1st Reaction Time	*rs*	0.427	-0.212
2.	**Word Fluency-Animals** Subsequent-RT	*rs*	0.211	0.005
3.	**Word Fluency-Vehicles** Subsequent-RT	*rs*	0.341	0.037
4.	**Phoneme Fluency-|a|** Subsequent-RT	*rs*	-0.498	-0.262
PERSONS WITH APHASIA				
1.	**Word Fluency-Animals** 1st Reaction Time	*rs*	0.284	0.203
2.	**Word Fluency-Animals** Subsequent-RT	*rs*	-0.115	*0.719
3.	**Word Fluency-Vehicles** Subsequent-RT	*rs*	-0.195	0.323
4.	**Phoneme Fluency-|a|** Subsequent-RT	*rs*	0.223	*0.704

Note: Pearson's correlation

The final level of analysis of the correlation between the naming and the executive functions test is the cluster analysis, which is further divided into quantitative and time course as the cluster analysis includes both quantitative and time course parameters. Table 4.38 indicates the correlation between the quantitative parameters of the cluster analysis for the naming tests and the quantitative parameters of the executive functions test.

Table 4.38

Correlation (Spearman's correlation) between the Naming test parameters and the Executive Function parameters-Cluster Analysis-Quantitative Parameters (Level III) for healthy control and persons with aphasia

Correlation Analysis-Cluster Analysis (Quantitative parameters)					
HEALTHY CONTROLS					
Naming Test			**Executive Functions Test**		
	Parameters	**Correlation coefficient**	**Stroop Test-**Stroop correct responses	**Digit Span Backward-** Total Score	**Sem-back test-** Accuracy
1.	**Word Fluency-Animals** Cluster Size	*rs*	0.453	0.219	-0.126
2.	**Word Fluency-Animals** Number of Switches	*rs*	0.189	*0.623	0.103
3.	**Word Fluency-Vehicles** Cluster Size	*rs*	0.199	0.074	0.178
4.	**Word Fluency-Vehicles** Number of Switches	*rs*	-0.021	0.131	-0.121
5.	**Phoneme Fluency-|s|**	*rs*	0.234	0.087	-0.329

	Cluster Size				
6.	**Phoneme Fluency-|s|** Number of Switches	*rs*	0.496	0.164	-0.075
7.	**Phoneme Fluency-|a|** Cluster Size	*rs*	0.548	0.241	-0.224
8.	**Phoneme Fluency-|a|** Number of Switches	*rs*	0.143	-0.156	-0.330
	PERSONS WITH APHASIA				
1.	**Word Fluency-Animals** Cluster Size	*rs*	0.262	0.518	*0.954
2.	**Word Fluency-Animals** Number of Switches	*rs*	*0.809	*0.666	0.127
3.	**Word Fluency-Vehicles** Cluster Size	*rs*	-0.369	-0.378	0.146
4.	**Word Fluency-Vehicles** Number of Switches	*rs*	*0.602	0.308	0.191
5.	**Phoneme Fluency-|s|** Cluster Size	*rs*	*0.646	0.578	0*.718
6.	**Phoneme Fluency-|s|** Number of Switches	*rs*	0.380	0.484	0.147
7.	**Phoneme Fluency-|a|** Cluster Size	*rs*	0.224	0.364	*0.746
8.	**Phoneme Fluency-|a|** Number of Switches	*rs*	*0.610	0.545	*0.815

Note: Spearman's correlation

The quantitative parameters of the cluster analysis in the above table exhibited a significant correlation between word fluency-animals (Number of Switches) and the Digit Span Test score for the HC. There was no other significantly correlating parameter in the HC group. Among the group of PWA, a significant correlation was obtained between these parameters, the word fluency-animals (cluster size) and the Sem-back accuracy, the word fluency-animals (number of switches) and the 2 executive function tests (Stroop accuracy and the Digit Span Test Score). For PWA a significant correlation was found when word fluency-vehicles (number of switches), phoneme fluency-|s| (cluster size), and phoneme fluency-|a| (number of switches) were compared with Stroop correct response.

The correlation between the time course parameters of the cluster analysis for naming and the executive functions test was assessed using both non-parametric and parametric tests, as it contained both non-normally and normally distributed data. The Spearman's correlation was used for data that was non-normally distributed and the Pearson's correlation was used for data that was normally distributed.

Table 4.39

Correlation (Spearman's correlation) between the Naming test parameters and the Executive Function parameters-Cluster Analysis- Time Course Parameters (Level III) for healthy control and persons with aphasia

Correlational Analysis- Cluster Analysis (Time Course parameters)					
HEALTHY CONTROLS					
Naming Tests		**Executive Functions Test**			
Parameters	**Correlation coefficient**	**Stroop Ratio**	**Digit Span Backward-** Total span	**Trail Making Test-** Ratio	**Sem-back test-** Reaction Time
1. **Word Fluency-Animals** Within Cluster Pause	*rs*	0.525	-0.568	0.147	-0.336
2. **Word Fluency-Animals** Between Cluster Pause	*rs*	-0.051	-0.319	0.222	-0.015
3. **Word Fluency-Vehicles** Within Cluster Pause	*rs*	0.288	-0.422	0.152	-0.051
4. **Word Fluency-Vehicles** Between Cluster Pause	*rs*	-0.108	0.023	---	---

5.	**Phoneme Fluency-|s|** Within Cluster Pause	*rs*	0.310	-0.415	0.090	-0.358
6.	**Phoneme Fluency-|s|** Between Cluster Pause	*rs*	0.130	-0.014	---	---
7.	**Phoneme Fluency-|a|** Within Cluster Pause	*rs*	-0.396	0.394	-0.158	0.062
8.	**Phoneme Fluency-|a|** Between Cluster Pause	*rs*	0.288	-0.084	---	---
	PERSONS WITH APHASIA					
1.	**Word Fluency-Animals** Within Cluster Pause	*rs*	-0.367	-0.074	-0.341	-0.095
2.	**Word Fluency-Animals** Between Cluster Pause	*rs*	0.037	-0.094	0.015	*0.701
3.	**Word Fluency-Vehicles** Within Cluster Pause	*rs*	-0.222	0.189	0.323	0.275

4.	**Word Fluency-Vehicles** Between Cluster Pause	*rs*	0.160	-0.269	---	---
5.	**Phoneme Fluency-|s|** Within Cluster Pause	*rs*	-0.438	0.410	0.003	-0.003
6.	**Phoneme Fluency-|s|** Between Cluster Pause	*rs*	0.350	-0.243	---	---
7.	**Phoneme Fluency-|a|** Within Cluster Pause	*rs*	-0.425	0.005	0.434	0.119
8.	**Phoneme Fluency-|a|** Between Cluster Pause	*rs*	0.084	0.048	---	---

Note: Spearman's correlation; the sign (---) indicates a normally distributed parameter, and hence, Pearson's correlation has been provided in another table.

In Table 4.39, the results showed no significant correlation between any of the time course parameters of the naming test and the time course parameters of the executive functions test for the HC. In the case of PWA, a strong correlation was observed only between Sem-back reaction time and the word fluency-animals (between cluster pauses).

Table 4.40

Correlation (Pearson's correlation) between the Naming test parameters and the Executive Function parameters-Cluster Analysis- Time Course Analysis (Level III) for healthy control and persons with aphasia

Correlational Analysis- Cluster Analysis (Time Course parameters)				
HEALTHY CONTROLS				
Naming Tests			**Executive Functions Test**	
	Parameters	**Correlation coefficient**	**Trail Making Test-** Ratio	**Sem-back test-** Reaction Time
1.	**Word Fluency- Vehicles** Between Cluster Pause	*rs*	0.219	-0.025
2.	**Phoneme Fluency- |s|** Between Cluster Pause	*rs*	-0.240	0.133
3.	**Phoneme Fluency- |a|** Between Cluster Pause	*rs*	-0.426	0.054
PERSONS WITH APHASIA				
1.	**Word Fluency- Vehicles** Between Cluster Pause	*rs*	-0.378	0.261
2.	**Phoneme Fluency- |s|** Between Cluster Pause	*rs*	-0.317	-0.041
3.	**Phoneme Fluency- |a|** Between Cluster Pause	*rs*	0.423	*0.724

Note: Pearson's correlation.

Pearson’s correlation analysis performed for normally distributed time course parameters of the cluster analysis for the naming test and the executive function parameters presented above in the table revealed no significantly strong correlation between the two tests in most instances. A significant correlation was between phoneme fluency-|a| (between cluster pause) and the Sem-back reaction time only for PWA.

CHAPTER V

DISCUSSION

The study aimed to demonstrate the link or the association between naming and executive functions in Persons with Aphasia and to find out the extent of association with reference to the executive functions affecting naming performance in persons with Aphasia and Healthy individuals (termed as healthy controls) using a multi-dimensional approach. In this study, the executive functions were analyzed using the quantitative (accuracy) and time course analysis (reaction times and total duration), and the naming abilities were analyzed at three levels: the quantitative analysis, the time course analysis, and the cluster analysis.

In the past, researchers have made efforts to understand the connection between executive functions and naming skills over several decades. Researchers have employed many methods to establish the association between executive functions and naming abilities in Healthy Individuals and Persons with Aphasia. The executive function abilities often assessed in healthy neurotypicals and individuals diagnosed to have aphasia include inhibition ability, working memory span, updating abilities, and cognitive flexibility. The naming abilities assessed in individuals with aphasia and their healthy counterparts include confrontation, responsive, and generative naming.

According to previous studies, healthy individuals show a slight decline in their executive functions, especially around the age of 70 years. Aging and education are factors that affect the performance of healthy individuals on executive functions (Clarys et al., 2009; Fisk & Warr, 1996; Hester et al., 2004; Idowu & Szameitat, 2023; Lee & Chan, 2000; Płotek et al., 2014; Verhaeghen, 2011). The elderly individuals mainly show a decline in inhibition, dual tasking, updating, and shifting, with their performance being significantly poor in accuracy and reaction times compared to their younger counterparts. There is poor agreement as to which cognitive process shows deterioration first, but it is generally agreed that inhibition shows greater deterioration, followed by updating, shifting, and dual-tasking. These changes observed as healthy individuals grow older may be due to structural changes in the pre-frontal cortex, as suggested by the prefrontal-executive theory, or they might be due to poor attentional control, inhibition, speed of processing, and deficits in building strategy (Idowu & Szameitat, 2023). In terms of education, it is said to have a large impact on the performance of executive functions, especially the tests for cognitive flexibility. These findings may be obtained as cognitive flexibility tests such as the Trail Making Tests use numbers, letters, and colors, thus showing an influence of language and formal education (Lee & Chan, 2000; Płotek et al., 2014).

Naming ability in healthy individuals has also been shown to be affected by age and education levels, with age having a detrimental effect on naming and education, showing a positive correlation with naming performance (Troyer, 2000; Welch et al., 1996). Studies have also been done on bilinguals and monolinguals to establish the effect of bilingualism on naming performance, which indicates that bilingual individuals with large vocabulary showed better performance in verbal fluency tasks (Sandoval et al., 2010).

Persons with aphasia, though aphasia is a language deficit, show significant difficulty in both non-verbal and verbal executive function tests; though there is no thorough correlation between executive functions and severity of aphasia, the persons with aphasia still perform poorer on executive functions tests when compared to their healthy counterparts (Dutta et al., 2023; Mayer & Murray, 2012; Purdy, 2002). This relationship between executive functions and aphasia often makes one question whether executive function plays any role in the language deficits observed in persons with aphasia. Language has long been considered a part of higher-order cognitive skills; hence, many researchers have resorted to investigating the relationship between executive functions and naming tests.

Many studies on bilingual and monolingual healthy individuals have suggested that fundamental cognitive functions (executive functions) such as cognitive flexibility, working memory updating ability, and inhibition control affect the individual's performance on speech discrimination, naming, and sentence interpretation (Constantinidou et al., 2012; Crowther & Martin, 2014; Gonzalez-Burgos et al., 2019; Higby et al., 2019; Luo et al., 2010; Marsh et al., 2019; Patra et al., 2020a; Shao et al., 2013, 2014).

Similarly, studies on individuals with aphasia have also suggested a correlation between executive functions and naming abilities (Wall et al., 2017). Working memory and cognitive control abilities were found to be correlated to their performance in naming tests (Bose et al., 2017, 2022; Carpenter et al., 2020, 2021; Hirshorn & Thompson-Schill, 2006; Patra et al., 2020a). These findings may be obtained due to the heavy reliance of cluster parameters on controlled search strategy and language proficiency (Carpenter et al., 2021). Moreover, success in verbal fluency tasks is contingent on a multitude of cognitive processes, including but not limited to short-term memory, initiation and upkeep of word production sets, cognitive adaptability, long-term vocabulary retention, and the ability to inhibit responses (Carpenter et al., 2020). There has been some evidence over the years that there is a correlation between executive functions and naming ability, although there are some studies that have found no clear correlation between executive functions and naming ability (Faroqi-Shah et al., 2018).

Additionally, many studies mentioned above have used only one form of naming tests and executive functions tests to examine the correlation between naming and executive abilities, with a majority of them using only the quantitative analysis or the accuracy of responses as a measure. Only a handful of studies have employed extended analysis, such as the time course and cluster analysis (Bose et al., 2017, 2022; Luo et al., 2010; Patra et al., 2020a; Troyer, 2000). The areas of time course analysis and cluster analysis remain largely unexplored.

Hence, the present study attempted to investigate the association between executive functions and naming abilities using four executive functions tests, three types of naming tests, and three levels of analysis: quantitative, time course, and cluster analysis. The performance of the healthy controls and the persons with aphasia were obtained and compared to extract information on which group performed better on the tests employed. The performance variation across naming and executive function tests across various parameters within each group was also employed to understand if there were significant differences in the performances of participants between executive functions tests and naming tests. Efforts were also made to ascertain the relationship between executive functions and assessments of naming abilities. The outcomes of the present study are discussed here in the following sections.

5.1 Differences between the healthy controls and persons with aphasia for the executive functions' tests and naming tests:

The study's first aim was to find the Executive Functions (updating, shifting, inhibition, working memory) that predict successful and unsuccessful word retrieval during the naming test in persons with Aphasia and healthy controls.

5.1.1 Quantitative Analysis of Executive Functions:

The outcomes of the current study suggest that the performance of persons with aphasia on executive function tests was poor compared to the performance of the healthy controls. Based on the analysis of raw data, individuals with aphasia were found to have performed poorest on the Stroop tests, followed by Backward Digit Span tests and the Sem-back tests in terms of quantitative analysis for quantitative analysis.

5.1.2 Time Course Analysis of Executive Functions:

The findings from this study suggested that individuals with aphasia performed less effectively on executive function tests in comparison to the performance of the healthy control group. In terms of the time course analysis of executive functions tests, persons with aphasia were found to have increased reaction time for the congruent condition when compared to the healthy controls and lower reaction time for the incongruent condition and lower Stroop difference when compared to the healthy control this discrepancy may have occurred due to 2 reasons; these reaction times might have occurred owing to guess responses by the persons with aphasia or the inability to read might have caused a reduction in the interference effect of Stroop test. Hence, a much more reliable measure in these cases is the Stroop ratio, which indicates poor inhibitory control in individuals with aphasia. Poor performance in Stroop tests for individuals with aphasia can be due to a slowed rate of information processing, as the Stroop test requires quick responses, poor attentional control, or increased interference in language processing. The Stroop test requires the participants to inhibit automatic reading response, which may lead to poor performance in persons with aphasia as their language processing ability is compromised.

The results obtained for all the o”her ’xecutive function tests, the Backward Digit Span, the Sem-back reaction times, and the trail-making tests showed poor performance in individuals with aphasia when compared to the healthy controls, indicating poorer memory span and ongoing information processing, poor information updating ability, and poor ability to shift across mental sets in persons with aphasia (Dutta et al., 2023; Mayer & Murray, 2012; Purdy, 2002).

Poor performance on working memory tests may be due to poor attentional control, poor encoding and retrieval of information, and increased interference. The digit span tests often assess the capacity of the phonological loop and the visual sketch pad if the information is visualized and the backward digit span also engages the articulatory control process (Hilbert et al., 2015). Hence, the deficits observed in persons with Aphasia may be due to impairment in these processes. These findings from this study are similar to the outcomes obtained from the previous studies, which also indicate poor executive abilities in individuals with Aphasia (Dutta et al., 2023; Purdy, 2002).

Additionally, individuals with aphasia also performed poorly on the trail-making test and required a greater duration of time to complete the task. They also exhibited greater TMT differences and TMT ratios. The inability to perform well on the trail-making test may be because cognitive flexibility is a complex executive function that relies on working memory and inhibitory control. Hence, the deficiency in inhibitory control and working memory ability indicates poor cognitive flexibility (Diamond, 2013).

5.1.3 Quantitative Analysis of Naming Tests:

In the case of naming tests, the persons with Aphasia performed poorly on all the naming tests compared to the healthy controls, as aphasia is a language disorder. For quantitative analysis, the persons with aphasia showed poor mean accuracy scores across all naming tests (confrontation naming, responsive naming, and generative naming). Poor responses were also observed for the Fluency Difference Score (FDS), which gauges the differences in performance between semantic and phoneme fluency. Persons with Aphasia were found to have greater FDS, indicating an executive function deficit and poor ability to monitor and maintain performance on the phoneme fluency tasks (Friesen et al., 2015).

5.1.4 Time Course Analysis of Naming Tests:

For time course analysis of the naming tests, the patients with aphasia showed longer 1st and subsequent reaction times (used for generative naming tests only), where the prolonged 1st reaction times indicated task preparation, vocabulary size, difficulty accessing the lexicon, and poor word retrieval ability (Wixted & Rohrer, 1994) and the increased Sub-RT indicating reduced processing speed, quick exhaustion of mental lexicon and the need to think for longer duration. The reduced number of responses and longer duration of Sub-RT, especially during the later stages of the verbal fluency task, indicates the declining rate of word retrieval often seen when there is structural damage and loss of the mental lexicon (Wixted & Rohrer, 1994). As there is less chance of damage to the mental lexicon in individuals with aphasia, the delay in the reaction times is attributed to poor retrieval of words (Bose et al., 2022).

The findings obtained for the quantitative and time course analysis are similar to the findings of the previous study, with the previous studies also indicating a reduced number of correct responses and increased reaction time latencies in individuals with aphasia compared to the healthy controls (Bose et al., 2022; Patra et al., 2020a, 2020c, 2020b).

5.1.5 Cluster Analysis of Naming Tests:

The cluster analysis was done only for the generative naming tasks. In the case of the cluster analysis, all the individuals with Aphasia were found to have slightly reduced cluster size for all the word and phoneme fluency tasks and a reduced frequency of switches compared to healthy controls. The persons with aphasia also exhibited increased within-cluster pauses and pauses between the clusters. These findings are in support of the findings obtained from the previous studies (Bose et al., 2017, 2022; Carpenter et al., 2020, 2021; Patra et al., 2020a, 2020c, 2020b)

According to previous studies, the reduced size of clusters and increased duration of the mean pauses within the cluster indicate reduced integrity of the semantic store, a slower ability to retrieve information, weaker semantic network (Kavé et al., 2011; Troyer, 2000; Velázquez-Cardoso et al., 2014) whereas a reduced frequency or number of switches and increased mean between cluster duration indicated the search strategy employed by the participants, it indicates increased processing time and effort to retrieve the words and difficulty inhibiting the previously activated cluster.

Additionally, along with the descriptive statistics results presented above, a between-group comparison was performed to analyze if these differences were statistically noteworthy. A statistically meaningful difference between groups was obtained for all the tests of executive function ability and all the tests of naming ability (confrontation naming, responsive, and generative naming) in terms of quantitative analysis.

In terms of time course analysis, a significant difference was obtained only for the trail-making test of the executive functions and the confrontation naming, the responsive naming, and word fluency-animals category of the generative naming; these findings may be owing to two reasons: the reduced sample size which might have caused an inability to determine a statistically significant difference for time-related parameters or a greater difficulty in semantic access and retrieval abilities exhibited by individuals with aphasia which affects the 1st reaction time of confrontation and responsive naming explicitly.

For cluster analysis, no statistically noteworthy distinction was obtained for the cluster size except for phoneme fluency-|s|, which indicated that persons with aphasia produced almost the same cluster size as the healthy controls. A statistically significant difference was obtained for the within-cluster pause, which indicates that though persons with aphasia produced similar cluster sizes, they took more time to produce words within a particular subcategory, indicating poor working memory and inhibitory control that work hand in hand with selection of novel appropriate word and inhibition of inappropriate or previously produced word.

A statistically significant difference was obtained for all the switch parameters, although the significance was not obtained for the between cluster pause, indicating greater difficulty with the executive functions and the ability to switch between subcategories of words. These findings of the between-group comparison are in line with the previous studies conducted on similar topics, as mentioned before.

5.2 Differences between the performances of participants on executive functions and naming tests within each group:

One of the primary aims of the research was to understand the differences and similarities in the performance of participants in naming and executive functions tests and to outline the executive and linguistic bases of different types of naming tests using quantitative, time course, clustering, and switching parameters in persons with Aphasia and healthy control.

In the present study, the differences between the performances of participants on executive functions and naming tests were obtained by analyzing the data at 3 significant levels of analysis: the quantitative analysis, time course analysis, and cluster analysis (used only for the verbal fluency tasks).

5.2.1 Quantitative and Time Course Analysis of Naming Tests:

A statistically significant difference in terms of quantitative analysis and time course analysis was observed between the executive functions test and confrontation naming for healthy controls and persons with aphasia. No similarities in performance were observed, especially for confrontation naming when compared to executive functions, possibly because this test and the parameters derived from it (the accuracy of responses and the 1st reaction time) majorly indicate a person's ability to access their mental lexicon and retrieve words. These naming tests depend heavily on the lexical process rather than the executive functions.

On the other hand, the performance of persons with aphasia on the responsive naming test showed similarity with their performance on the Stroop task in terms of quantitative analysis. This observation was probably made due to the fact that both responsive naming and Stroop tasks require persons with aphasia to process the stimuli presented to them and inhibit the automatic response for a more appropriate response.

A similar finding was obtained regarding time course analysis of the responsive naming, where the performance of healthy controls was similar to their performance on the Sem-back test. This is possibly due to the Sem-back test's ability to tap into individuals' working memory abilities. In order to perform the Sem-back test, one must be able to store and actively manipulate and update information, which is a process quite similar to the consistent updating of information during the responsive naming test. Additionally, reduced ability to hold semantic information due to limited working memory capacity and poor allocation of attentional and working memory resources can lead to poor word retrieval in responsive naming and poor performance on the Sem-back test.

For generative naming, a statistically meaningful difference in terms of quantitative and time course analysis was not found for all the parameters derived from the word and the phoneme fluency test. For quantitative analysis, phoneme and word fluency task parameters were found to have similar performance, especially with the Backward Digit Span and Sem-back tests.

There can be three primary reasons for the similarity between performance on verbal fluency and Sem-back test and Digit Span test for healthy controls and persons with aphasia. The first reason is that all of these tests require the participants to internally verbalize the stimulus to stabilize their performance on tests. The second reason for the similarity in performance between verbal fluency and the Digit span and Sem-back test is that all of these tests involve retrieval and consistent updating of the stored information. The tests actively make use of the limited capacity of the central executive function, phonemic loop, and the articulatory control process. The third reason for the similarity in performance could be because verbal fluency tasks reflect both lexical processing and executive functions.

For example, the 1st reaction time for a verbal fluency task indicates the task preparation, retrieval, and access abilities, whereas the subsequent reaction time majorly indicates the processing speed and ability to switch across various subcategories in order to maintain the response for a longer duration of time.

For time course analysis, a similar finding as in the quantitative analysis was obtained, with all the naming tests showing statistically significant differences from the executive functions' tests, such as the Stroop test, Trail making test, and the digit span test. Only the word and phoneme fluency test parameters showed similarity with the Sem-back test, which is again speculated to be caused due to the involvement of working memory in the verbal fluency and the Sem-back test (Mayer & Murray, 2012; Murray, 2012). Additionally, similarity in terms of performance may also be due to the executive bases of some of the time course parameters of word and phoneme tasks, such as the Sub-RT (Bose et al., 2022; Patra et al., 2020a).

5.2.2 Cluster Analysis of Naming Tests:

Similar findings were obtained for the cluster analysis where the quantitative parameters of the cluster analysis, especially the performance of both the groups on the number of switches obtained for word and phoneme fluency tasks, did not show any statistically significant difference when compared to participants' performance on the digit span test. The similarity in the performance is due to the "number of switches" being a parameter that majorly taps executive functions rather than the lexical process involved in naming.

All the other quantitative parameters of cluster analysis showed noteworthy differences on comparison with the quantitative parameters of the executive functions test, the Stroop test, the Digit Span Test, and the Sem-back test.

Similar to the findings obtained for quantitative parameters of cluster analysis. The time course parameters also showed a significant difference compared to the time course parameters of the executive functions test. No statistically significant difference was obtained for the within-cluster pause of the word and phoneme fluency test compared to the Sem-back test reaction times. This finding may be obtained as the working memory helps build the cluster and provides more examples from the same semantic subcategory. Better working memory facilitates access to a greater number of examples from the same semantic category by allocating the limited amount of working memory capacity to selecting the appropriate word and inhibiting words from the inappropriate subcategories.

All these findings mentioned above are in support of the previous studies investigating the performance of healthy controls and persons with aphasia (Bose et al., 2022; Carpenter et al., 2020, 2021; Patra et al., 2020a, 2020c).

5.3 Correlations between the executive functions and naming tests within each group:

The final aim of the study was to understand the correlation between the Executive Functions (updating, shifting, inhibition, working memory) and the naming tests (confrontation naming, responsive naming, and generative naming) in persons with Aphasia and healthy control and to segregate the types of naming tests that majorly tap into executive functions versus linguistic abilities.

5.3.1 Quantitative and Time Course of Naming Tests:

The outcome of the investigation showed no statistically noteworthy correlation between the quantitative and time course parameters of confrontation naming and executive functions. A statistically meaningful interrelationship was found between the responsive naming test and the Digit Span test only in quantitative analysis for persons with aphasia, possibly due to both tests' extensive use of working memory span.

A statistically noteworthy correlation was found for the accuracy score of the word fluency test versus the accuracy score of the Stroop test and the Digit Span test for both control group and persons with aphasia, which indicates that better inhibitory control and working memory span improves the generative naming performance in terms of accuracy of responses produced (Bose et al., 2022).

In the context of time course analysis, a significant correlation was obtained only for the Subsequent reaction time of the word fluency-animals and phoneme fluency-|a| task when compared to the Sem-back reaction times in persons with aphasia.

5.3.2 Cluster Analysis of Naming Tests:

In the case of cluster analysis, a statistically significant correlation was obtained for the number of switches and cluster size parameters of the word and the phoneme fluency tasks when compared to the Stroop test, Digit Span test, and Sem-back accuracy. This correlation indicates that greater performance on the Stroop test, digit span test, and Sem-back test ensures a greater ability to search more profoundly and more quickly into a particular semantic subcategory and switch from one semantic category to another, producing a wide range of words in a verbal fluency task.

A significant correlation was also obtained for the Between Cluster Pauses of the word fluency task of animals and phoneme fluency task-|a| and the Sem-back test.

The point to be noted across the results of correlation is that correlation was obtained not only for the parameters of naming tests that are predominantly executive in nature (Sub-RT, number of switches, between cluster pause, etc.) but also for parameters that are predominantly lexical in nature (cluster size, within cluster pause, etc.) and parameters that are both lexical and executive in nature such as the correct responses. Hence, this indicates that better performance in executive functions ensures better performance in naming tests, especially the responsive and generative naming tests. These findings are in line with the previously performed studies (Bose et al., 2022; Patra et al., 2020c, 2020b).

CHAPTER VI

SUMMARY AND CONCLUSION

This study aimed to demonstrate the relationship between naming and executive functions in Persons with Aphasia and to find out the extent of association with reference to the executive functions affecting naming performance in persons with Aphasia and Healthy controls.

The objectives of the study were to find out the Executive Functions (updating, shifting, inhibition, working memory) that predict successful and unsuccessful word retrieval using the naming test in persons with Aphasia and healthy control. To outline the executive and linguistic bases of different types of naming tests using quantitative, time course, clustering, and switching parameters in persons with Aphasia and healthy control. To investigate the correlation between the Executive Functions (updating, shifting, inhibition, working memory) and the naming tests (confrontation naming, responsive naming, and generative naming) in persons with Aphasia and healthy control. To segregate the types of naming tests that majorly tap into executive functions versus linguistic abilities in persons with Aphasia and healthy control.

Twenty-eight participants took part in the study. The participants were divided into two groups. The first group of participants consisted of 14 healthy controls (HC), and the second group consisted of 14 persons with Aphasia (PWA). All the healthy control group participants were age and education matched with the persons with aphasia group. The age range of participants spanned from 18 to 59 years and all of them were speakers of Kannada. All the subjects in the study had at least 10 years of education.

All the persons with Aphasia chosen for the study were right-handed (pre-morbidly) and had experienced not more than a single episode of stroke involving the left hemisphere. All the participants were diagnosed with Aphasia on a standardized test for Aphasia (Western Aphasia Battery in Kannada- WAB-K); with an AQ<93.8. All patients selected for the study had persistent Aphasia for at least 1-year post-stroke and additionally had an accuracy score of at least 10% on the Boston Naming Test-Kannada, Action Naming Test-Kannada, and Phonology and Semantics sections of Linguistic profile Test.

Participants with other neurological illnesses, psychiatric disorders, ongoing substance abuse, visual field or other sensory-perceptual deficits, and scores below the cutoff (<26) on Montreal Cognitive Assessment were excluded from the study.

Four executive function assessments and three distinct naming evaluations were employed to ascertain the executive function and naming abilities in both Persons with Aphasia and the cohort of Healthy Controls and establish the interrelationship between these variables within each group.

The participants underwent a series of executive function assessments, including the Trail Making Test (paper and pen task) for evaluating cognitive flexibility or the ability to shift between tasks, the Stroop Test (from *PsyToolsKit*) for measuring inhibitory control, the Sem-back test for the "Fruits" category (from *Psychology Software Tool's E-Prime Software, Version 2*) for gauging working memory updating skills, and the Backward Digit Span Test (from the *Weschler's Memory Scale*) for evaluating working memory span. The classification of executive functions examined in this study adhered to the framework introduced by Friedman & Miyake in 2000.

The naming assessments encompassed the Confrontation Naming Test, Responsive Naming Test, and Generative Naming Test, all derived from the naming segment of the Battery for Cognitive-Communication Disorders – Kannada BCC-K (Goswami, 2015). Consistent with the BCC-K guidelines, identical stimuli were utilized across all naming tests, with the exception of the Generative Naming Test, where word fluency was evaluated within the domains of animals and vehicles, while phonemic fluency was assessed using the sounds |s| and |a|.

Within the domain of Executive Functions, an evaluation was conducted on the Trail Making Test, encompassing the total time taken to complete two specific tasks (TMT-A and TMT-B). Additionally, calculations were made for the TMT Difference (TMT-D) and the TMT Ratio (TMT-R). In the context of the Stroop test, assessments were performed on accuracy (SCR) as well as the response time under both congruent and incongruent conditions (SC and SIC, respectively). Furthermore, calculations were derived for the Stroop Difference (SD) and the Stroop Ratio (SR) based on these metrics. The Sem-back test underwent analysis for both accuracy and the mean Reaction Time. Lastly, the Backward Digit Span Test was utilized to evaluate the complete range or the span of repeated numbers (DSB S) and the corresponding score (DSB SC) achieved by the participants.

All the previously mentioned Naming assessments were subjected to analysis within three primary measurement categories: Quantitative Analysis (QA). This encompasses the measurement of accuracy to quantify the count of accurate responses. The Fluency Difference Score (FDS) was computed, furnishing insights into the discrepancy between word and phonemic fluency concerning their respective accuracies.

The Time Course Analysis (TCA) involves the examination of reaction time measures. Within the scope of Time Course Analysis, two specific parameters were assessed: the 1st Reaction Time (1st RT) and the Subsequent Reaction Time (Sub-RT).

The Cluster Analysis (CA) involved the integration of measurements directed at the evaluation of proficiencies pertaining to both clustering and switching. The comprehensive scope of the Cluster Analysis (CA) involved the evaluation of four specific parameters: the Number of Switches (NoS), the cluster size (CS), the mean Within Cluster Pause (WCP), and the mean Between Cluster Pause (BCP). Only the accuracy and 1st RT of the Confrontation Naming and Responsive Naming tests were evaluated. All eight parameters mentioned earlier were considered during the assessment of the Generative Naming tests.

These parameters were extracted for all the 28 participants in the study. The Shapiro-Wilk Test of Normality was performed on the acquired dataset; it was observed that the parameters derived from the executive functions and naming assessments exhibited normal and non-normal distribution. Hence, both parametric and non-parametric tests were applied accordingly for the statistical analyses of the gathered data.

The results from Descriptive statistics, Mann Whitney U test, and Independent Sample t-test were used for between-group comparison. The descriptive statistics results of this study indicated that the performance of persons with aphasia on “executive function tests” (both quantitative and time course parameters) and the “naming tests” were poor compared to the performance of the healthy controls across all levels of analysis (the quantitative, time course and cluster analysis).

For executive functions tests, the person with aphasia obtained a mean total score of 20.5 on the Stroop test compared to the healthy controls who obtained 33.07. Similarly, healthy controls obtained a score of 9.07 and 15 on the Digit Span Test and Sem-back test, respectively, compared to persons with aphasia who obtained a score of 6 and 12.57.

In the case of naming tests, for healthy controls, an average score of 39.71 and 9.96 was obtained for confrontation and responsive naming tests when compared to an average score of 36.86 and 8.93 obtained by persons with aphasia.

For FDS, higher values were obtained for persons with aphasia with 0.444 and 0.437 scores compared to healthy control with 0.392 and 0.242 on word fluency for animals’ v/s phoneme fluency |a| and word fluency for vehicles’ v/s phoneme fluency |s| respectively which indicates poor executive control in persons with aphasia.

For generative naming, the highest accuracy score was obtained for word fluency animals for persons with aphasia and healthy controls, with a score of 11 and 17.93, respectively. Followed by a score of 7.36 and 14.36 for persons with aphasia and healthy controls, respectively, on word fluency-vehicles. A score of 5.29 and 14.5 was obtained for persons with aphasia and healthy controls, respectively, for phoneme fluency task-|s| and a score of 5.86 and 11.21 was obtained for persons with aphasia and healthy controls, respectively, for phoneme fluency task-|a|. This trend clearly indicates that the scores dropped for phoneme fluency, especially in persons with aphasia. The scores also indicate that the animals category was the easiest category in the verbal fluency test, followed by the vehicles category.

In terms of cluster analysis, the cluster size for verbal tasks remained stable across word and phoneme fluency for the healthy control, with them scoring a cluster size of 1.5-1.6 on average across all generative naming tasks, whereas the cluster size for persons with aphasia declined significantly for phoneme fluency tasks with an approximate cluster size of 1.46 to 1.55 for word fluency and a cluster size of 0.428 and 0.882 for phoneme fluency. Similar trends were also observed for number switches, where persons with aphasia performed poorly on all varieties of generative naming tests, scoring an average of 3-6 switches when compared to healthy controls who scored an average of 7 to 9 switches and the number of switches showed a decline with the highest number of switches obtained for animals category followed by |s| vehicles and |a| categories.

In the Between-group comparison performed using Mann Whitney U test and Independent Sample t-test, in terms of time course analysis, a significant difference was obtained only for the "trail-making test" of the executive functions and the "confrontation naming," "responsive naming," and "word fluency-animals category" of the generative naming.

In terms of cluster analysis, no statistically significant difference was obtained for the "cluster size," but a statistically significant difference was obtained for the "within-cluster pause." A statistically significant difference was obtained for all the "number of switches" parameters, although the significance was not obtained for the "between cluster pause."

The Wilcoxon Sign Ranked test and the Paired Samples t-test were used for within-group comparison. A statistically significant difference in terms of "quantitative analysis" and "time course analysis" was observed between the "executive functions test" and "confrontation naming" for healthy controls and persons with aphasia. On the other hand, the performance of persons with aphasia on the "responsive naming test" showed similarity with their performance on the "Stroop task" in terms of "quantitative analysis." A similar finding was obtained regarding "time course analysis," where the performance of healthy controls on responsive naming was similar to their performance on the Sem-back test.

For time course analysis and quantitative analysis, a statistically significant difference was obtained, with all the naming tests showing statistically significant differences from the executive functions' tests, such as the "Stroop test," the "Trail making test," and the "digit span test." Only the "word and phoneme fluency test parameters" showed similarity with the "Sem-back test." For generative naming, a statistically significant difference in terms of quantitative and time course analysis was not found for all the parameters derived from the word and the phoneme fluency test. For quantitative analysis, the "parameters of phoneme and word fluency tasks" were found to have similar performance, especially with the "backward digit span" and "Sem-back tests."

Similar findings were obtained for the "cluster analysis," where the quantitative parameters of the cluster analysis, especially the performance of both the groups on the "number of switches" obtained for word and phoneme fluency tasks, did not show any statistically significant difference when compared to participants' performance on the "digit span test." All the "other quantitative parameters" of "cluster analysis" showed significant differences when compared with the "quantitative parameters" of the "executive functions test," i.e., the Stroop test, Digit Span Test, and Sem-back test.

Similar to the findings obtained for quantitative parameters of "cluster analysis." The "time course parameters" also showed a significant difference when compared to the "time course parameters" of the "executive functions test." No statistically significant difference was obtained for the “within-cluster pause of the word and phoneme fluency test” compared to the “Sem-back test reaction times.”

A correlational analysis was perfo”med ’o understand the relationship between executive functions and naming tests under the 3 levels of analysis. Pearson’s and Spearman’s correlation analyses were used accordingly, as some parameters were normally distributed and others were not.

The results of the study showed no statistically significant correlation between the “quantitative and time course parameters” of “confrontation naming” and “executive functions.” A statistically significant correlation was found between the “responsive naming test” and the “Digit Span test” only in the context of “quantitative analysis” for persons with Aphasia. A statistically significant correlation was found between the “accuracy score of the word fluency test” and the “accuracy score of the Stroop test” and the “Digit Span test” for both healthy control and persons with aphasia.

In the case of “time course analysis,” a significant correlation was obtained only for the “Subsequent reaction time of the word fluency-animals” and “phoneme fluency-|a| task” when compared to the “Sem-back reaction times” in persons with aphasia.

In “cluster analysis,” a statistically significant correlation was obtained for the “number of switches” and “cluster size” parameters of the “word and the phoneme fluency tasks” when compared to the “Stroop test,” “Digit Span test,” and the “Sem-back accuracy.” A significant correlation was also obtained for the “Between Cluster Pauses of the word fluency task of animals” and “phoneme fluency task-|a|” and the “Sem-back test.”

To summarize, the study's key findings were that the persons with aphasia performed poorer than healthy controls on executive functions and naming tests. There was a significant difference in the performance of participants between the confrontation naming and executive functions across all levels of analysis. Some similarities were observed in the performance of healthy control and persons with aphasia for responsive naming and verbal fluency tests when compared with the executive functions tests. Additionally, strong correlations were observed for responsive naming and verbal fluency parameters compared with the executive functions' tests. Based on the correlational analysis and the within-group comparison, the naming tests can be segregated into 2 categories where the confrontation naming taps into only the lexical processing, whereas the responsive and generative naming tasks tap into both lexical and executive functions bases of the naming performance.

These findings have been supported by previous research conducted in the same line (Bose et al., 2017, 2022; Carpenter et al., 2020, 2021; Patra et al., 2020a, 2020c, 2020b; Troyer, 2000b, 2000a). In the present study, the major factors contributing to the naming abilities of persons with aphasia were the property of words, age of acquisition of words, age, education, language proficiency and executive functions. Among the executive functions, the working memory span and working memory updating abilities were found to have an impact, followed by the inhibitory functions. With reference to neurotypical individuals and persons with aphasia, the executive functions work hand in hand where the working memory helps select goal-oriented responses, and inhibition clears limited working memory space by removing irrelevant information, which is highly necessary for selecting accurate words during naming tasks in spite of the lexical competition (Diamond, 2013).

6.1 Implication

Executive function difficulties are frequently seen in clinical groups with linguistic abnormalities, such as Aphasia. These difficulties are usually seen in various naming tests. Hence, having a measure to tap into executive control skills is extremely important, and this study will shed more light on these grounds. Naming tests are commonly found across both executive control tests and language tests. This study provides better clarity on which variety of these tests have predominant executive control and linguistic bases.

It is plausible that persons with Aphasia who exhibit impairments in both naming and verbal fluency tests benefit from rehabilitation that focuses on executive control in addition to conventional language intervention.

This study shows if it is critical to employ a wide variety of naming and executive control techniques to access aphasia patients' lexical and executive control abilities. The present study provides evidence as to whether semantic fluency tests are sufficient to analyze executive control deficits or whether additional measures are necessary. The study also provides evidence on whether assessing naming in PWA concerning reaction times provides better information about the mechanism underlying the word retrieval deficits observed in Aphasia.

6.2 Limitations and Future Directions

This study provides evidence and supports the notion that the language test batteries used for persons with aphasia must be combined with executive function tests. The future should focus on establishing norms for these parameters and replicating the study in the same population with increased participants. The derived parameters in this study were calculated manually, but in the future, there is scope for the development of software that provides this information.

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APPENDIX A

Quantitative, Time Course and Cluster Analysis for Executive Functions Test and Naming Tests.

Formula for Stroop Difference and Stroop Ratio

$$\text{Stroop Difference} = RT_{INCONGRUENT\,TRIAL} - RT_{NEUTRAL\,TRIAL}$$

$$\text{Percentage Stroop ratio } (\%) = \left[\frac{RT_{INCONGRUENT\,TRIAL} - RT_{NEUTRAL\,TRIAL}}{\frac{RT_{INCONGRUENT\,TRIAL} + RT_{NEUTRAL\,TRIAL}}{2}} \right] \times 100$$

The formula for calculation of Fluency Difference Score.

$$FDS = \left(CR_{semantic\,fluency} - CR_{letter\,fluency}\right) / CR_{semantic\,fluency}$$

Formula for TMT difference and TMT ratio.

TMT D= TMT A- TMT B

TMT R= TMT B/ TMT A

Formulae for cluster Analysis

Within Cluster Pause= Sum of pause duration within a cluster / number of pauses

Mean Within Cluster Pause= Sum of WCP for all clusters / Number of Clusters

Mean Between Cluster Pause= Sum of all Between Cluster pauses / Number of Switches